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EMPOWERING SCIENCE AND MATHEMATICS FOR GLOBAL COMPETITIVENESS

Edited by
Yuli Rahmawati and Peter Charles Taylor

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Preface

We are delighted to publish the SMIC Conference Proceedings 2018 as an important outcome of the Science and Mathematics International Conference (SMIC) 2018. The conference was organized by the Faculty of Mathematics and Natural Sciences, Universitas Negeri Jakarta (UNJ), and took place in the Lumire Hotel and Convention Centre, Jakarta, 2–4 November 2018. The theme of the conference was ***Empowering Research and Education in Science and Mathematics for Global Competitiveness***.

We received 214 registrations and accepted 119 proposals from researchers in 12 countries and many parts of Indonesia. Conference participants came from Australia, USA, Japan, Philippines, Nepal, Vietnam, Egypt, Malaysia, Thailand, China, Ghana and Nigeria. The main speakers were drawn from Indonesia, Australia, Germany, Egypt, Singapore, Philippines, and Malaysia. We received papers on a range of topics in the closely related fields of mathematics, science, mathematics education and science education. The conference generated new ideas for the further development of theory and applications of research that will enhance the quality of science and mathematics research, teaching and learning.

The conference commenced with 3 one-day workshops facilitated by: Dr. Elisabeth Taylor (Values and Character Teaching, Edith Cowan University, Australia), Dr. Rachel Sheffield (STEM, Curtin University, Australia), and Dr. Rekha Koul (Learning Environment Research, Curtin University, Australia). Plenary sessions were presented by outstanding keynote speakers: Prof. Intan Ahmad, Ph.D (UNJ, ITB, Ministry of Research, Technology, and Higher Education, Indonesia), Prof. Berinderjeet Kaur, Ph.D (NIE Singapore), Prof. Dr. Russell Tytler (Deakin University, Australia), Prof. Dr Akrajas Ali Umar (National University of Malaysia), Prof. Dr. Carlene Arceo (The University of Philippines), Prof. Dr. Peter Charles Taylor (Murdoch University, Australia), Dr. Mohamed Helmy Khafagy (Fayoum University, Egypt), and Prof. Dr. Hans-Dieter Barke (Muenster University, Germany). We were also proud to have presentations by specially invited speakers: Prof. Dr. Asep Kuswandi (UNPAD, Indonesia), Prof. Dr. Liliasari (UPI, Indonesia), Prof. Herawati Susilo, Ph.D (UM, Indonesia), Isnaeni, Ph.D (LIPI, Indonesia), Sri Fatmawati, Ph.D (ITS, Indonesia), and Setia Pramana, Ph.D (STIS, Indonesia).

We conducted blind reviews of 82 papers through the EasyChair platform (https://easychair.org). The review process involved 59 reviewers from 11 countries: Australia, USA, Philippines, Thailand, Malaysia, China, Ghana, Egypt, Nepal, Pakistan, and Indonesia. 72 papers were accepted for publication in the proceedings. The authors recognise that globalisation processes link education to technological and economic development, and that education systems face the challenging task of preparing students to live productively and ethically in a complex and competitive world that confronts them with local, national and global issues.

The papers selected for this proceeding contribute to our understanding of important new developments in (i) science and mathematics, especially nanotechnology, materials, environmental science, statistics and computer science; and (ii) science and mathematics education, in particular environmental sustainability, STEM and STEAM pedagogies, technology education, and green chemistry. Importantly, papers by leading educators provide innovative strategies for transforming mathematics and science education policies and practices, helping to empower teachers to develop students' 21st century skills. We are excited that the papers chosen for this proceeding will enable STEM practitioners, STE(A)M educators and citizens to meet the challenges of global competitiveness and sustainability for the 21st century.

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Profuse thanks to all the presenters, participants, student volunteers and all others who directly or indirectly contributed to enabling the publication of the SMIC 2018 conference proceedings. There are many parties that we cannot mention one by one who supported the conference. Hopefully, this publication will benefit not only the conference participants but also all the representing countries, as well as the broader development of science and technology education.

Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Green synthesis and characterization of Zinc Oxide (ZnO) nanoparticles using *Uncaria gambir* leaf extract

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ABSTRACT: The aim of this work is to investigate the capabilities of *Uncaria Gambir* Leaf Extract (UGLE) in the synthesis of ZnO Nanoparticles (NPs) via a green approach. We made two types of nanoparticles. The first nanoparticles were prepared by dissolving $Zn(Ac)_2.2H_2O$ in UGLE and the second nanoparticles were prepared by dissolving $Zn(Ac)_2.2H_2O$ in isopropanol. The ZnO NPs were characterized by Differential Thermal Analysis and Thermogravimetric Analysis (DTA-TGA), Fourier Trasform Infra Red (FTIR) spectroscopy, X-Ray Diffractometer (XRD) and Scanning Electron Microscopy (SEM). The synthesized NPs have a wurtzite hexagonal structure, with the average particle size, as calculated from XRD analysis, being 65 nm and 35 nm, for ZnO NPs without UGLE and with UGLE, respectively. Scanning Electron Microscopy (SEM) analysis revealed a ZnO rod without UGLE and a spherical shape with UGLE.

1 INTRODUCTION

The field of nanotechnology is one of the most studied in modern materials science. Today, the green synthesis of metal oxide nanoparticles is an interesting issue in the fields of nanoscale and nanotechnology. The use of plant extracts in nanoparticle synthesis is one of the most environmentally friendly alternative methods (Yuvakkumar et al., 2015). Utilizing plant extracts in synthesizing nanoparticles has produced highly stable nanoparticles (Gunalan et al., 2013) in various shapes and particle sizes (Rafaie et al., 2014).

In recent years, ZnO has been extensively studied due to its unique optical and electronic properties (Iwan et al., 2018). It has wide applications in the field of optoelectronic devices (Al-Ghamdi et al., 2014), photocatalysts (Toubane et al., 2016), antimicrobials (Jayaseelan et al., 2012), antioxidants (Nagajyothi et al., 2014) and so forth. Previous green synthesis of ZnO nanoparticles (NPs) has been reported, such as *Cassia fistula* (Suresh et al., 2015), *Passiflora caerulea* (Santhoshkumar et al., 2017) and *Lycopersicon esculentum* (Sutradhar & Saha, 2016).

Gambir is a specific plant from West Sumatra, Indonesia and nearly 90% of its production is from this area (Fauza, 2014). Gambir leaf extract contains flavonoids which are a group of secondary metabolites produced by plants belonging to a large group of polyphenols. Following previous studies, it is known that the polyphenol content of gambier extract can reduce Ag (I) to Ag (0) (Arief et al., 2015).

In this study, ZnO nanoparticles were synthesized using *Uncaria gambir* leaf extract through the sol-gel method. The synthesized ZnO NPs were characterized using Differential Thermal Analysis and Thermogravimetric Analysis (DTA-TGA), Fourier Trasform Infra Red (FTIR) spectroscopy, X-Ray Diffractometer (XRD) and Scanning Electron Microscopy (SEM).

2 METHOD

Uncaria gambir Robx. leaves were collected from the Agricultural Garden of Universitas Andalas, Padang, West Sumatera, Indonesia. Zinc acetate dihydrate ($Zn(CH_3CO_2)_2.2H_2O$) and isopropanol ($(CH_3)_2CHOH$) were purchased from Merck, Germany. The gambir leaves were subjected to washing several times with fresh water to remove any dust particles. They were cut into pieces and dried in the shade for seven days. The dried leaves were crushed using a grinder. *Uncaria gambir* leaf extract (UGLE) was prepared through the maceration of gambir leaves in an ethanol solvent (1:6) for four days followed by filtration and evaporation to get the concentrated extract. The color of the extract was dark brown. Subsequently, 10 g of concentrated UGLE was dissolved in 100 ml of isopropanol.

Nanoparticles of ZnO were synthesized through the sol-gel method. One gram of zinc acetate dihydrate was dissolved in 10 ml of UGLE. For comparison, 1 g of zinc acetate dihydrate was dissolved in 10 ml of isopropanol. These mixtures were stirred for 2.5 h at 65°C and then were dried at 100°C to yield ZnO powder. Finally, the powder was treated in an air heated furnace at 500°C for 1 h. The thermal behavior of the powder was examined with a Shimadzu DTG-60 simultaneous DTA-TG. Fourier transform infrared spectra were recorded in the 400–4000 cm^{-1} region using a Perkin Elmer Frontier FT-IR Spectrometer. The structure and the crystallinity of the powder were analyzed through an X-ray diffractometer using an X'pert pro, PANalytical. The morphology and size distribution were examined with a Scanning Electron Microscope (Hitachi SU 3500).

3 RESULTS AND DISCUSSION

3.1 *DTA-TGA analysis*

Figure 1 presents typical differential thermal analysis and thermogravimetric analysis (DTA-TGA) curves of the ZnO precursor sol with UGLE, analyzed at temperatures ranging from 25 to 575°C. The weight loss at about 100°C indicates the evaporation of H_2O and 2-propanol, endothermically caused by the dehydration of zinc acetate dihydrate (Kim et al., 2017). The weight loss in the range of 100–450 °C indicates the evaporation of acetic acid, while in the range of 460–530 °C it represents the change from zinc acetate to zinc oxide

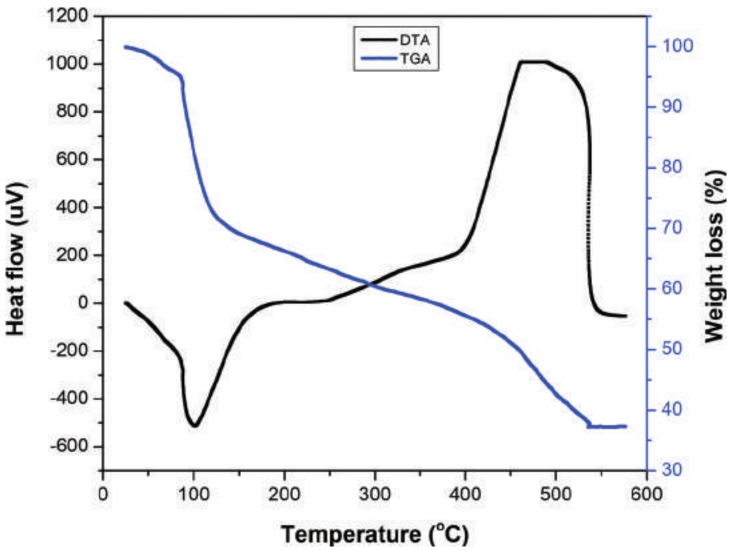

Figure 1. DTA-TGA curves of ZnO precursor sol with UGLE.

(Ramesh et al., 2015). The results show that a calcination temperature of 500°C would be suitable for synthesizing ZnO nanoparticles.

3.2 *FTIR analysis*

FTIR spectrum of UGLE and ZnO powder synthesized without and with UGLE shown in Figure 2. ZnO powder samples synthesized without UGLE showed absorption bands at 2329, 2046, 880 and 528 cm^{-1} (Figure 2(a)). UGLE shows absorption bands at 3333, 2968, 1618, 1377, 1303, 947, 812 and 608 cm^{-1} (Figure 2(b)). The ZnO powder synthesized using UGLE showed absorption bands at 2307, 2071, 1572, 1238 and 562 cm^{-1} (Figure 2(c)). These absorption bands were observed in the region of between 500–3500 cm^{-1} and consist of 3333 cm^{-1} (amine), 2968 cm^{-1} and 1377 cm^{-1} (alkanes), 1618 cm^{-1} (alkenes), 1303 cm^{-1} (nitro compound), and 1121 cm^{-1} (alcohol, ether, carboxylic acid, ester); the band is slightly wider in the wavelength range 550 to 637 cm^{-1} (CH, C = C, NH). ZnO stretches were found in the wavelength range of 400 to 600 cm^{-1} (Sangeetha et al., 2011). In this study, ZnO stretch without UGLE occured at the wavelength of 528 cm^{-1}, and stretched ZnO with UGLE occurred at the wavelength of 562 cm^{-1}. In general, metal oxides are characterized by intrinsic absorption bands below 1000 cm^{-1} arising from interatomic vibrations (Matinise et al., 2017).

3.3 *XRD analysis*

X-ray diffraction was used to further confirm the crystallinity of ZnO nanoparticles. The XRD patterns of ZnO powder synthesized without and with UGLE are shown in Figure 3. The XRD peaks were identified as (100), (002), (101), (102), (110), (103), (200), (112), (201),

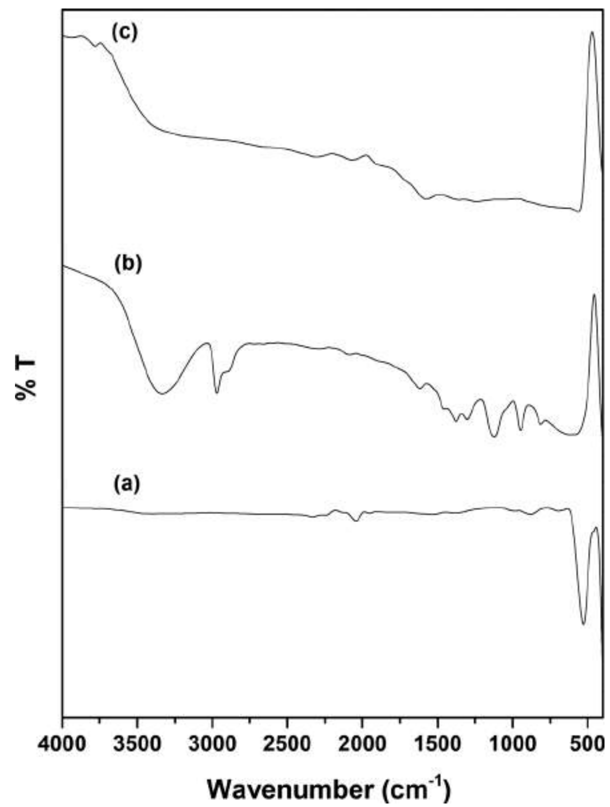

Figure 2. FTIR spectra of (a) ZnO NPs without UGLE, (b) UGLE and (c) ZnO NPs with UGLE.

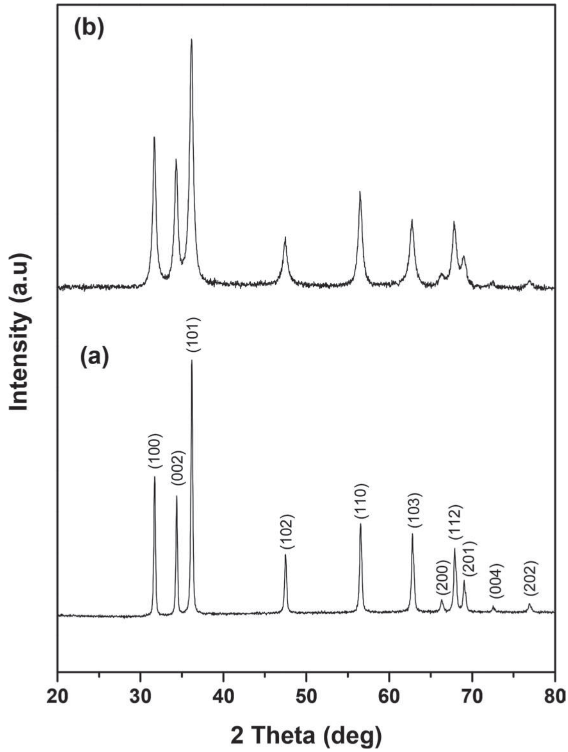

Figure 3. XRD pattern of ZnO NPs (a) without UGLE and (b) with UGLE.

(004) and (202) in both powder samples. This shows that the formed nanoparticles are polycrystalline with hexagonal wurtzite structures. The diffraction peaks correspond with ZnO 01-076-0704 ICSD (inorganic crystal structure database) data. The narrow and strong diffraction peaks in both types of ZnO NPs show that the resulting products have a good crystallinity. The decrease in the intensity and widening of the FWHM (full width at half maximum) of ZnO NPs with UGLE (Figure 3(b)) indicates changes in particle size.

The size of ZnO NPs synthesized without and with UGLE were found to be 65 and 35 nm, respectively, which have been calculated using the Scherrer equation (Foo et al., 2014):

$$D = \frac{\kappa\lambda}{\mathrm{FWHM}\cos\theta} \tag{1}$$

where κ is the Scherrer constant that depends on the shape of crystallite (0.9); λ is the wavelength of the X-ray used, which is 1.54 Å; FWHM is the width of the line at half the maximum intensity; and θ is the Bragg angle. The average size of ZnO NPs with UGLE is smaller than the size of ZnO NPs without UGLE. This indicates that *Uncaria gambir* leaf extract is responsible for the reduction of the particle size.

3.4 *SEM analysis*

The morphology of nanostructures was investigated using scanning electron microscopy (SEM). Figure 4(a) shows an image of ZnO NPs synthesized without UGLE. Most of the nanoparticles are rod-shaped and are clearly observable, with a diameter of approximately 60–120 nm. Meanwhile, Figure 4(b) shows that ZnO NPs synthesized using UGLE have a spherical shape and a particle size in the range of 50–80 nm. It can be concluded from these results that *Uncaria gambir* leaf extract does affect the shape and the particle size of ZnO nanoparticles.

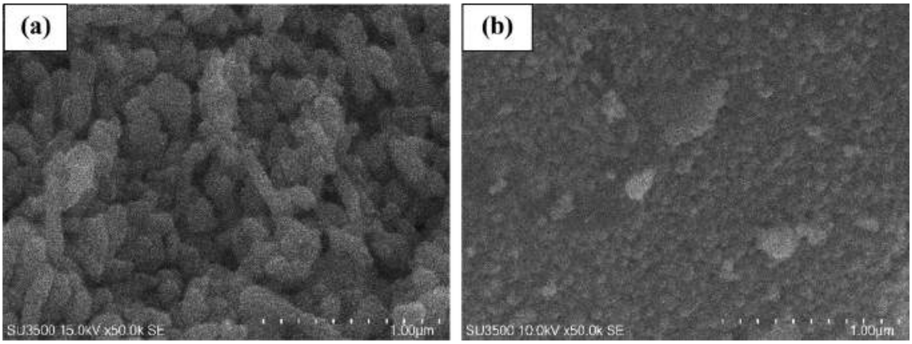

Figure 4. SEM images of ZnO NPs (a) without UGLE and (b) with UGLE.

4 CONCLUSION

The green synthesis of ZnO nanoparticles using *Uncaria gambir* leaf extract has been successfully carried out. The XRD pattern shows the high crystallinity of ZnO NPs with a hexagonal wurtzite structure. The particle size of ZnO NPs with UGLE (35 nm) is smaller than that of ZnO NPs without UGLE (65 nm). SEM analysis confirmed the spherical shape of ZnO NPs with UGLE and the rod shape of ZnO NPs without UGLE. The particle size of the spherical shaped NPs is in the range of 50–80 nm and the diameter of the rod-shaped NPs is approximately 60–120 nm. This shows that *Uncaria gambir* leaf extract affects the shape and the size of ZnO nanoparticles.

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The effect of dopant Indium Tin Oxide (ITO) nanoparticle concentration on the characteristics and conductive properties of cholesteryl acrylate polymer-ITO composite

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ABSTRACT: The Cholesteryl Acrylate Polymer-ITO (CAP-ITO) composite in this study was successfully synthesized through a UV curing method with a variation in ITO nanoparticle dopant concentration. The results of the fourier-transform infrared spectroscopy characterization show a reduced peak hydroxyl and the carbonyl group in the spectrum shows an interaction between cholesteryl acrylate polymer and ITO. The results of testing the effect of ITO nanoparticle dopant on the CAP-ITO composite conductivity with an inductance, capacitance and resistance meter show that the addition of ITO as a dopant in a polymer cholesteryl acrylate can increase the conductivity of the composite even when compared to an ITO micrometer-sized dopant. A CAP-ITO composite with 10% w/w ITO concentration has the highest conductivity value that is equal to 5.70×10^{-7} S/m and reaches the threshold value at an ITO concentration of 20% w/w. These results are also supported by scanning electron microscope characterization which shows an equal morphological structure for the CAP-ITO composite with ITO 10% w/w.

1 INTRODUCTION

Liquid crystal is a material that is applied in many industries because it has important function. Liquid crystal material has an important function in the development of many modern technologies such as thermometers, radiation detection sensors (Zhang et al., 2018) and various devices in the LCD screen industry (Liang et al., 2018).

Cholesteryl acrylate is a cholesteric phase liquid crystal which is produced from the Steglich esterification reaction of cholesterol and acrylate precursors (Afrizal et al., 2011). Chiral carbon atoms in the structure make it possible for the helical structure that is formed to enhance its a variety of unique properties. The helical structure of liquid cholesteric crystals has a regular direction macroscopically under an electric field or magnetic field which is useful in the application of a signal reader from a sensor (Hands et al., 2010).

Cholesteryl acrylate also has an acrylic group (double bond) which shows that this liquid crystal is a polymerizable monomer. However, the resulting cholesteryl acrylate polymer is an insulator so it cannot conduct electric current (Ubaeni, 2016). Whereas in the application of the latest modern technology, a conductive cholesteric liquid crystal polymer is needed. One way to improve the conductive properties of cholesteric liquid crystalline polymers is to combine liquid crystals with a conductive dopant.

One of the conductive dopants that has superior properties compared to other conductive dopants is Indium Tin Oxide (ITO). ITO is a conductive oxide that can improve the conductivity properties of a liquid crystal polymer (Petkoska, 2014). Nanometer-sized material has properties that are superior to larger sizes, including electrical conductivity (Pokropivny, 2007). Therefore, in this study ITO nanoparticles will be used as dopants in cholesteryl acrylate polymers.

2 METHOD

This research was carried out in the Chemical Research Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Jakarta. Cholesteryl acrylate monomer was synthesized through a Steglich esterification reaction (Afrizal, 2011). The process of making a mixture of cholesteryl acrylate-ITO solution was carried out by mixing 10 mg of cholesteryl acrylate monomer with 1 μL of Darocur 1173 initiator in 0.4 mL dichloromethane solvent which was then supplemented with ITO dopants with variations in concentration of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% and 50% w/w. A homogeneous solution of cholesteryl acrylate-ITO was poured on the surface of a glass plate which has been placed on a hotplate at a temperature of 75–80 °C. The photopolymerization process was carried out for 30 minutes using ultraviolet radiation in a UV curing box.

3 RESULT AND DISCUSSION

3.1 *Conductivity properties*

The polymer synthesis in this study uses free radical reactions. Radicals on monomers can form due to homolytic reactions at the initiator because of the energy absorbed from the given UV radiation.

CAP-ITO composite conductivity was measured using an inductance, capacitance and resistance meter at a frequency of 1 kHz with a constant voltage of 1 Volt. From the resulting data, it can be seen that the addition of ITO nanoparticles as dopants in cholesteryl acrylate polymers can increase the electrical conductivity of composites even when compared with micrometer-sized ITO particles (Islami, 2018). The CAP-ITO composite (ITO 10% w/w) which shows an significant increase in electrical conductivity is 5.70×10^{-7} S/m and has a relative permittivity of 129. Where as the CAP-ITO composite (ITO 20% w/w) which is seen to provide the lowest electrical conductivity and relative permittivity is 1.25×10^{-7} S/m and 11.1. This happens because the ITO which fills the cavity of the cholesteryl acrylate polymer has reached the threshold which causes the ability of electron transport to decrease so that the conductivity of the sample decreases. Every material that was loaded had a threshold value for dopant concentration (Petkoska & Jacobs, 2008). This led to a decrease in the conductivity of the cholesteryl acrylate-ITO polymer composite (ITO 20% w/w).

The increase in the conductivity of the composite is caused when an electric field is applied, there is a flow of energy with in the sample so that the electrons in the cholesteryl acrylate polymer flow from the valence band to the conduction band. ITO can polarize electrons in cholesteryl acrylate by inducing electrons in cholesteryl acrylate. This causes the existing electrons in the CAP-ITO composite to be more mobilized than the electrons in the cholesteryl acrylate polymer that has not been doped with ITO.

Table 1. Electrical conductivity and relative permittivity of CAP-ITO composites at a frequency of 1 kHz.

Sample	G (S)	Cs (C^2/Nm)	σ (S/m)	ε_r
CAP + 0% ITO	19.694×10^{-9}	27.349×10^{-12}	9.65×10^{-8}	15.1
CAP + 5% ITO	26.488×10^{-9}	27.349×10^{-12}	1.30×10^{-7}	15.1
CAP + 10% ITO	116.24×10^{-9}	232.09×10^{-12}	5.70×10^{-7}	129
CAP + 15% ITO	31.773×10^{-9}	93.600×10^{-12}	1.56×10^{-7}	51.8
CAP + 20% ITO	25.416×10^{-9}	20.006×10^{-12}	1.25×10^{-7}	11.1
CAP + 25% ITO	29.719×10^{-9}	31.689×10^{-12}	1.46×10^{-7}	17.5
CAP + 30% ITO	34.224×10^{-9}	32.142×10^{-12}	1.68×10^{-7}	17.8
CAP + 35% ITO	35.434×10^{-9}	45.816×10^{-12}	1.74×10^{-7}	25.4
CAP + 40% ITO	45.101×10^{-9}	57.770×10^{-12}	2.21×10^{-7}	32.0
CAP + 45% ITO	51.130×10^{-9}	56.786×10^{-12}	2.51×10^{-7}	31.4
CAP + 50% ITO	67.910×10^{-9}	93.312×10^{-12}	3.33×10^{-7}	51.7

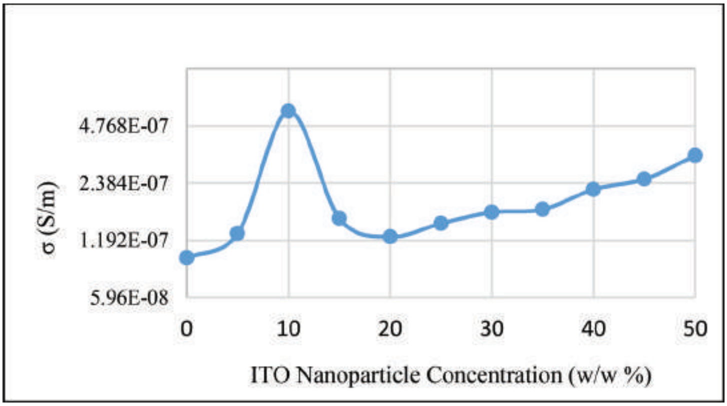


Figure 1. The effect of ITO nanoparticle concentration on the conductivity of the composite.

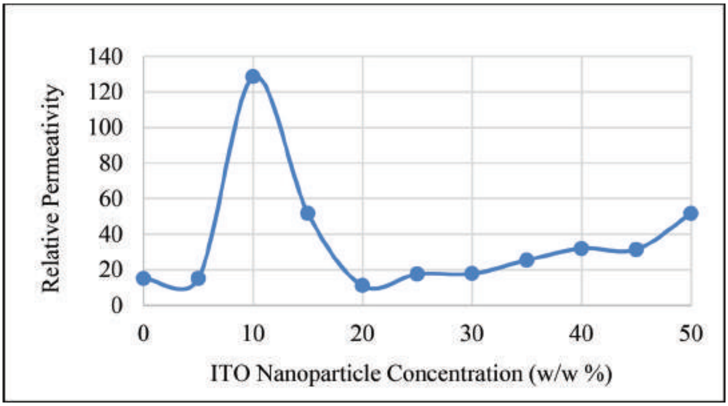


Figure 2. The effect of ITO nanoparticle concentration on the relative permeativity of the composite.

3.2 *Functional groups characteristics of CAP-ITO composite*

The CAP-ITO IR spectrum with ITO concentrations of 10% w/w and 20% w/w it is seen that the more ITO concentrations, the intensity of the hydroxyl and carbonyl group absorption peaks on the composite decreases. The IR spectrum from the peak absorption of carbonyl groups of CAP and CAP-ITO composites at wave numbers 1726.36–1690 cm^{-1} experienced a shift towards smaller wave numbers due to an increase in energy to stretch C=O. This is also observed in the hydroxyl group, where the absorption peak also shifts to a smaller wave number. This indicates that there is an interaction between cholesteryl acrylate and the ITO surface which fills the cavities of cholesteryl acrylate. CAP-ITO composites in a long chain form a helical structure and ITO interacts with the O-H and C=O groups from the cholesteryl acrylate polymer.

A reduction in intensity or a shifting of the absorption peak toward smaller wave numbers due to a weakening of the bonds that occur in between the atoms in a functional group, can also be caused by an increase in the mass of atoms that interact with the functional group. Based on this, the alleged interaction between the two groups with the ITO dopant which has a relatively larger atomic mass causes the weakening of the bonds that occur in between the atoms in the group so that the resulting peak intensity decreases and the absorption peak shifts to a smaller wave number.

The reduced intensity of the absorption of hydroxyl and carbonyl groups is thought to cause the crystallinity of the composite to decrease. With the disappearance of the two groups

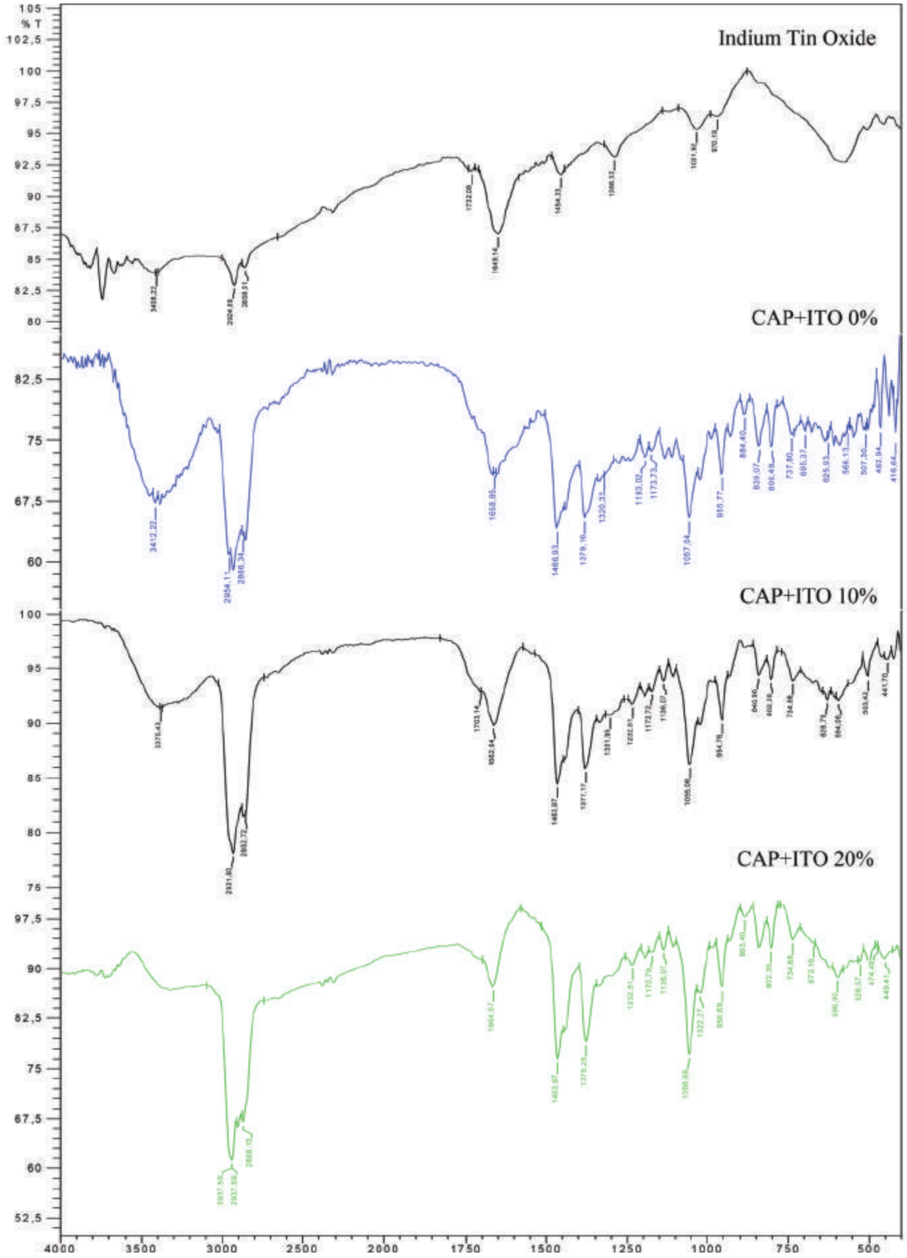
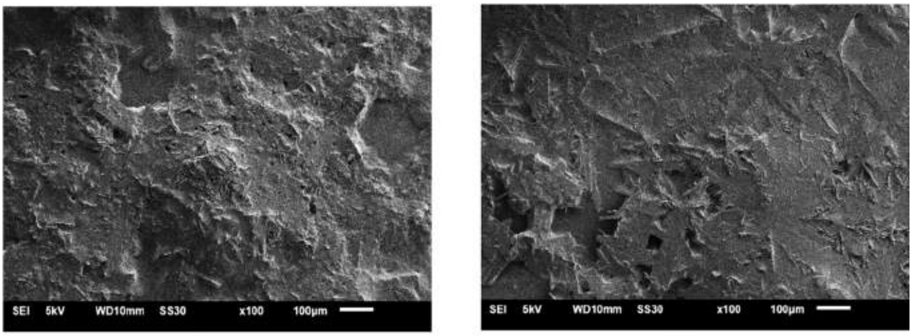


Figure 3. IR spectrum ITO, CAP, CAP-ITO composite (10% and 20% w/w).

from the CAP-ITO composite with an ITO concentration of 20% w/w it can be estimated that the crystallinity of the composite is the lowest.

3.3 *Surface morphology of CAP-ITO composite*

Figure 4 shows the polymer structure with morphology which appears to have a bar shape with branched fibers with morphological structures forming crosslinked networks. This indicates that the photopolymerization process has been successfully carried out. The CAP-ITO composite



(a) (b)

Figure 4. Surface morphology of CAP-ITO composite (a) 10% and (b) 20% w/w.

(ITO 10% w/w) has a uniform morphological structure. This shows that the ITO has filled cavities from the polymer of cholesteryl acrylate in an optimal manner which causes an electron transport from the cholesteryl acrylate polymer so that the electrical conductivity of cholesteryl acrylate polymer will increase. However CAP-ITO composite (ITO 20% w/w) has a morphology structure that is less uniform. This happened because the ITO which filled the polymer cavity of cholestyl acrylate had reached the threshold which caused the ability of electron transport to decrease so that there was a decrease in the conductivity of the CAP-ITO composite.

This result is also confirmed by the CAP-ITO composite functional group analysis conducted with FTIR. The IR spectrum results from CAP-ITO composites showed that the addition of ITO concentrations of 20% w/w, absorption peaks from hydroxyl and carbonyl groups resulted in a decrease in crystallinity in the CAP-ITO composite. The higher crystallinity of a material, the better its conductive properties, this is due to the molecular regularity in arranging itself in a material that will facilitate the process of electron transport with in it.

4 CONCLUSION

The results of testing the effect of ITO dopants on the conductive properties of cholesteryl acrylate-ITO polymer composites were carried out using the LCR Meter at a frequency of 1 kHz and a constant voltage of 1 Volt, indicated that the addition of ITO nanoparticles as dopants in cholesteryl acrylate polymers could increase the composite's conductivity. The optimum addition of dopant ITO nanoparticles to the cholesteryl acrylate polymer was observed at 10% w/w ITO concentration with a conductivity value of 5.70×10^{-7} S/m and reached a threshold at 20% ITO concentration w/w. This result is confirmed by the functional group analysis and surface morphology of the CAP-ITO composites produced.

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A comparison of digital signal modulation techniques through multipath Rayleigh fading channel using a MIMO-OSTBC system

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ABSTRACT: Digital signal modulation is a technique of transforming binary data into a continuous signal so that it can be carried by the signal carrier in a certain band-pass channel. There are several digital signal modulation techniques that are often used, these are Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), and Quadrature Amplitude Modulation (QAM) and are simulated in this study using Matlab® Simulink. Two parameters are employed to compare the performance of five signal modulation techniques through a multipath Rayleigh fading channel, they are Bit Error Rate (BER) and the Power Spectral Density (PSD). The simulation results show that, in terms of bit error rate, BPSK has the lowest rate (2.75e-5), followed by QAM (2.81e-5), QPSK (2.61e-3), 16-QAM (2.72e-3) and 16-QPSK (6.34e-3). In terms of power spectral density, 16-QPSK ranked first with (55.508 dBm), BPSK came second (55.561 dBm), followed by QPSK (59.589 dBm), then QAM (66.436 dBm), and finally 16-QAM (89.722 dBm).

1 INTRODUCTION

The demand for high data rates in wireless communication has been increasing rapidly. Several techniques have been proposed in order to increase the data rate using multiple-symbol transfer modulation techniques, such as Quadrature Amplitude Modulation (QAM) (Farag, 2006; Jasper & Butler, 1994) and Quadrature Phase Shift Keying (QPSK) (Beach et al., 2003; Dennis, 1991). Techniques have also been developed to prevent or minimize the error rate in data transmission, for instance using a Multiple Input Multiple Output (MIMO) system (Alamouti, 1998). A high data rate can increase productivity, enabling online management tools, online data sharing, online collaboration, and so on (Commonwealth of Australia, 2018; Crandall, 2010; Sigala, 2003). This requirement for increased productivity is inseparable from the requirement for a telecommunications infrastructure that provides a good wireless connection. The development of telecommunications technology has been increasing rapidly, in line with its demand, such as the technology of Space-Time Block Codes (STBC) that is used in 4G wireless and mobile communications (Raleigh & Cioffi, 1998). STBC was invented by Alamouti (1998) and works as an encoding scheme between spatial multiplexing and space-time diversity. Furthermore, the ability of wireless communications to avoid or minimize the effects of an obstacle that often causes problems is expected, including lost connections, slower data rate, or even the damage of infrastructure caused by weather (Luomala & Hakala, 2015; Nadeem et al., 2010; Nweke & Ukwu, 2015). These technologies have enabled the use of high-speed data rate connections despite various obstacles and weather conditions.

To help decide which modulation techniques work best for certain communication types, regardless of obstacles and weather conditions, simulations of different modulation methods can be carried out and compared. One way to do it is by using Matlab software and its Simulink toolboxes. For instance, Prameela and Humaira (Devi & Nishat, 2017), who had carried out a performance evaluation of the digital signal modulation methods of Binary Phase

Shift Keying (BPSK), QPSK and QAM, concluded that BPSK has the best performance. In addition, specifically related to signal modulation that is used by Code Division Multiple Access (CDMA), Kumar and Gupta (2015) concluded that QAM (in any order of their simulation) is the most suitable application in massive MIMO systems. Despite the fact that only an Additive White Gaussian Noise (AWGN) channel is used, Proloy and Ahmed (2017) have shown that channel coding used in telecommunication systems is quite impacted to the performance of the modulation technique itself. These numerical investigations could help to understand which digital signal modulation technique is most suitable for a particular application, such as mobile communications, satellite communications, and microwave digital radio.

To the best of our knowledge, there has not been any simulation for multipath Rayleigh fading and MIMO-OSTBC (Multiple Input Multiple Output-Orthogonal Space-Time Block Codes). According to the survey paper on digital modulation techniques by Jain and Yadav (2015), BPSK, QPSK, and QAM are the most popular modulation methods due to the efficiency and the data rate offered by these techniques. Thus, the aim of this paper is to carry out a comparison of BPSK, QPSK, QAM, 16-QPSK, and 16-QAM digital signal modulation methods by employing a MIMO-OSTBC system through a multipath Rayleigh fading channel.

2 METHOD

The simulation model has been built using Matlab Simulink Toolboxes and consists of a binary generator using Bernoulli distribution, a modulator, an OSTBC encoder with three transmitters at a rate of ¾, then it is channeled through the multipath Rayleigh fading channel and Additive White Gaussian Noise (AWGN), and before the signal enters the demodulator block model, the OSTBC combiner is employed as a decoder with three transmitters and two receivers, with a rate of ¾, the same as its encoder. After this, the signal is demodulated with the demodulator block. In order to calculate the Bit Error Rate (BER), the error rate calculation block is employed and then displayed by the BER display block. In addition, the Power Spectral Density (PSD) is calculated by employing a Welch periodogram block and then analyzed using the spectrum analyzer block. The Welch periodogram algorithm adopts a Fast Fourier Transform (FFT) to compute the strength of the energy as a function of the frequency (R & Andrews, 2015). However, since this method is quite complex to calculate, some researchers have proposed some method to use it in various size of window samples (Gupta et al., 2013) and have made some improvements to the calculation itself by modifying the periodogram averages (Johnson & Long, 1999).

The simulation model runs with a Signal to Noise Ratio (SNR) input value of 5 dB and is run ten times with sample quantities from 1,000,000 to 10,000,000, increasing by 1,000,000 samples per simulation. The constellation diagrams are presented in order to visualize the performance of the model. The models of BPSK, QPSK, 16-QPSK, QAM, and 16-QAM modulation are presented in Figures 1 to 5.

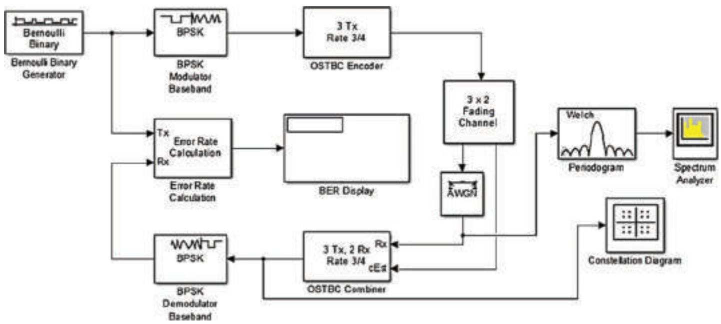

Figure 1. The simulation model of BPSK modulation.

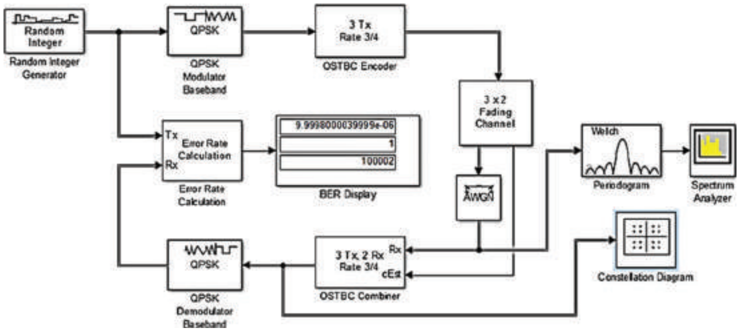

Figure 2. The simulation model of QPSK modulation.

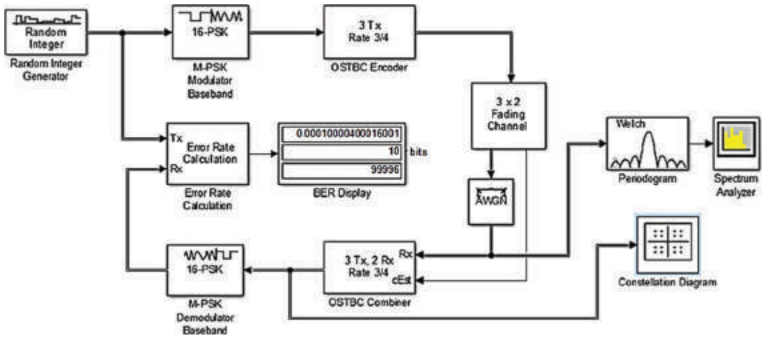

Figure 3. The simulation model of 16-QPSK modulation.

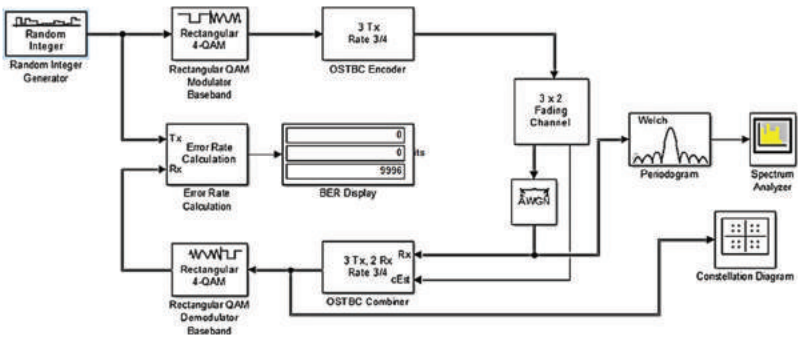

Figure 4. The simulation model of QAM modulation.

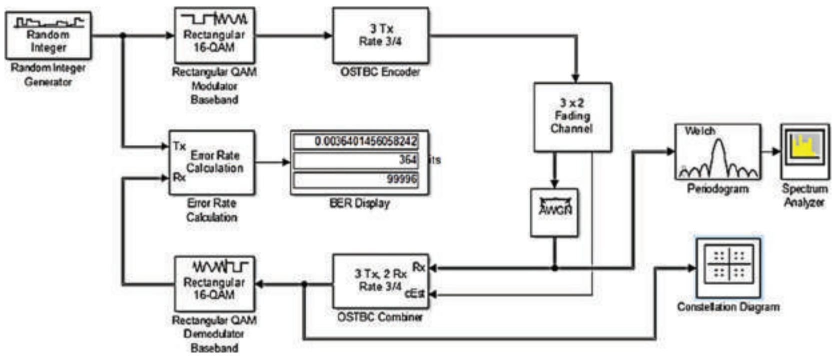

Figure 5. The simulation model of 16-QAM modulation.

3 RESULTS AND DISCUSSIONS

3.1 *Bit Error Rate (BER)*

In order to obtain valid results, the simulation is run ten times with different number of samples, thus the consistence of the tested parameters could be conducted. The average error percentages of each simulation are presented in Table 1. Each modulation technique has shown its BER performance using the proposed simulation model. The term NE stands for ‘Number of Error(s)’, and EP stands for ‘Error Percentages’.

From the simulation results, it can be seen that BPSK modulation has the best performance in the BER performance test with error percentage averages of 2.57e-5, followed by QAM modulation with 2.81e-5, QPSK with 2.61e-3, 16-QAM with 2.72e-3, and the last is 16-QPSK with 6.34e-3. It is well known that QAM techniques not only differentiate every single signal generated based on the phase degree, but also the signal level, so it is easy for the demodulator to correctly identify symbol that arrives at the receiver. Meanwhile, the PSK (Phase Shift Keying)

Table 1. Simulation results of the BER performance test.

		Simulation BER performance test results									
		BPSK		QPSK		16-QPSK		QAM		16-QAM	
Simulation number	Quantity of samples	NE	EP	NE	EP	NE	EP	NE	EP	NE	EP
1	1,000,000	26	2.60e-05	2,750	2.75e-03	6,642	6.64e-03	33	3.30e-05	2,804	2.80e-03
2	2,000,000	48	2.40e-05	5,259	2.63e-03	12,805	6.40e-03	57	2.85e-05	5,457	2.73e-03
3	3,000,000	55	1.83e-05	7,744	2.58e-03	19,210	6.40e-03	87	2.90e-05	8,089	2.70e-03
4	4,000,000	131	3.28e-05	10,659	2.66e-03	23,184	5.80e-03	123	3.08e-05	10,938	2.73e-03
5	5,000,000	145	2.90e-05	13,252	2.65e-03	32,369	6.47e-03	152	3.04e-05	13,728	2.75e-03
6	6,000,000	184	3.07e-05	15,372	2.56e-03	37,852	6.31e-03	161	2.68e-05	16,305	2.72e-03
7	7,000,000	190	2.71e-05	17,995	2.57e-03	44,392	6.34e-03	180	2.57e-05	18,963	2.71e-03
8	8,000,000	196	2.45e-05	20,585	2.57e-03	50,891	6.36e-03	205	2.56e-05	21,578	2.70e-03
9	9,000,000	197	2.19e-05	22,810	2.53e-03	56,562	6.28e-03	218	2.42e-05	24,233	2.69e-03
10	10,000,000	228	2.28e-05	25,750	2.58e-03	63,443	6.34e-03	273	2.73e-05	26,895	2.69e-03
Averages of EP		2.57e-05		2.61e-03		6.34e-03		2.81e-05		2.72e-03	

Note:
NE = Number of Error(s).
EP = Error Percentage.

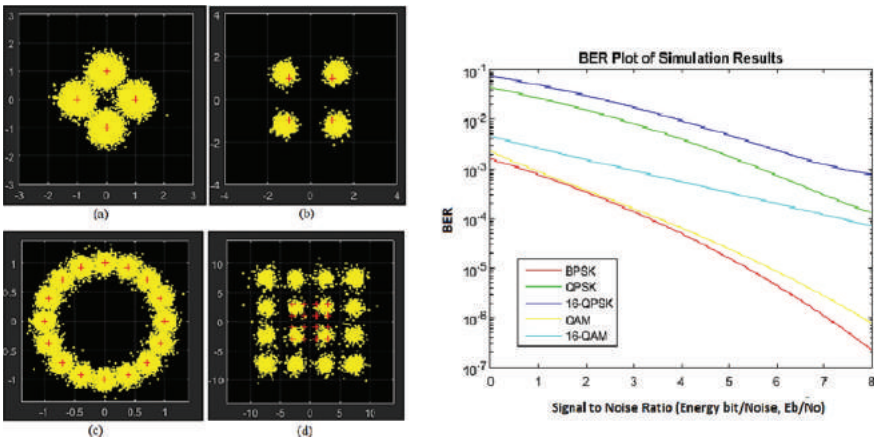

Figure 6. Constellation diagrams of (a) QPSK, (b) QAM, (c) 16-QPSK and (d) 16-QAM and the respective BER plot curves of the five modulation models.

modulation of any order (4 or 16) only uses the phase degree to differentiate every symbol transferred, so it will be more difficult to identify each symbol transferred to the demodulator. However, it is reasonable to identify the BPSK modulation method as the best technique in the BER test, because BPSK has the lowest modulation order, that is only two. Meanwhile, performance in the same order of both amplitude modulation and phase shift keying modulation, that is four (QAM and QPSK modulations), QAM leads the BER performance test with results of 2.72e3. Also, in the higher order, 16-QAM leads the BER performance test with 2.72e-03 compared to 16-QPSK with 6.34e-03, therefore 16-QAM is more than twice as good as 16-QPSK. Figure 6 shows the constellation diagram drawn from the simulation of QAM, QPSK, 16-QAM and 16-QPSK, and the BER plot curve.

3.2 *Power Spectral Density (PSD)*

The complexity of calculating the power spectrum has led to the development of some proposed from the above-mentioned method that adopts FFT like Welch's Periodogram, which is employed in this simulation. However, in Matlab Simulink, in order to generate valid simulation results in this study, the same initial seed is used in all simulations in order to generate identical random data. By using the same initial seed value, it is reasonable to say that the simulation is running under the same conditions and treatment. Also, in order to make sure that the captured data is fairly acquired the time sampling, which is the time at which the sample is acquired, is set to be the same in all simulations. Table 2 shows the simulation results using the same settings of initial seed and time sampling.

From Table 2 we could conclude that 16-QPSK and BPSK modulation has the lowest value in the PSD test. This table also shows that that PSK modulation of any order has the best performance in the PSD test with the 16-QPSK value of 55.508 dBm, BPSK has a value of 55.651 dBm, and QPSK has a value of 59.589 dBm. In contrast, the AM modulation of any order has the lowest performance, in QAM with the value of 66.436 dBm and 16-QAM with the value of 89.722 dBm. Overall, QPSK is dominating the PSD performance test more than QAM modulation.

Table 2. Simulation results of the PSD performance test.

Simulation number	Initial seed	Time sampling	Simulation PSD performance test results (dBm)				
			BPSK	QPSK	16-QPSK	QAM	16-QAM
1	33	0.015	57.096	57.918	56.66	68.01	90.994
2	33	0.033	57.003	59.818	54.679	67.251	91.973
3	33	0.051	57.117	59.796	53.956	65.789	88.744
4	33	0.069	48.86	58.703	53.334	62.7	90.111
5	33	0.087	55.721	60.22	54.538	66.041	91.717
6	33	0.105	59.198	60.383	52.662	65.009	89.853
7	33	0.123	57.056	58.693	56.236	67.009	90.278
8	33	0.141	56.168	56.488	52.777	63.635	90.349
9	33	0.159	55.62	56.759	54.597	66.513	91.61
10	33	0.177	56.816	62.677	55.875	68.231	89.732
11	66	0.015	51.932	56.677	52.078	63.51	86.99
12	66	0.033	55.171	59.369	57.063	67.468	87.557
13	66	0.051	53.37	58.888	55.743	67.389	86.85
14	66	0.069	57.048	60.629	57.595	66.537	92.378
15	66	0.087	60.064	60.884	57.409	70.327	89.795
16	66	0.105	58.188	61.631	55.461	66.84	91.733
17	66	0.123	50.833	60.219	55.026	62.727	89.119
18	66	0.141	56.168	58.008	57.793	68.391	88.535
19	66	0.159	53.715	59.874	57.11	66.637	87.225
20	66	0.177	55.885	64.143	59.569	68.701	88.9
Averages PSD (dBm)			55.651	59.589	55.508	66.436	89.722

Table 3. Summary of simulation parameters performance tests results.

Simulation models	Average BER performance test	Average PSD performance test
BPSK	2.57e-05	55.651
QPSK	2.61e-03	59.589
16-QPSK	6.34e-03	55.508
QAM	2.81e-05	66.436
16-QAM	2.72e-03	89.722

In general, as the modulation order increases, the results of both performance test parameters, that is the BER and the PSD, show a decreasing performance, except for the PSD performance test of the 16-QPSK model as highlighted in Table 3. This particularly intriguing condition might be caused by the architecture of the modulation and the periodogram tool used for the tests. From the modulation architecture perspective, since 16-QPSK has 16 different modulated symbols and all of the symbols are only slightly different, this means that every symbol is near to another symbol as shown in the constellation diagram in Figure 6(c). With this condition, the difference of every symbol generated is also have probability to be near each other which causes the power consumption to be less, since there is rarely a need to generate a long range of generated phase symbols, such as from phase 0^o to 180^o. Another side is because of in the mentioned architecture, the periodogram also estimate the same way, since in FFT (Fast Fourier Transform) the PSD estimation will be reduced, due to the less effect on the transient phenomena of the signal which at the end produce a less results in PSD performance test, which is better.

Moreover, also in the PSD performance test, the QAM modulation family (QAM and 16-QAM) have a higher value compared to the PSK modulation family. As stated previously, in contrast to PSK modulation which only differentiates every symbol in the modulation by phase, QAM modulation also uses different signal levels, which in this case will lead to the transient phenomena that uses more energy. However, in the same cases, this differentiation of signal level also leads to a better BER test performance. Furthermore, the minimum differentiation of each signal level in the designed symbol needs to be precisely investigated, thus the required energy can be minimized without decreasing the error rates.

4 CONCLUSIONS

Overall, the simulation has shown some intriguing results. In the first performance test, which is the BER performance test, QAM modulation, with the same modulation order as other methods, dominates the performance test with a result of 2.81e-05. Meanwhile, the PSK modulation family (BPSK, QPSK, and 16-QPSK), in any modulation order, dominates the second performance test, which is the PSD performance test. The results show that as the modulation order gets higher the error rate (BER) and power spectrum (PSD) decrease their performance, except the PSD performance test of the 16-QPSK modulator. The QAM modulation technique with differentiation of both phase and signal level has figured out to perform a better performance than PSK modulation family technique which only based on phase difference as shown in constellation diagram. This study concludes that the QAM modulation family and the PSK modulation family have superior performance in different parameters; that are the QAM family modulation technique is superior in BER performance test and the PSK family modulation technique is superior in PSD performance test.

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Determining the elastic factor for an ecotechnic assessment of Medium Voltage (MV) transmission lines with a consideration of the conductor's skin effect

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ABSTRACT: In the design process of a Medium Voltage (MV) grid, an ecotechnic assessment must cover not only the technical matter but also the economic effect. An MV grid is a set of facilities including a conductor, insulator strings and connection devices. Existing operations indicate that the losses of a grid are approximately over 50% of the total network losses. Because of the importance of these losses, it must be taken into account in the design as well as in the operating procedure of the network. Certainly, it is a key factor which significantly influences an ecotechnic assessment. However, the application of the energy loss in ecotechnic assessment always gets the significant bias because of conductors' physical properties. This paper focuses on analyzing this kind of difference, which is called the skin effect. An algorithm based on Matlab calculations is utilized and the results are compared with real data measurement in order to ascertain an elastic factor corresponding to each line's cross section. The series of factors will help the power utilities to have a better ecotechnic assessment in the early stages of grid design.

1 THE ROLE OF THE CONDUCTOR CROSS-SECTION IN THE ZCOST FUNCTION FOR MV GRID ECOTECHNIC ASSESSMENT

1.1 *Zcost expression for an economic assessment of MV grids*

During the process of power planning or grid design, many economic methods and indicators could be applied to estimate the economical effort required, this is called a Cost-Benefit Analysis (CBA). Generally, a CBA has two main purposes: to determine if an investment or decision is sound—verifying whether its benefits outweigh the costs, and by how much; to provide a basis for comparing projects—which involves comparing the total expected cost of each option against its total expected benefits. In electrical construction, this can include the following methods (Vitiello et al., 2015; Neusel-Lange et al., 2014; Ulbig et al., 2017):

- Economic Net Present Value (NPV) – the difference between the discounted social benefits and cost;
- Economic Internal Rate of Return (IRR) – the discount rate that produces a zero value for the NPV;
- Benefit/Cost ratio – ratio between discounted economic benefits and costs;
- Zcost functions – express the cost occurring during the operation of the grid (over one year) including the operating and maintenance costs.

In the operational stage of MV grids, the first three indicators are not used. The Zcost function is utilized because it includes not only the investment of the construction but also the amount of money that operators and users have to pay for the grid's operation. Normally, the Zcost function is presented as shown in Equation 1 (Thanh, 2016; Khoa, 2010):

$$Z = \left(a_{vh} + a_{tc}\right) K + Y_{\Delta A} \tag{1}$$

where:

a_{vh} – the operation factor;
a_{tc} – standard recovery factor;
K – annual cost;
ΔA – power losses when power is transmitted over a long distance;
$Y_{\Delta A}$ – the payment (cost) for power losses.

In detail, Z can also be expressed by Equation 2:

$$Z = (a_{vh} + a_{tc}) C_{dd} m_0 \ell + C \frac{(P^2 + Q^2)}{U^2} \tau \frac{\delta}{S} \ell \tag{2}$$

where:

a_{vh} – the factor expressing the rate of operating cost for the transmission line each year;
a_{tc} – The factor expressing the rate of budget refund of transmission line each year;
C_{dd} – The unit invesment for a kg weight of conductor (đ/kg);
m_0 – the weighted unit of conductor (kg/km);
l – the length of conductor (km).

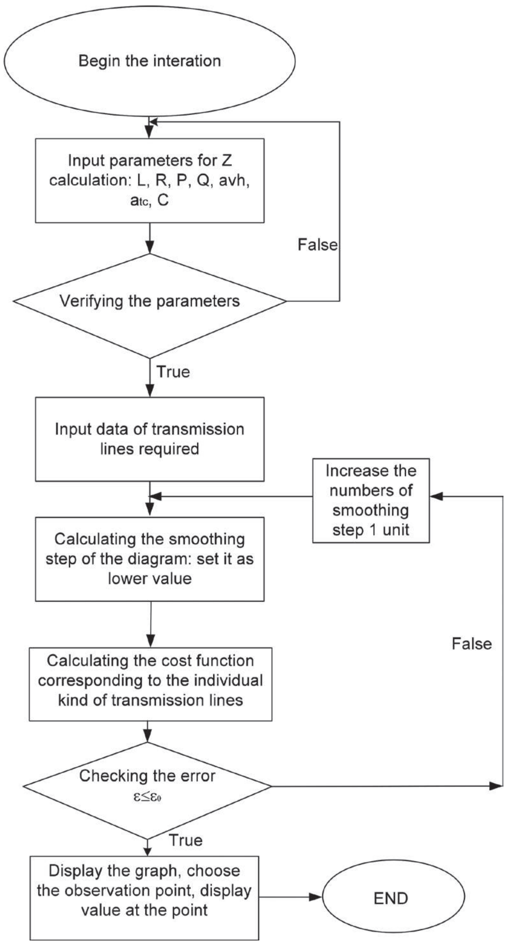

Figure 1. Flow chart presenting the calculation for acquiring the optimal value of cost function Z.

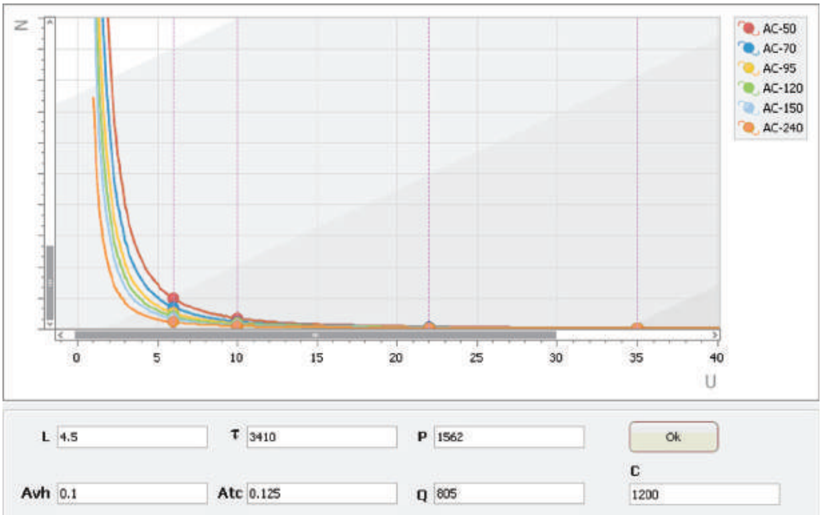

Figure 2. Results corresponding to the different types of conductor.

Table 1. Annual cost function of Quang Yen MV grid.

Type of conductor	Annual optimal cost function Z = f(U2), (106 VND)			
	6 kV	10 kV	22 kV	35 kV
AC35	172 552,65	92 443,62	52 462,87	43 562,17
AC50	168 668,84	73 556,47	50 353,93	40 253,63
AC70	147 446,83	65 912,15	49 070,23	39 075,13
AC95	139 741,99	52 190,12	44 464,50	36 213,50
AC120	139 960,928	48 221,648	43 767,75	34 261,35

1.2 *Using the Matlab application to find the optimal value of Zcost function corresponding to the conductor's cross sections*

It is clear that, in Equation 2, Z is a function of many variants including rated voltage (U) and conductor cross-section (S). In the design process of an MV grid, it should be economically optimal if S is selected correspondingly to U (Das et al., 2017). These selections will result in an optimal value of Z (Khoa, 2010). In order to determine the optimal value of Z corresponding to the rated voltage U and a conductor cross-section S, an algorithm has been formed in Figure 1 (Thanh, 2016), which uses the above equation, programming in Matlab, and the curves shown in Figure 2 to help find the optimal value of Z.

Table 1 shows some of the results of applying the equation, and the curves in Figure 2 to calculate the annual cost of MV grids in Quang Yen district, Quang Ninh province. These results are calculated based on data from the design stage of the grids. They are also used to compare with real measurement data obtained from live operations of the grids to identify an elastic correction factor. This process will be explained in part 2.

2 THE IMPACT OF THE SKIN EFFECT ON THE ESTIMATION OF ZCOST FUNCTION

In power transmission, if a current is flowing through one or more nearby conductors, its distribution within the first conductor will be constrained to smaller regions, the resulting current crowding is termed the proximity effect and could significantly increase the AC resistance of the adjacent conductors (Lobao et al., 2013; Vitiello et al., 2015).

Considering this effect, the total losses in a conductor will be the result of two effects: skin and proximity, ones of which are expressed in Equation 3 (Lobao et al., 2013):

$$P_{total} = P_{skin} + P_{prox} \tag{3}$$

where

$$P_{skin} = I^2_{rms} \times R_{AC}$$

$$P_{prox} = (cR + d)\left(\frac{\mu_0 \mu_r I}{2\pi r}\right)^2 \quad (if\ R \geq \delta)$$
$$P_{prox} = aR^b\left(\frac{\mu_0 \mu_r I}{2\pi r}\right)^2 \quad (if\ R < \delta) \tag{4}$$

and a, b, c, and d are constants in accordance with the type of material (copper and aluminum); R is conductor radius, and δ is the skin depth, as shown in Equation 5:

$$\delta = \sqrt{\frac{2}{\sigma \omega \mu_0 \mu_r}} \tag{5}$$

Base on Equation 3, many experiments have been carried out to calculate an economic analysis, including the NPV and IRR (Neusel-Lange et al.; 2014; Lobao et al., 2013) of power losses with consideration for the skin effect. Some results are obtained with even 14.3% bias with traditional computing (the tranditional computing eliminates the impact of the effect).

3 COMPUTING ELASTIC FACTOR TO CORRECT THE BIAS OF ZCOST FUNCTION

As mentioned in part 1, the skin effect has a very strong influence on power losses in conductors; hence it will bias the economic analysis relying on the losses. The following is the expression to show the computing procedure of an 'elastic factor' to eliminate this bias.

3.1 *Case study*

The grid that is applied to compute the power losses in Quang Yen 10 kV and 22 kV is shown in Figures 3 and 4.

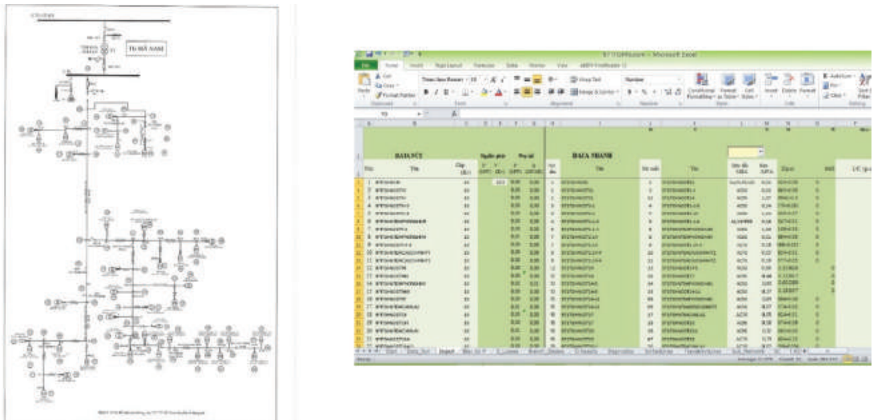

Figure 3. Single line diagram of 10 kV Quang Yen grid and its nodded procedure in the Smart Simulator.

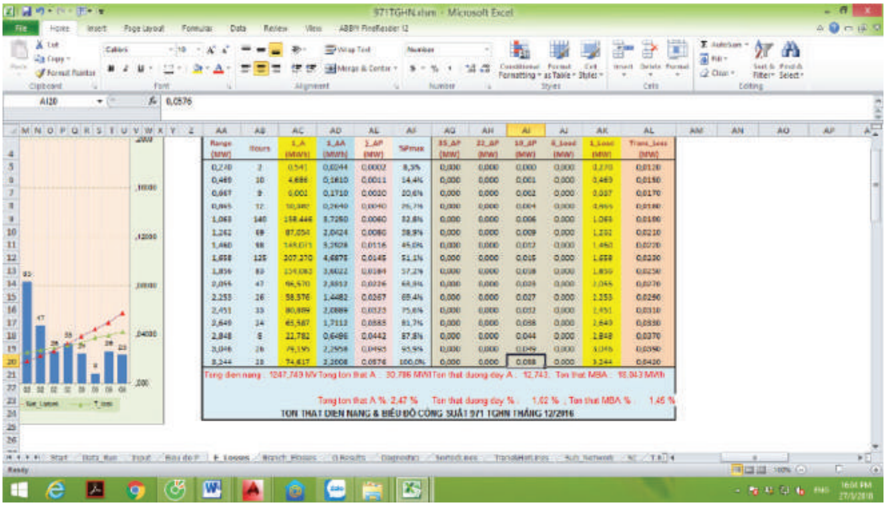

Figure 4. Power losses results of feeder no 971.

Table 2. Results of power losses bias (kWh) which influence the Zcost function between a theoretical calculation (by a Smart Simulator) and the real measurement of the Quang Yen grids.

			Power losses (kWh)		
Feeder No	U $_{rated}$ (kV)	S (mm^2)	Smart Sim. calculation	Real data measurement	Elastic factor
971 TG	10	AC50	2,351	2,703	1.1497
971 TG	22	AC50	1,154	1,327	1.1499
973	10	AC70	2,473	2,962.65	1.1979
973	22	AC70	1,185	1,422	1.2
933 TG T3 Ha Nam	10	AC70	2,262	2,709.9	1.198
933 TG T3 Ha Nam	22	AC70	1,054	1,262.7	1.198

Table 3. The elastic factor corresponding to the cross-section of conductors and rated voltage.

S (mm^2)	AC35	AC50	AC70	AC95	AC120
Elastic factor (10 kV)	1.151	1.149	1.2	1.22	1.23
Elastic factor (22 kV)	1.15	1.149	1.2	1.2,198	1.2,297

3.2 *Calculating the elastic factor*

Utilizing a Smart Simulator (SS) and comparing with real data measurements from the Quang Ninh power company (Khue, 2018), the results show a bias as presented in Table 2. In dividing the simulated data by the real measurement, a table of the elastic factors can be created as shown in the last column of the table.

A similar calculation is implemented in Table 2 using a series of factors in accordance with the typical cross-section of steel-cored aluminum lines.

In Table 2, the elastic factor is derived by dividing the real measurement by the Smart Simulator calculation.

4 CONCLUSION

Based on the above calculations, using a Matlab method to make an ecotechnic analysis has proved effective. In some cases, where real-world data or relevant expertise is not available, using Matlab is a smart alternative. However, if the calculations are made only using a Matlab computation this can result in a significant error relating to the conductor's skin effect.

The calculation process in section 3 obtain a series of the elastic factors that can be embedded in the Zcost function. The series of factors can help to improve the results of the ecotechnic analysis. Though over the procedure the following conclusions are identified:

- The rated MV voltages have no impact on elastic factors;
- Corresponding to the typical cross-section of steel-cored aluminum conductors, the elastic factors vary from 1.15 to 1.2. This means that if the skin effect is taken into account, power losses of from 15% to 20% must be added to the theoretical calculation.

In the initial stage of an ecotechnic analysis of an energy project, using the optimal Zcost function with the above calculated series factors is a good recommendation that can give a project manager a general view on the economic effects of the project.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)
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Impact of power harmonics on precise and discriminative tripping of the relay system for earthing protection in underground 6 kV grids of Quảng Ninh underground mines

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ABSTRACT: The ratio of earthing in underground mines' electrical systems is in the range of 75% to 86% of the total faults. When an earth fault happens, there are always odd power harmonic levels (3, 5, 7, 9, 11 and 13). These harmonics can have a bad influence on the relay system, and consequently the protection system could operate abnormally or have wrong tripping. This article is based on real data measurements and on simulation in MATLAB, to analyze the kinds of harmonics to fill/eliminate in order to improve the sensitivity, as well as to improve the discriminative tripping of the relay system. The analysis also provides recommendations for operators of the 6 kV grid in order to have a better relay protection system performance.

1 INTRODUCTION

In the power system of Vietnamese 6 kV mining grids, the ratio of one-phase earthing is in the range of 75% to 86% (Bun, 2016). To discriminatively trip open the faulted feeder, Earthing Protection Relays (EPRs) are utilized using signals supplied from zero sequence current transformers and zero sequence voltage transformers. Based on evidence from the operation of EPRs in the main 35/6 kV transformer substations, some inappropriate tripping has occurred in feeders containing power electronic converters. The operation of such devices could lead to high-level power harmonics, including harmonic levels 5, 7, 11 and 13. These harmonics are the main cause of abnormal operation as well as the inappropriate tripping of the EPR system.

The following parts of the paper will analyze the incidence of harmonics in 6 kV feeders, and their impact on earthing relay systems. Based on the comparison of a simulation implemented in MATLAB simulation software with real-world measurements, solutions are recommended to eliminate their negative effect and improve the EPR's sensitivity.

2 ANALYZING THE EFFECT OF POWER HARMONICS ON MINING GRIDS' 6 KV FEEDERS AND THEIR IMPACT ON EARTHING RELAY SYSTEMS

2.1 *The introduction of the influence of power harmonics on earthing relay systems*

Many tools and methods could be implemented to calculate and determine the minimum and maximum impact of power harmonics on earthing relay systems. However, one of the most effective methods is simulation. Implementing in MATLAB, a simulation could include not only the influence of the grids' parameters but also some restrictions and limitations of outdoor climate indications (Мирошник & Соколов, 2016).

The source of power harmonics mainly comes from power electronic devices and the magnetizing process of transformers. Normally, the highest level of harmonics emitted by the latter device is level 5 or 7 (Vinokurova et al., 2015). In power electronic devices, including controllable or uncontrollable ones, the percentage of THD corresponding to harmonic levels 5, 7, 11 and 13 are 20%, 14%, 9% and 8%, respectively (Шуин et al., 2009). However, with regard to earthing in the 6 kV grid, the percentage of harmonic levels 11 and 13 is sometimes even higher than for harmonic levels 5 and 7. The THD value caused by a power electronic device containing control elements (diode, thyristor) depends on either load currents, or control angle α and conversion angle γ; this relation is shown in Figure 1. In the figure, the value I_v is the Root Mean Square (RMS) of the harmonic current, and I_1 is the RMS of the fundamental current.

When earthing occurs, because of the existence of the harmonic current, the total rms of the earthing current includes not only the fundamental component but also the harmonic components. The modification of the power harmonic current will lead to a change in the capacitance current. This value will vary in the range from $I_{v\Sigma min}$ to $I_{v\Sigma max}$ and is represented by factor Z (Шуин, 2013):

$$Z = \frac{I_{v\Sigma max}}{I_{v\Sigma \min}} = \frac{\alpha_{\max} I_{C\Sigma}}{\alpha_{\min} I_{C\Sigma}} = \frac{\alpha_{\max}}{\alpha_{\min}} \tag{1}$$

where $\alpha_{\max}$ and $\alpha_{\min}$ are modifying the level of harmonic currents on the fundamental current.

In 6 kV mining grids, the average value of THD corresponding to the kind of loads is shown in Table 1.

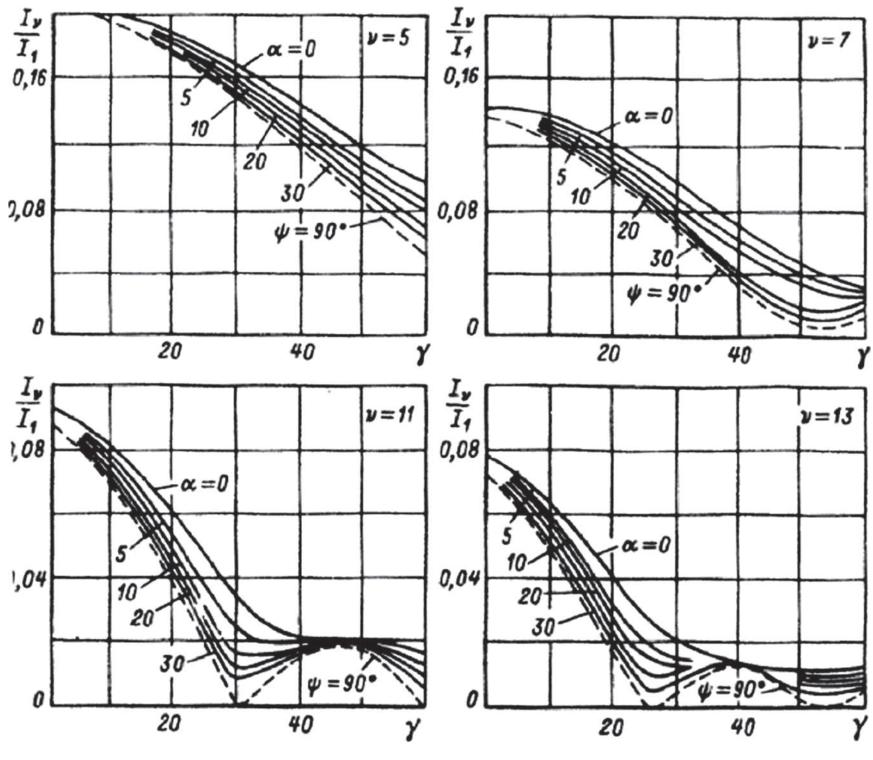

Figure 1. Curves present the relation of (I_v/I_1) versus the conversion angle.

Table 1. The average value of THD corresponding to the typical loads in 6 kV mining grids.

THD (%)				
Synchronous motors	6 kV asynchronous motors	LV asynchronous motors	Lighting	Power electronic conversion
4	7	6	15	4

The above analysis shows that the harmonic currents will modify the rms of fault current when earthing. Moreover, it will make the current fluctuate in a wide range. The following part of the paper will show the proof through real-time measurements and simulation in MATLAB.

2.2 *The evidence for power harmonics on 6 kV mining grids*

Measurements were taken in 6 kV mining grids that contain power electronic converters, such as rectifiers and inverters. Some current and voltage waveform results are shown in Figures 2 and 3.

The spectrums of harmonic current in Figures 2 and 3 prove that the power electronic devices emit huge amounts of harmonics on the grid. The simulation illustrated in Figure 4 shows the impact of those on the relay system.

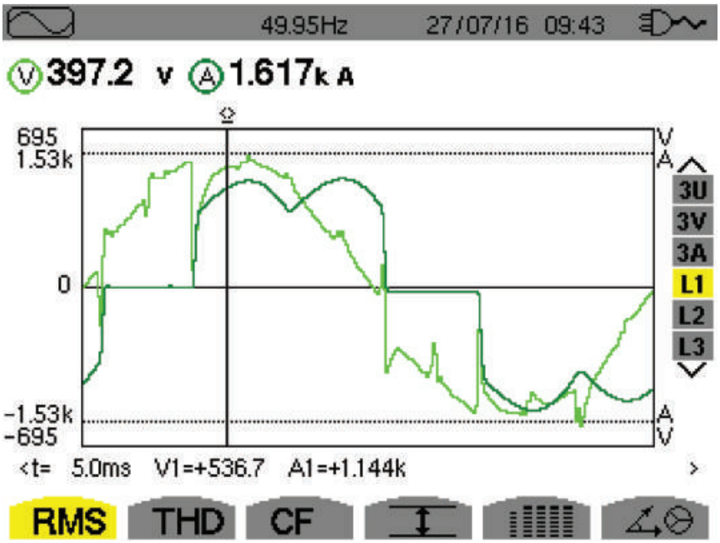

Figure 2. Voltage and current waveform of 6 kV inverter measured at the front end.

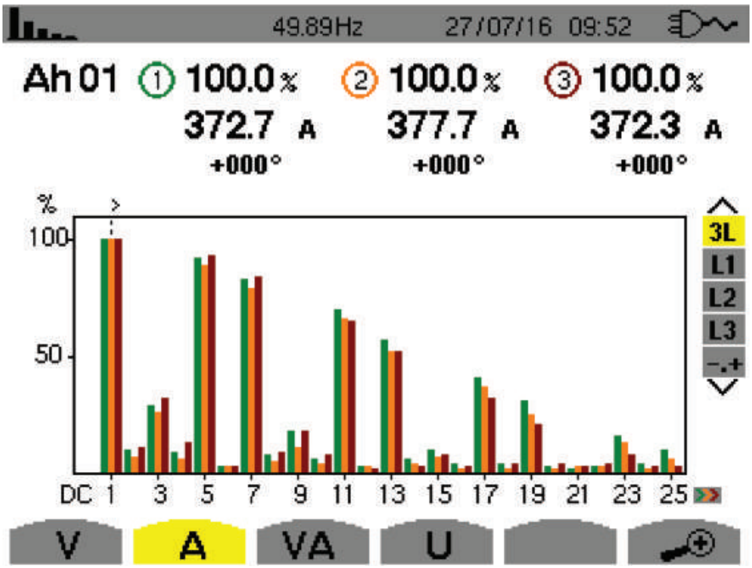

Figure 3. Spectrum of harmonic current caused by the 6 kV inverter in mining grids.

Implementing the simulation in MATLAB, the zero sequence current and zero sequence voltage waveforms at the fault point are shown in Figure 5; the spectrum of harmonic current is shown in Figure 6.

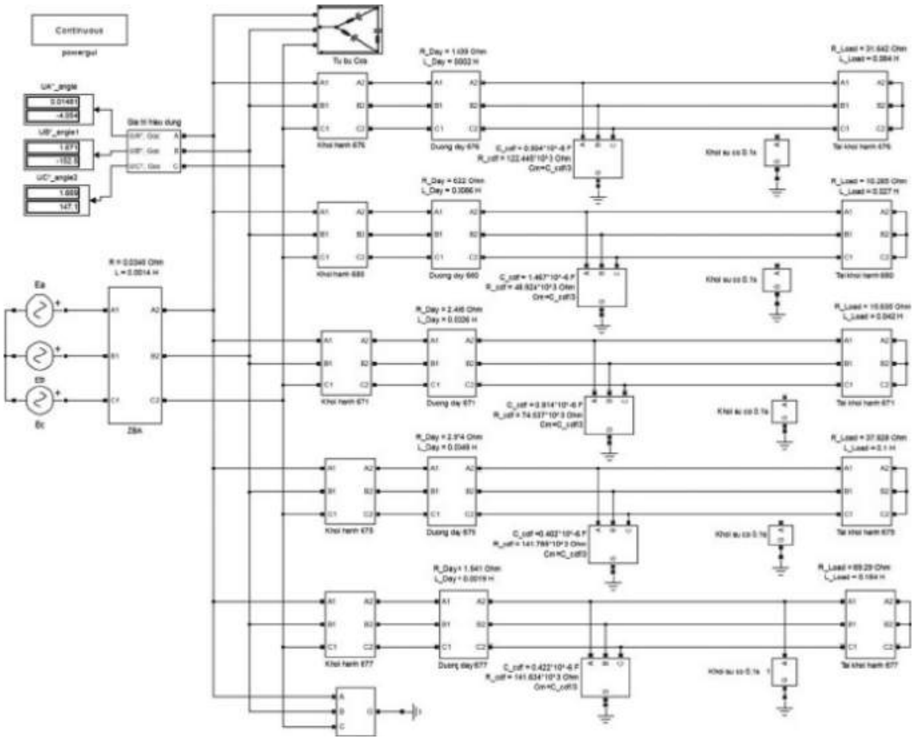

Figure 4. Diagram of MATLAB simulation of the 6 kV grid.

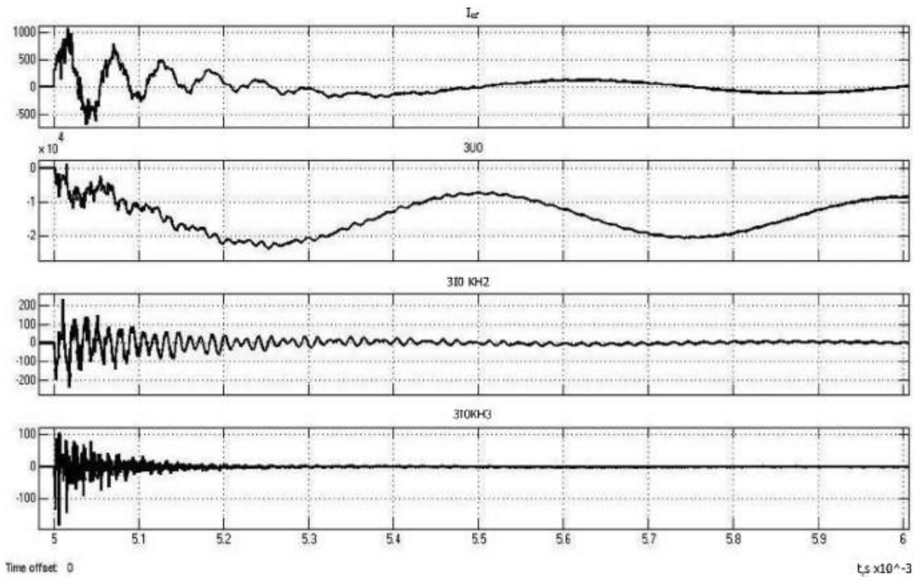

Figure 5. Voltage waveform at the earthing point in 6 kV mining grid.

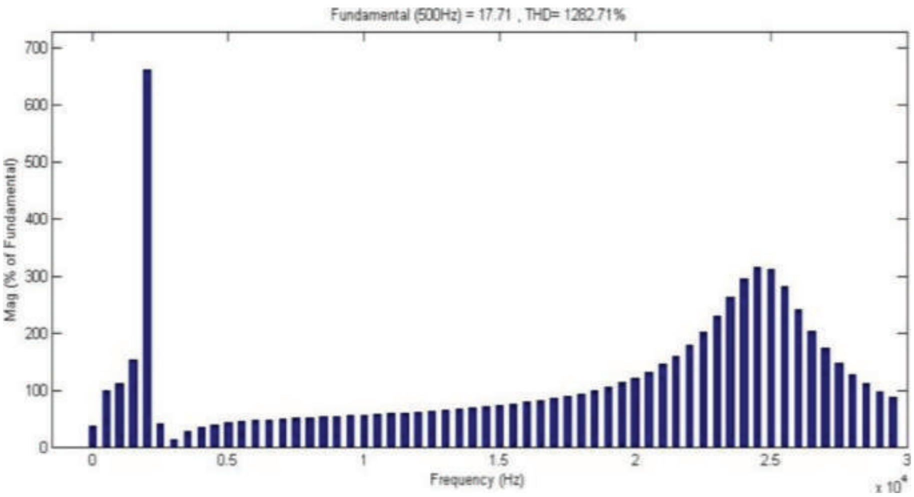

Figure 6. Spectrum of harmonic current caused by the earthing current.

2.3 *Analyzing and calculating the impact of harmonic current on earthing relay system*

In Figure 5, the fluctuating frequency of zero sequence current ($3I_0$) is very high (nearly 650 Hz). To meet the sensitivity of the relay system, the setting value of the earthing relay must satisfy the following equation:

$$I_{C.cdi} \geq K_{at}.3I_{0i.v.max} = K_{at}.\alpha_{max} I_{Ci} \tag{2}$$

where K_{at} is the safety factor; $3I_{0i.v.max}$ is the component of maximum harmonic current contained in zero sequence current of feeder number i; α_{max} is the maximum value of harmonic current determined by curves in Figure 1; and I_{Ci} is the capacitance current of feeder I, calculated from Equation 3.

$$I_{Ci} = 3\omega C_{0i} U_f \tag{3}$$

where C_{0i} is the capacitance of the faulted feeder; $\omega = 2\pi.50$; and U_f is the rated voltage.

To ensure the earthing relay system operates precisely and is discriminatively tripped, the setting value of the relay obtained from Equation 2 must satisfy the requirement listed in Equation 4:

$$I_{C.cdi} \geq I_{C.cd.min} \tag{4}$$

where $I_{C.cd\,min}$ is the minimum set value of the relay, determined by the relay specification and the technical parameter of current transformer $3I_0$.

It is very simple to meet Equation 4 if the fault current is purely sinusoidal. However, the actual measurements above show that the earthing current is not totally sinusoidal. The problem is that to determine the maximum value of α_{max} in Equation 2 in order to deduct the minimum value of $I_{C.cd\,min}$ in Equation 4. If only harmonic current levels 5, 7, 11 and 13 are taken into account for α_{max} determination, this value can be calculated from Equation 5. Implementing the measurements as shown in Figures 2 and 3, the values of the K factors corresponding to particular harmonic current are listed in Table 2.

$$\alpha_{max} = 100\sqrt{(5K_{U5})^2 + (7K_{U7})^2 + (11K_{U11})^2 + (13K_{U13})^2} \approx 65\% \tag{5}$$

Table 2. The set of K factors corresponding to harmonic level.

Level of harmonic current v	5	7	11	13
$K_{U.v.TC}$ (%)	4.1	3.03	1.99	2.0
$K_{U.v}$ (%)	6.05	4.51	3.0	2.98

Table 3. Simulation results to determine the minimum value of $\alpha_{\min}$ and $I_{C\Sigma}$.

L – The length of the feeder (km)	2.7	3.2	3.5	1.6	1.8	3.2	1.1
Type of conductor	AC50	AC70	AC50	AC95	AC50	AC70	AC95
$I_{C\Sigma}$	5.02	6.1	6.3	5.4	5.5	6.04	6.07
$\alpha_{\min}$	0.04	0.06	0.055	0.07	0.05	0.12	0.11
$\alpha_{\max}$	0.32	0.4	0.287	0.67	0.34	0.26	0.27

To ensure the sensitivity of the earthing relay, the relay sensitivity factor must satisfy the requirement listed in Equation 6:

$$K_{n.i} = \frac{3I_{0.i.v.\min}}{I_{C.cd.i}} \leq \frac{\alpha_{\min}(I_{C\Sigma} - I_{C.i})}{I_{C.cd.i}} \geq K_{n.\min} \tag{6}$$

where $3I_{0.v\min}$ is the minimum value of harmonic current contributing to the total earthing current $3I_0$; $\alpha_{\min}$ is the minimum ratio defined by Figure 1; $K_{n\min} = 1.5$, the minimum value of sensitivity factor defined by the IEEE.

Based on Figure 1 and Equation 6, the values obtained from the MATLAB simulation are as follows: the minimum value of $\alpha_{\min}$ is 0.04; the maximum value of $\alpha_{\max}$ is 0.4; the minimum value of $I_{C\Sigma}$ is 5 A. These values are listed in Table 3.

The values in Table 3 are used to obtain the constraint relation of capacitance current in 6 kV feeders of mining grids, as shown in Equation 7 (Шуин et al., 2009; Шуин, 2013):

$$I_{C.i*} = \frac{I_{C.i}}{I_{C\Sigma}} \leq \frac{1}{1 + \dfrac{\alpha_{\max}}{\alpha_{\min}} K_{at}.K_{n.\min}} = \frac{1}{1 + Z_{\max} K_{at}.K_{n.\min}} \tag{7}$$

$$I_{C.i*} = \frac{I_{C.i}}{I_{C\Sigma}} \leq \frac{1}{1 + \dfrac{0.4}{0.04} 1{,}5.1{,}5} \approx 0.043$$

The above calculation shows that to obtain the sensitivity, as well as the discriminative tripping of the earthing relay with the consideration of harmonic current, the individual capacitance current of each feeder could not be higher than 4.3% of the total earthing current of the grid. This value is much lower than 10% when there is no harmonic current on the grid (Мирошник & Соколов, 2016).

3 CONCLUSION

Based on the measurements and on the simulation in MATLAB, the paper calculated the earthing relay's setting value, as well as the constraint of the feeder's capacitance current to achieve the sensitivity and discriminative tripping. When calculating the setting value of the earthing relay with harmonic consideration, the ratio $I_{C.i*}$ is much lower than the value indicated in other research (Мирошник & Соколов, 2016). To increase the range of $I_{C.i*}$ in a

6 kV mining grid, the most effective solution is to use the filter. By utilizing the passive filter for eliminating the harmonic levels 5, 7, 11 and 13, the value of $I_{C.i*}$ could be 0.7 (Vinokurova et al., 2015). In the case of considering the harmonic current in the feeder having a length no longer than 4 km, the value of $I_{C.i*}$ should not be higher than 4.3%.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Microwave-assisted synthesis and *in vivo* anti-diabetic activity of 5-(2-bromophenyl)-3-(naphthalen-1-yl)-4,5-dihydro-1*H*-pyrazole

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ABSTRACT: Abromo-substituted pyrazoline, 5-(2-bromophenyl)-3-(naphthalen-1-yl)-4,5-dihydro-1*H*-pyrazole (Compound 2), has been synthesized under microwave irradiation. The reaction occurred in a short time with a yield of 82%. The structure of this compound was characterized on the basis of spectroscopic data, including Ultraviolet–Visible (UV-Vis), Fourier-Transform Infrared (FTIR) spectroscopy, High-Resolution Mass Spectrometry (HRMS), and ^{1}H and ^{13}C Nuclear Magnetic Resonance (NMR). According to an *in vivo* anti-diabetic assay, the oral administration of Compound 2 in dosages of 25, 50 and 100 mg/kg of body weight showed significant ($p < 0.05$) increasing percentage changes in blood glucose level and weight of treated diabetic mice, compared to the negative control. Then, as an anti-diabetic drug, the oral administration of Compound 2 at a dosage of 100 mg/kg of body weight did not show a significant difference ($p > 0.05$) in the ability to reduce blood glucose level and prevent weight loss of diabetic mice in comparison to the use of glibenclamide. In addition, the oral administration of Compound 2 at dosages of 25, 50 and 100 mg/kg body weight did not show a significant ($p > 0.05$) effect on the relative weight of organs of treated diabetic mice compared to the normal control.

1 INTRODUCTION

Diabetes mellitus is a group of metabolic diseases characterized by chronic hyperglycemia and caused by defects in insulin secretion, insulin action, or both (Sperling et al., 2014). Diabetes mellitus is a major human health concern and very prevalent disease affecting the citizens throughout the world. In 2000, the number of people in the world estimated to have diabetes was 171 million. Latest estimates predict a global prevalence of 366 million people with diabetes by 2030 (Wild et al., 2004), expected to rise to 592 million by 2035 (Forouhi & Wareham, 2014).

Pyrazolines have played a crucial role in drug discovery research and have been used widely as important pharmacophores or intermediates for synthesis of bioactive compounds (Bhosle et al., 2012). Substituted pyrazolines have been reported to have good potencies as anticancer (Havrylyuk et al., 2009; Jasril et al., 2017) and anti-inflammatory (Amir et al., 2008) agents. Some patented pyrazolines have been used for the treatment of food disorders, including obesity and metabolic syndromes, in patients with developed diabetes (Buschmann, 2007), and for treatment of diabetes and related diseases, especially type 2 diabetes (Sulsky & Robl, 2002). In addition, the presence of a bromine atom in an organic compound has been reported as enhancing hypoglycemic activity. Some researchers have reported that the introduction of bromine to coumarin sulfonylurea can enhance its hypoglycemic activity (Qi & Zhang, 2013), and some bromo-substituted pyrazoles show higher hypoglycemic activity than anti-diabetic drugs (Faidallah et al., 2016). Therefore, we are interested in synthesizing a bromo-substituted pyrazoline and exploring the potential of the synthesized compound as a new anti-diabetic agent.

Some conventional methods, such as grinding, stirring and reflux, have been applied to synthesize substituted pyrazolines. However, a microwave-assisted synthesis method is a more attractive alternative for researchers, with many advantages. When compared to more conventional methods, this method reduces the reaction time and can also increase the yield by reducing the formation of by products (Razzaq & Kappe, 2008).

The aim of this study is to synthesize and to explore the potential of a bromo-substituted pyrazoline (5-(2-bromophenyl)-3-(naphthalen-1-yl)-4,5-dihydro-1*H*-pyrazole) as an anti-diabetic agent, given that the prevalence of diabetes mellitus patients is increasing every year. The synthesis was conducted under microwave irradiation. Then, the anti-diabetic activity was evaluated to obtain the effect of oral administration of the compound (Compound 2) at various dosages on percentage change of blood glucose level, percentage change of weight, and the relative weight of liver, kidney, and heart in treated diabetic mice.

2 METHOD

2.1 *General information*

The materials used to synthesize the bromo-substituted pyrazoline included 1-acetyl naphthalene, 2-bromobenzaldehyde, potassium hydroxide, hydrochloric acid, hydrazine hydrate, glacial acetic acid and some organic solvents, such as ethanol, n-hexane, and ethyl acetate. The materials used to evaluate the anti-diabetic activity included alloxan, glucose, sodium carboxymethylcellulose (NaCMC) and glibenclamide.

The synthesis reactions were performed in a Samsung ME109F domestic microwave oven, the melting point was determined on an SMP 11 apparatus (uncorrected), the Thin-Layer Chromatography (TLC) analysis was performed using GF_{254} silica gel (Merck) under an Ultraviolet (UV) lamp at 254/366 nm (Camag™), the UV spectra were recorded on a Genesys™ 10S UV–Vis spectrophotometer, the FTIR spectra were recorded in KBr powder on a Shimadzu® FTIR Prestige-21 spectrophotometer, the ^{1}H and ^{13}C NMR spectra were recorded on a JEOL JNM ECA at 500 and 125 MHz, respectively, the mass spectra were recorded on an LC-MS (Mariner Biospectrometry), and the blood glucose levels were measured with a GlucoDr™Blood Glucose Test Meter (All Medicus).

2.2 *Procedure*

The synthesis of Compound 2 was conducted via a two-step reaction. First, a bromo-substituted chalcone (Compound 1) was synthesized via Claisen–Schmidt condensation. Second, the bromo-substituted pyrazoline (Compound 2) was synthesized via Michael addition, followed by intramolecular cyclization (Jasril et al., 2016), as depicted in Figure 1.

2.2.1 *Synthesis of Compound 1*

Amounts of 1-acetylnaphthalene (5 mmol) and 2-bromobenzaldehyde (5 mmol) were dissolved in absolute ethanol (10 mL). Then, potassium hydroxide (5 mL, 1 N) was added to the solution. The mixture was irradiated using a domestic microwave. The progress of the

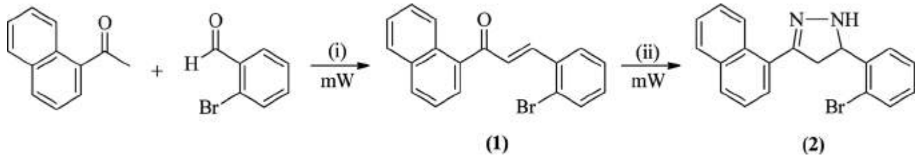

Figure 1. The synthesis scheme for bromo-substituted pyrazoline: (i) KOH, EtOH, 180 W, 3 min; (ii) $NH_2NH_2.H_2O$, AcOH, EtOH, 180 W, 2 min.

reaction was observed by TLC analysis. After the reaction was complete, cold distilled water (10 mL) was added to the mixture, which was then neutralized with hydrochloric acid (1 N) to afford the precipitate. This precipitate was filtered *in vacuo*, washed with cold *n*-hexane, dried in a desiccator, and recrystallized in a mixture of ethyl acetate and *n*-hexane to obtain pure Compound 1.

2.2.2 *Synthesis of Compound 2*

Compound 1 (1 mmol) was dissolved in absolute ethanol (15 mL) in a closed reaction vessel using an ultrasonicator. Then, hydrazine hydrate (5 mmol) and glacial acetic acid (five drops) were added to the solution. The mixture was irradiated using a domestic microwave and the progress of the reaction was observed using TLC analysis. After the reaction was complete, the mixture was cooled in an ice bath to afford the precipitate. The precipitate was filtered *in vacuo*, washed with cold *n*-hexane, dried in a desiccator, and recrystallized in a mixture of ethyl acetate and *n*-hexane to obtain pure Compound 2.

2.3 *In vivo anti-diabetic assay*

The animals used in this study are male albino mice (*Mus musculus* L.) of 20–30 g weight. The mice were divided into six groups, randomly. Each group contains five mice. The first group is a normal control (not induced to be diabetic and not treated); the second group is a negative control (induced to be diabetic, but just treated with 1% NaCMC). The third group is a positive control (induced to be diabetic and treated with glibenclamide at a dosage of 0.65 mg/kg of body weight). Groups four through six were induced to be diabetic and treated with Compound 2 at dosages of 25, 50 and 100 mg/kg of body weight, respectively.

Before use, the mice were acclimatized for one week. Then, the mice were fasted for 18 h and induced to be diabetic with alloxan solution (175 mg/kg), intraperitoneally. Blood glucose levels before and after induction was measured. Following the alloxan injection, 10% glucose solution was given to the mice for two days. From the third until the seventh day, drinking water was given to the mice and the mice were moved into cages, each cage containing one mouse, and their blood glucose levels were measured. If mice were judged diabetic (blood glucose level $\geq$ 200 mg/dl), they were treated orally with a suspension of Compound 2. Compound 2 was administered orally to the diabetic mice at dosages of 25, 50, and 100 mg/kg of body weight, once a day for a week. The volume administered was 1% of mouse weight (made up in 5 ml of 1% NaCMC suspension). Blood was taken from the mice's tails, placed on GlucoDr™ blood glucose test strips, and the blood glucose levels on the first, third, fifth, and seventh days after the diabetic state were measured. The mice's weight losses were also measured on the first, third, fifth, and seventh days after the diabetic state, with an analytical balance. On the eighth day, all mice were sacrificed, and their hearts, livers, and kidneys were collected. The organs were dried on filter paper and their weight measured with the analytical balance.

2.4 *Data analysis*

The data relating to changes in blood glucose level (%) and weight (%) were analyzed by two-way analysis of variance (ANOVA), and the data regarding relative weight of organs were analyzed by one-way ANOVA followed by a Tukey's post-hoc test.

3 RESULTS AND DISCUSSION

3.1 *Synthesis of (E)-3-(2-bromopheny)-1-(naphthalen-1-yl)prop-2-en-1-one (Compound 1)*

Compound 1 was obtained as a yellow solid at 73% yield. Mp: 102–103°C. UV (MeOH) λ_{max} (nm): 212 and 380. FTIR (KBr) $\tilde{\upsilon}$ (cm^{-1}): 3064 (aromatic C-H), 1655 (conjugated C=O), 1597 and 1506 (aromatic C=C), 649 (C-Br). ^1H NMR (500 MHz, $CDCl_3$) δ (ppm): 8.38 (d, 1H), 8.00 (t, 1H), 7.98 (d, 1H$_\beta$, $J = 15.5$ Hz), 7.91 (d, 1H), 7.81 (d, 1H), 7.70 (d, 1H), 7.57 (m, 4H), 7.35 (t, 1H), 7.24 (d, 1H), 7.22 (d, 1H$_\alpha$, $J = 15.5$ Hz). ^{13}C NMR (125 MHz, $CDCl_3$) δ (ppm): 195.1, 144.3, 136.6, 134.9, 134.0, 133.6, 132.1, 131.5, 130.6, 129.7, 128.6, 128.0, 127.9, 127.7, 127.6, 126.6, 126.0, 125.8, 124.5. HRMS (ES+): m/z $[M+H]^+$ = 337.3219; m/z$[(M+2)+H]^+$ = 339.3165.

3.2 *Synthesis of 5-(2-bromophenyl)-3-(naphthalen-1-yl)-4,5-dihydro-1H-pyrazole (Compound 2)*

Compound 2 was obtained as a white solid at 82% yield. Mp: 102–104°C. UV (MeOH) λ_{max} (nm): 225 and 317. FTIR (KBr) $\tilde{\upsilon}$ (cm^{-1}): 3328 (N-H), 3053 (aromatic C-H), 2861 (aliphatic C-H), 1592 (conjugated C=N), 1504 and 1465 (aromatic C=C), 1023 (C-N), 565 (C-Br). ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm): 9.19 (d, 1H), 7.86 (d, 1H), 7.82 (d, 1H), 7.69 (dd, 1H), 7.58 (t, 2H), 7.51 (t, 2H), 7.43 (t, 1H), 7.33 (t, 1H), 7.15 (td, 1H), 5.33 (t, 1H, $J_1 = 10$ Hz, $J_2 = 9.5$ Hz), 3.83 (dd, 1H, $J_1 = 16$ Hz, $J_2 = 10$ Hz), 3.11 (dd, 1H, $J_1 = 16$ Hz, $J_2 = 9$ Hz). ^{13}C NMR (125 MHz, $CDCl_3$) δ (ppm): 42.8, 62.7, 123.1, 124.9, 126.1, 127.0, 127.1, 127.4, 128.0, 128.5, 129.1, 129.7, 130.9, 133.0, 134.1, 141.5, 151.9. HRMS (ES-): m/z $[M-H]^+$ = 349.2994; m/z $[(M+2)-H]^+$ = 351.2969.

3.3 *In vivo anti-diabetic assay*

The oral administration of Compound 2 at dosages of 25, 50 and 100 mg/kg body weight showed significant ($p < 0.05$) increases of percentage change in blood glucose level of the mice compared to the negative control, as depicted in Figure 2. A higher percentage change in blood glucose level indicated a better ability to reduce blood glucose levels. This means that the higher dosages of Compound 2 showed the better ability to reduce blood glucose levels in diabetic mice. By the seventh day, Compound 2 at dosages of 25, 50 and 100 mg/kg body weight was able to reduce blood glucose levels by 35.85%, 39.22%, and 40.54%, respectively; the anti-diabetic drug glibenclamide was able to reduce blood glucose levels by 47.93%. Based on the statistical analysis, the oral administration of Compound 2 at a dosage of 100 mg/kg body weight did not show a significant difference ($p > 0.05$) in the ability to reduce the blood glucose level of diabetic mice when compared to glibenclamide.

The oral administration of Compound 2 at dosages of 25, 50 and 100 mg/kg body weight also showed the ability to significantly ($p < 0.05$) increase the percentage change in weight of the mice compared to the negative control, as depicted in Figure 3. A higher percentage change in weight indicated a better ability to prevent weight loss in diabetic mice. From the first until the seventh day, the negative control showed the weight of the diabetic mice decreasing, whereas the groups treated with Compound 2 at dosages of 25, 50 and 100 mg/kg

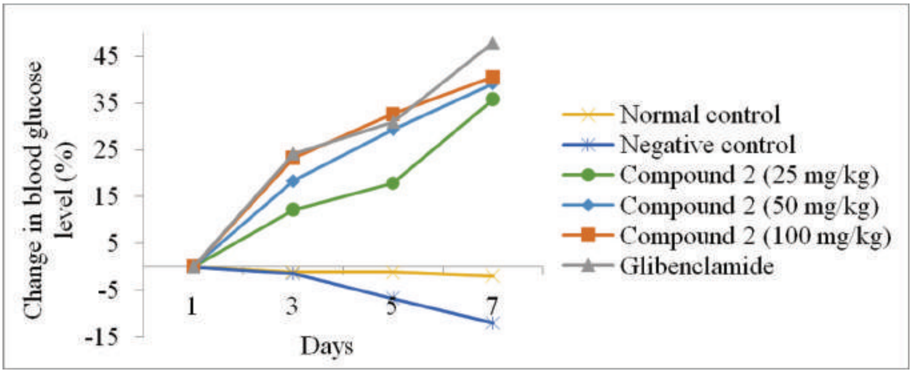

Figure 2. The effect of oral administration of Compound 2 on percentage change in blood glucose level of diabetic mice.

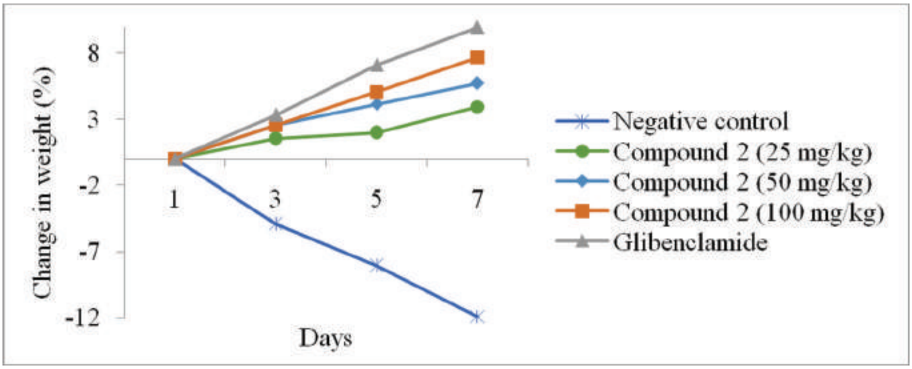

Figure 3. The effect of oral administration of Compound 2 on percentage change in weight of diabetic mice.

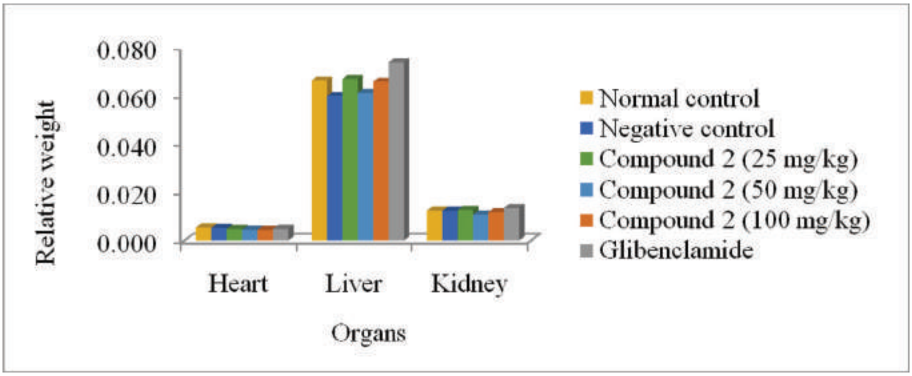

Figure 4. The effect of oral administration of Compound 2 for a week on the relative weight of mice organs.

body weight showed increasing body weight. This result indicated that the oral administration of Compound 2 at all three dosages was able to prevent weight loss in the diabetic mice. By the seventh day, Compound 2 at dosages of 20, 50 and 100 mg/kg of body weight showed increases in weight of 3.94%, 5.71%, and 7.67%, respectively; the anti-diabetic drug glibenclamide gave an increase in weight of 9.95%. Based on the statistical analysis, the oral administration of Compound 2 at a dosage of 100 mg/kg of body weight did not show a significant ($p > 0.05$) difference in the ability to prevent the weight loss of diabetic mice compared to glibenclamide.

The oral administration of Compound 2 at dosages of 25, 50 and 100 mg/kg body weight also did not show a significant effect ($p > 0.05$) on the relative weight of the organs of diabetic mice compared to the normal control, as depicted in Figure 4. This result indicated that the oral administration of Compound 2 for a week did not show a potential toxic effect on the heart, liver and kidney of treated diabetic mice.

4 CONCLUSION

In summary, we have synthesized a bromo-substituted pyrazoline (Compound 2) under microwave irradiation. The reaction occurred in a short time with 82% yield and all spectroscopic data confirmed the structure of the product expected. Based on *in vivo* anti-diabetic assay, Compound 2 at dosages of 25, 50 and 100 mg/kg of body weight showed a good ability to significantly ($p < 0.05$) reduce the blood glucose level and prevent weight loss of treated diabetic mice, compared to the negative control. However, the oral administration of Compound 2 at a dosage of 100 mg/kg of body weight did not show a significant difference ($p > 0.05$) in the ability to reduce the blood glucose level and to prevent the weight loss of diabetic mice when compared to the anti-diabetic drug glibenclamide. The oral administration of Compound 2 for a week to diabetic mice showed no potential toxic effect on the heart, liver, and kidney of the treated mice.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Design, molecular docking study, synthesis and *in vivo* evaluation of some bromonaphthyl pyrazolines as new anti-inflammatory agents

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ABSTRACT: Two bromonaphthyl chalcones (Compounds 1a and 1b) and four bromonaphthyl pyrazolines (Compounds 2a, 3a, 2b and 3b) have been docked to evaluate their potency as anti-inflammatory agents. The molecular docking study showed that Compounds 2a and 3a have good potency as anti-inflammatory agents. Compounds 2a and 3a have been synthesized under microwave irradiation via a two-step reaction. The structures of both compounds were confirmed on the basis of spectroscopic data, including Ultraviolet-Visible (UV-Vis), Fourier-Transform Infrared Spectroscopy (FTIR), High-Resolution Mass Spectrometry (HRMS), and ^{1}H and ^{13}C Nuclear Magnetic Resonance (NMR). The *in vivo* evaluation showed that the oral administration of Compounds 2a and 3a at dosages of 25, 50 and 100 mg/kg of body weight showed a good ability to significantly ($p < 0.05$) reduce inflammation of a carrageenan-induced paw edema in male albino mice (*Mus musculus* L.), compared to the negative control. In addition, the administration of Compounds 2a and 3a at dosages of 25, 50 and 100 mg/kg of body weight did not show a significant difference in ability to inhibit the edema volume ($p > 0.05$) when compared to the anti-inflammatory drug, diclofenac sodium.

1 INTRODUCTION

Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) are the most commonly used drugs to treat inflammation because they are effective in the management of pain, fever, redness, and edema arising as a consequence of inflammatory mediator release (Ferreira, 2002). Some studies showed that both the therapeutic and the side effects of NSAIDs are dependent on the inhibition of cyclooxygenase (COX) (Warner et al., 1999). Many studies have reported that COX-2 inhibition is responsible for the therapeutic effects of NSAIDs, while COX-1 inhibition causes the gastrointestinal and renal side effects (Patrignani, 2000; Zhao et al., 2001).

Pyrazolines play a crucial role in drug discovery research (Bhosle et al., 2012). Substituted pyrazolines have been reported to have good potencies as analgesic and anti-inflammatory agents (Amir et al., 2008). In addition, several bromo-substituted pyrazoles have also been reported to have good potency as a selective COX-2 inhibitor (El-Sayed et al., 2012). Therefore, it becomes interesting to design and synthesize a variety of bromonaphthyl pyrazolines and then explore their potency as new anti-inflammatory agents with a computational approach.

Computational approaches can aid drug design in various ways (Baldi, 2010). Molecular docking is a powerful approach for structure-based drug discovery and it also assists in ensuring the biological activity of a designed ligand and in observing the interactions between ligand and receptor (Meng et al., 2011)., The interactions of the ligands with amino acid residues of the active site were determined from their spatial arrangements (Ikhtiarudin et al.,2017). In this study, a combination of molecular docking study and *in vivo* evaluation have been under taken to explore the potential of some bromonaphthyl pyrazolines as new anti-inflammatory agents. The molecular docking study was conducted to evaluate the potency of bromonaphthyl chalcone and pyrazolines as COX-2 inhibitors. Then, an *in vivo* evaluation was conducted to investigate the effect of oral administration of the synthesized compounds at various dosages on inflammation of a carrageenan-induced paw edema in male albino mice (*Mus musculus* L.).

2 METHOD

2.1 *General information*

The materials used to synthesize the bromonaphthyl chalcones and pyrazolines included 1-acetyl naphthalene, 2-acetyl naphthalene, 2-bromobenzaldehyde, potassium hydroxide, hydrochloric acid, hydrazine hydrate, phenylhydrazine, glacial acetic acid and some organic solvents, such as ethanol, *n*-hexane, and ethyl acetate. The materials used to evaluate the *in vivo* anti-inflammatory activity included carrageenan, sodium carboxymethylcellulose (NaCMC), sodium chloride and diclofenac sodium.

All of the synthesis reactionswere performed in a Samsung ME109F domestic microwave oven. Melting point was determined on a SMP 11 apparatus (uncorrected). UV spectra were recorded on a Genesys™ 10S UV–Vis spectrophotometer, FT-IR spectra were recorded in KBr powder on a Shimadzu® FT-IR Prestige-21 spectrophotometer, and ^{1}H and ^{13}C NMR spectral data were recorded on a JEOL JNM ECA at 500 and 125 MHz, respectively. HRMS data were recorded on an LC-MS (Mariner Biospectrometry), and the edema volumes were measured by plethysmometer (Ugo Basile).

2.2 *Procedure*

2.2.1 *Molecular docking study of designed compound*

Molecular docking study was performed using the AutoDock software package (Jasril et al., 2017). Protein data was downloaded from the protein database (PDB ID: 1CX2). The rigid protein and flexible ligand were prepared using the tools of the AutoDock 1.5.6 software package. Polar and nonpolar hydrogen atoms were then individually added and merged into the protein structure. Kollman charges and solvation parameters were determined. Gasteiger charges were added to minimize the ligand structures, and all bonds were made rotatable and flexible by allowing the detection of root torsion. A grid box of the protein structure was then generated using AutoGrid 4 software with default atom types (carbon, hydrogen, oxygen, and nitrogen), a grid spacing of 0.41 Å, dimensions of $126 \times 126 \times 126$ points along the *x*, *y* and *z*-axes, and centered on the protein for the docking. The protein was solvated with a three-site model (TIP3P) water box with a 2.5 Å layer of water for each direction of the coordinate structure and a CHARMM (Chemistry at Harvard Macromolecular Mechanics) force field was used. The structures of the six ligands are depicted in Figure 1.

2.2.2 *Synthesis of Compounds 2a and 3a*

Synthesis of Compounds 2a and 3a were conducted via a two-step reaction. First, bromonaphthyl chalcone, Compound 1a, was synthesized via Claisen–Schmidt condensation as follows: amounts of 1-acetylnaphthalene (5 mmol) and 2-bromobenzaldehyde (5 mmol) were dissolved in absolute ethanol (10 ml), and then potassium hydroxide (5 mL, 1 N) was added to the solution. The mixture was then irradiated using a domestic microwave (180 W) for 3 min and Thin-Layer Chromatography (TLC) analysis was used to observe the progress of the reaction. After the reaction completed, cold distilled water (10 ml) was added to the mixture and then neutralized with hydrochloric acid (1 N) to afford the precipitate. This precipitate

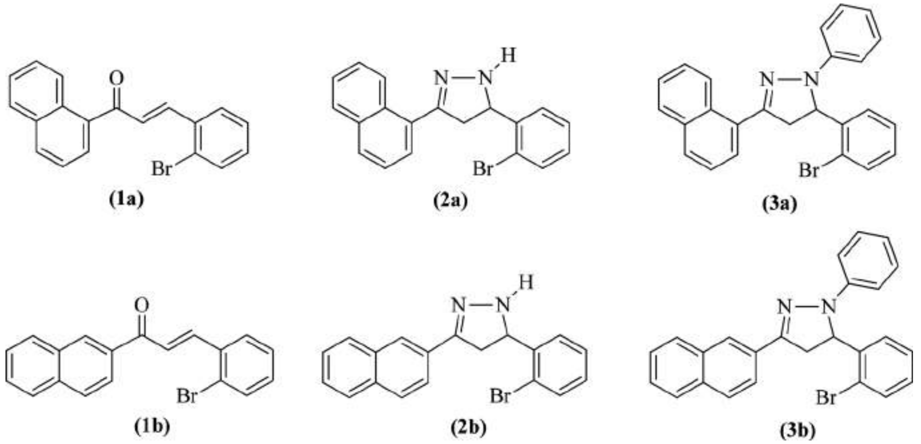


Figure 1. Structures of the six synthesized ligand compounds.

was filtered *in vacuo*, washed with cold *n*-hexane, dried in a desiccator and recrystallized in a mixture of ethyl acetate and *n*-hexane to obtain pure Compound 1a.

The second step is the synthesis of bromonaphthyl pyrazolines (Compounds 2a and 3a) via Michael addition, followed by intramolecular cyclization (Jasril et al., 2016) using the following procedure: an amount of Compound 1a (1 mmol) was dissolved in absolute ethanol (15 ml) in a closed reaction vessel using an ultrasonicator. Then, hydrazine hydrate or phenylhydrazine (5 mmol) and glacial acetic acid (five drops) were added to the solution. The mixture was irradiated using a domestic microwave (180 W) for 2 min. The reaction progress was observed by TLC analysis. After the reaction was complete, the mixture was cooled in an ice bath to afford the precipitate. This precipitate was filtered *in vacuo*, washed with cold *n*-hexane, dried in a desiccator and recrystallized in a mixture of ethyl acetate and *n*-hexane to obtain pure Compound 2a and Compound 3a.

2.2.3 *In vivo anti-inflammatory evaluation*

The animals used in this study were male albino mice (*Mus musculus* L.), 2–3 months old of 20–30 g weight. Before use, the mice were acclimatized for a week. Then the mice were fasted for 18 h. The mice were divided into eight groups, randomly. Each group contained five mice. The first group is a negative control (induced to inflammation, but just treated with 1% NaCMC). The second group is a positive control (induced to inflammation and treated with diclofenac sodium at a dosage of 0.65 mg/kg of body weight). Groups three through five were induced to inflammation and treated with Compound 2a at dosages of 25, 50 and 100 mg/kg of body weight, respectively. Groups six through eight were induced to inflammation and treated with Compound 3a at dosages of 25, 50 and 100 mg/kg of body weight, respectively. Before induction with carrageenan, all mice weights were measured and their paw volumes were measured by plethysmometer (Ugo Basile) and noted as initial volume (V_0). Then, the mice in groups three through fivewere treated orally with Compound 2a, and the mice in groups six through eight with Compound 3a, at dosages of 25, 50 and 100 mg/kg of body weight, respectively. After 30 minutes, the left hind paws of the mice were injected subplantary with carrageenan solution (0.05 ml). The induced paw volumes were measured every hour for five hours and were noted as induced paw volume (V_t): edema volume is the difference between the induced paw volume (V_t) and the initial volume (V_0). The percentage of edema inhibition is then calculated.

2.3 *Data analysis*

The data obtained in this study were analyzed statistically with two-way analysis of variance (ANOVA), followed by a Tukey's post-hoc test.

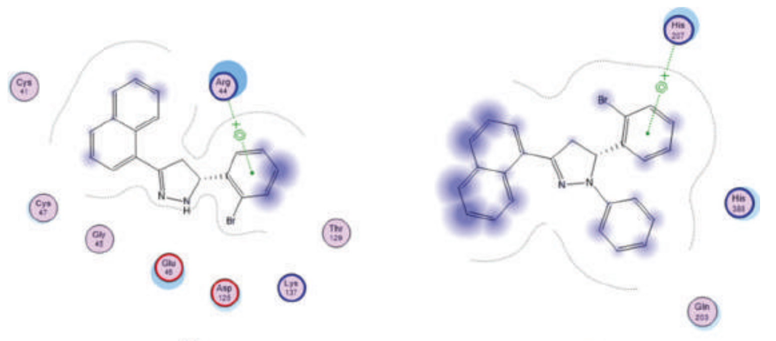
3 RESULTS AND DISCUSSION

3.1 *Molecular docking study*

Six compounds (Compounds 1a, 1b, 2a, 2b, 3a, and 3b) were docked into COX-2 (PDB ID: 1CX2). The docking results are depicted in Table 1. Based on the docking score, two compounds are identified as active: these are Compounds 2a (–8.67 kcal/mol) and 3a (–7.98 kcal/mol). Based on the docking result, the binding affinity of both Compounds 2a and 3a within the enzyme binding pockets constructed the van der Waals, hydrophobic and π interactions with amino acid residues in a hydrophobic channel of the COX-2 (Zarghi & Arfaei, 2011), as presented in Figure 2. In this study, both compounds are not showing any hydrogen bonding constructs with important residues (i.e. the active site), but there are two van der Waals interactions between Compound 2a with Glu 46 and Asp125 residues, which presumably causes another mode of action that will probably increase the activity oc Compound 2a (Yaeghoobi et al., 2016). Nepetolide also forms an interaction with this Asp125 residue (Rehman et al., 2018). In addition, Compound 2a also shows two hydrophobic interactions, with Arg44 and Lys137 residues, and a π interaction with Thr129 residue. These interactions also can be observed when some other active compounds docked into COX-2 (Rehman et al., 2018; Abbas et al., 2017). In our case, Compound 3a did not show any van der Waals interaction. However, it still has two hydrophobic interactions, with His207 and His388 residues, and a π interaction with Gln203 residue. We also found another active compound that formed an

Table 1. Molecular docking results.

Ligand	Estimated free energy of binding (kcal/mol)	Estimated inhibition of constants (μM)	Interaction		
			van der Waals	Hydrophobic	π
1a	–3.46	38.90	–	–	His214, His386
1b	–3.89	42.45	–	Lys79, Lys83, Arg120	Ser119, Tyr115, Tyr122
2a	–8.67	15.34	Glu46, Asp125	Arg44, Lys137	Cys41, Cys47, Gly45, Thr129
2b	–6.43	30.53	Glu256	Lys333	Tyr234, Gln241, Thr237
3a	–7.98	19.89	–	His207, His388	Gln203
3b	–4.59	37.67	–	Lys79, Lys83, Arg120	Ser119, His214



(a) (b)

Figure 2. Interactions of synthesized compounds with amino acid residues in COX-2: (a) Compound 2a; (b) Compound 3a.

interaction with His207 residue (Abbas et al., 2017), which presumably caused this compound to also have another mode of action by which to inhibit the COX-2.

3.2 *Synthesis of Compounds 1a, 2a and 3a*

(*E*)-3-(2-bromopheny)-1-(naphthalen-1-yl)prop-2-en-1-one (Compound 1a):

Compound 1a was obtained as a yellow solid at 63% yield. Mp: 102–103°C. UV (MeOH) λ_{max} (nm): 212 and 380. FT-IR (KBr) $\bar{\nu}$ (cm^{-1}): 3064 (aromatic C-H), 1655 (conjugated C=O), 1597 and 1506 (aromatic C=C), 649 (C-Br). ^1H NMR (500 MHz, $CDCl_3$) δ (ppm): 8.38 (d, 1H), 8.00 (t, 1H), 7.98 (d, $1H_\beta$, J = 15.5 Hz), 7.91 (d, 1H), 7.81 (d, 1H), 7.70 (d, 1H), 7.57 (m, 4H), 7.35 (t, 1H), 7.24 (d, 1H), 7.22 (d, $1H_\alpha$, J = 15.5 Hz). ^{13}C NMR (125 MHz, $CDCl_3$) δ (ppm): 195.1, 144.3, 136.6, 134.9, 134.0, 133.6, 132.1, 131.5, 130.6, 129.7, 128.6, 128.0, 127.9, 127.7, 127.6, 126.6, 126.0, 125.8, 124.5. HRMS (ES+): m/z $[M+H]^+$ = 337.3219; m/z $[(M+2)+H]^+$ = 339.3165.

5-(2-bromophenyl)-3-(naphthalen-1-yl)-4,5-dihydro-1*H*-pyrazole (Compound 2a):

Compound 2a was obtained as a white solid at 72% yield. Mp: 102–104°C. UV (MeOH) λ_{max} (nm): 225 and 317. FT-IR (KBr) $\bar{\nu}$ (cm^{-1}): 3328 (N-H), 3053 (aromatic C-H), 2861 (aliphatic C-H), 1592 (conjugated C=N), 1504 and 1465 (aromatic C=C), 1023 (C-N), 565 (C-Br). ^1H NMR (500 MHz, $CDCl_3$) δ (ppm): 9.19 (d, 1H), 7.86 (d, 1H), 7.82 (d, 1H), 7.69 (dd, 1H), 7.58 (t, 2H), 7.51 (t, 2H), 7.43 (t, 1H), 7.33 (t, 1H), 7.15 (td, 1H), 5.33 (t, 1H, J_1 = 10 Hz, J_2 = 9.5 Hz), 3.83 (dd, 1H, J_1 = 16 Hz, J_2 = 10 Hz), 3.11 (dd, 1H, J_1 = 16 Hz, J_2 = 9 Hz). ^{13}C NMR (125 MHz, $CDCl_3$)δ (ppm): 42.8, 62.7, 123.1, 124.9, 126.1, 127.0, 127.1, 127.4, 128.0, 128.5, 129.1, 129.7, 130.9, 133.0, 134.1, 141.5, 151.9. HRMS (ES-): m/z $[M-H]^+$ = 349.2994; m/z $[(M+2)–H]^+$ = 351.2969.

5-(2-bromophenyl)-3-(naphthalen-1-yl)-1-phenyl-4,5-dihydro-1*H*-pyrazole (Compound 3a):

Compound 3a was obtained as a yellow solid at 95% yield. Mp: 154–155°C. UV (EtOAc) λ_{max} (nm): 220 and 295. FT-IR (KBr) $\bar{\nu}$ (cm^{-1}): 3053 (aromatic C-H), 2903 (aliphatic C-H), 1595 (conjugated C=N), 1499 (aromatic C=C), 1136 (C-N), 665 (C-Br). ^1H NMR (500 MHz, $CDCl_3$) δ (ppm): 9.54 (d, 1H), 7.88 (d, 1H), 7.81 (d, 1H), 7.69 (t, 1H), 7.64 (t, 1H), 7.56 (t,1H), 7.47 (d, 1H), 7.42 (t, 1H), 7.28 (d, 1H), 7.25 (t, 2H), 7.20 (t, 1H), 7.13 (t, 1H), 7.07 (d, 2H), 6.84 (t, 1H), 5.64 (dd, 1H, J_1 = 6.5 Hz, J_2 = 12.5 Hz), 4.19 (dd, 1H, J_1 = 12 Hz, J_2 = 17 Hz), 3.26 (dd, 1H, J_1 = 6.5 Hz, J_2 = 17 Hz). ^{13}C NMR (125 MHz, $CDCl_3$) δ (ppm): 147.5, 144.3, 140.7, 134.2, 133.2, 130.6, 129.7, 129.2, 128.9, 128.7, 128.4, 127.4, 126.9, 126.2, 124.9, 121.9, 119.4, 113.3, 62.4, 44.5. HRMS (ESI): m/z $[M–H]^+$ = 425.3671; m/z $[(M+2)–H]^+$ = 427.3742.

3.3 *In vivo anti-inflammatory evaluation*

Based on the molecular docking study, two brominated pyrazoline analogs (Compounds 2a and 3a) showed good potency as new anti-inflammatory agents. Both compounds have been evaluated for their *in vivo* anti-inflammatory activity by the paw edema method. The *in vivo* evaluation of Compounds 2a and 3a at dosages of 25, 50 and 100 mg/kg of body weight showed promising activity in reducing paw edema volume in male albino mice (*Mus musculus* L.). The percentage of edema inhibition between one and five hours after carrageenan-induced paw edema was calculated and is depicted in Figure 3.

Higher dosages showed higher percentages of edema inhibition. Figure 3 shows that Compound 2a at its highest dosage can inhibit 72.42–96.62% of edema volume, and Compound 3a at its highest dosage can inhibit 74.82–92.6% of edema volume between one and five hours after carrageenan-induced paw edema. As an anti-inflammatory drug, both compounds showed higher inhibition than diclofenac sodium (79.65–89.74%). Based on statistical analysis, the oral administration of Compounds 2a and 3a at dosages of 25, 50 and 100 mg/kg of body weight showed a significantly ($p < 0.05$) good ability to inhibit the edema volume, compared to the negative control. In addition, the administration of Compounds 2a and 3a at dosages of 25, 50 and 100 mg/kg of body weight did not show a significant difference

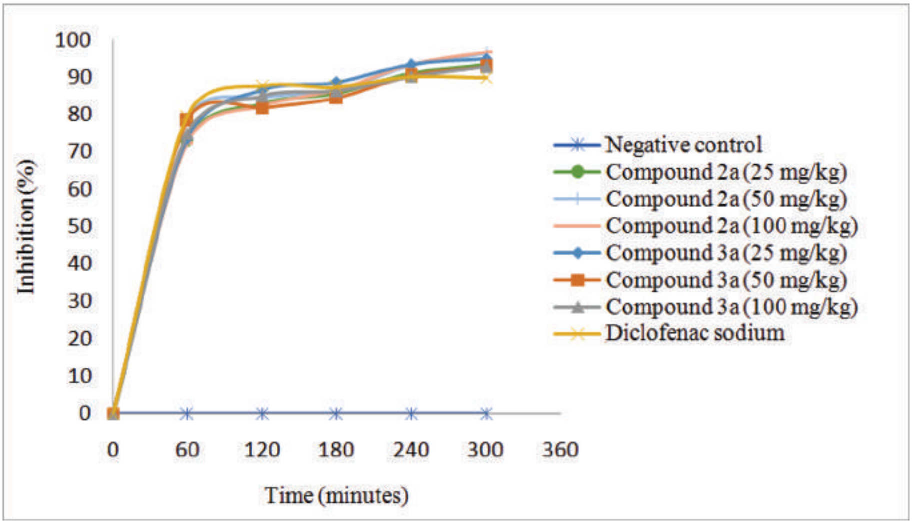


Figure 3. The percentage of edema inhibition over five hours following carrageenan-induced paw edema.

($p > 0.05$) in ability to inhibit the edema volume compared to the use of diclofenac sodium as an anti-inflammatory drug.

4 CONCLUSION

In summary, we have designed, synthesized and explored several bromonaphtyl pyrazolines as anti-inflammatory agents using a computational approach. Synthesis reactions were conducted under microwave irradiation and all spectroscopic data agreed with the structures of the products expected. Based on *in vivo* evaluation, the oral administration of Compounds 2a and 3a at dosages of 25, 50 and 100 mg/kg of body weight showed a good ability to significantly ($p < 0.05$) inhibit the edema volume, compared with the negative control. In addition, the administration of Compounds 2a and 3a at dosages of 25, 50 and 100 mg/kg of body weight did not show a significant difference ($p > 0.05$) in ability to inhibit the edema volume compared to the use of diclofenac sodium as an anti-inflammatory drug. This strategy represents a logical progression for early-stage drug discovery that can be used to successfully identify drug candidates for anti-inflammatory agents.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Synthesis and analysis of Carbon Dots (CDs) from natural sources

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ABSTRACT: Carbon Dots (CDs) from some natural sources have been synthesized by the green synthesis method assisted by microwaves. The natural sources used are green mustard stem, green mustard leaf, bintaro skin, bintaro flesh, pumpkin skin and pumpkin flesh. To determine UV-Vis absorbance, energy gap, and photoluminescence spectra, CDs samples were analyzed using UV-Vis and a photoluminescence spectrometer. Absorbance peaks of all measured samples were observed in the Ultra Violet (UV) region (230–320 nm), whereas the results of the photoluminescence analysis of all samples have emission peaks at around a wavelength of 500 nm with an energy gap in the range of 1.9–3.0 eV. Based on these optical properties, CDs samples can be used for bioimaging and various optical devices such as light emitting diodes and solar cells.

1 INTRODUCTION

Carbon Dots (CDs) are new fluorescent nano particles. Some researchers have synthesized CDs from natural sources such as sugar, corn, ginger, egg shell membrane and many more (Isnaeni et al., 2017; Fatimah et al., 2017). CDs can be easily obtained from natural sources because they contain carbon. CDs are the luminescent carbon material which have chemical stability and biocompatibility properties, low toxicity, and strong photoluminescence (Hola et al., 2014 and Isnaeni et al., 2017). Because of their characteristics, CDs can be used insbioimaging, LED, and solar cells (Hola et al., 2014; Baker, S.N and Baker, G.A., 2010). CDs can be synthesized by techniques such as hydrothermal, electrochemical, and microwave. Some previous researchers chose the microwave method, which is synthesizing with microwave heating. This method is very simple and environmentally friendly (Jie et al., 2012). Within minutes, CDs can be obtained without the addition of chemicals. This is a simple and eco-friendly method. In this research, CDs are synthesized from green mustard stem, green mustard leaf, bintaro skin, bintaro flesh, pumpkin skin, and pumpkin flesh. They are selected as the carbon sources because they are available in large quantities and can be obtained easily and cheaply. The purpose of the research was to obtain CDs from these new sources and analyze their optical properties.

2 METHOD

The research synthesized CDs using the mentioned materials. The method is green synthesis assisted by microwaves. The green synthesis method uses natural sources without the addition of chemicals (Fengyi et al., 2014). Twenty grams of each source is measured out and crushed using a domestic electrical blender in 140 ml distilled water. The blended source is then filtered to get the extract solution. Each 20 ml of filtered solution is heated in a domestic microwave oven for 15 minutes, and the carbon crust appears on the bottom of crucible. The carbon crust is then cooled to room temperature for one hour. Next, the crust is dissolved in 20 ml distilled water and centrifuged for 30 minutes, to separate the precipitate from the brown liquid. The brown liquid, which contains the carbon dots, was characterized using UV-Vis absorbance and photoluminescence (PL).

3 RESULT AND DISCUSSION

Carbon dots from green mustard leaf, green mustard stem, bintaro flesh, bintaro skin, pumpkin flesh, and pumpkin skin have been successfully synthesized. The presence of carbon dots is indicated by the color of the solution. A brown color indicates that carbon dots have dissolved in the water solvent perfectly. The other indicator is light emitted from the solution under blue laser illumination as shown in Figure 5.

3.1 *UV-Vis absorbance of carbon dots solutions*

The absorbance of the CDs solutions are measured in order to investigate the optical properties of CDs made from the mentioned natural sources. Figure 1 shows the UV-Vis absorbance spectra of CDs solutions made of green mustard leaf and stem. There is a clear absorbance peak at a wavelength of 300 nm for CDs made of green mustard stem and leaf. There are two clear absorbance peaks for a CDs solution made of pumpkin skin at 220 nm and 300 nm and an absorbance peak at 290 nm for a CDs solution made of pumpkin flesh (as shown in Figure 2). The absorbance spectra of CDs solutions made of bintaro flesh and bintaro skin (Figure 3) shows three clear absorbance peaks at wavelengths of 220 nm, 250 nm and 290 nm for a CDs solution made of bintaro flesh, while there is an absorbance peak at 280 nm for a CDs solution made of bintaro skin. Absorbance of the CDs solutions of all measured samples

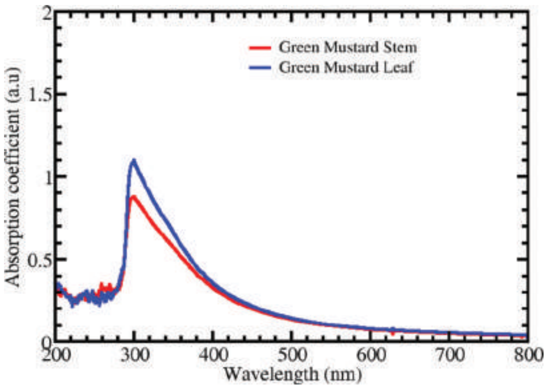

Figure 1. Absorbance spectra of carbon dots solutions made of green mustard stem and green mustard leaf.

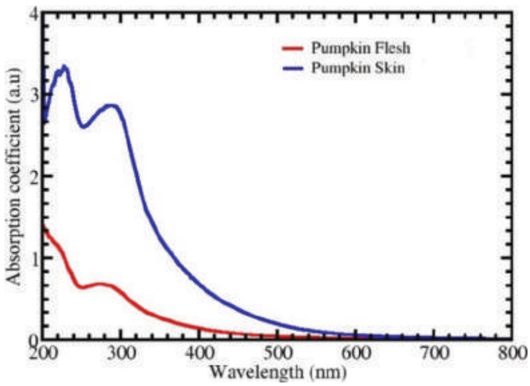

Figure 2. Absorbance spectra of carbon dots solutions made of pumpkin flesh and pumpkin skin.

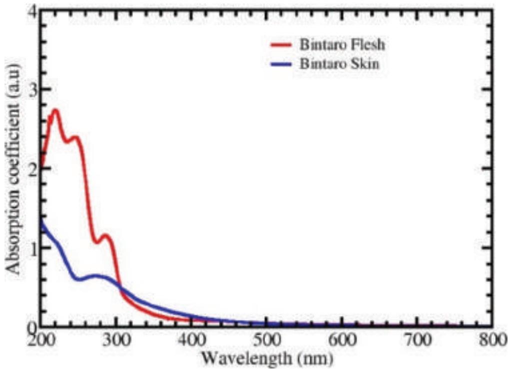

Figure 3. Absorbance spectra of carbon dots solutions made of bintaro flesh and bintaro skin.

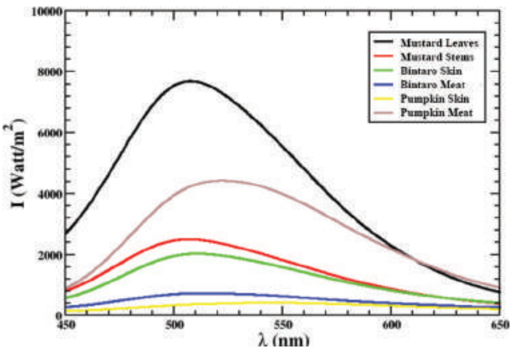

Figure 4. Photoluminescence spectra of carbon dots solutions.

is observed in the Ultra Violet (UV) region (230–320 nm), with a tail extending in to the visible range. Absorbance peaks around wavelengths of 220 nm, 250 nm and 280 nm are ascribed to the π-π* transition from the core of the carbon dots, and the absorbance peak around 300 nm is related to the n-π* transition from the surface of the carbon dots (Shoujun et al., 2015).

3.2 *Photoluminescence of carbon dots*

Photoluminescence was used to obtain the photoluminescence spectra of CDs (Figure 4). We found that all measured samples have an emission peak around the 500 nm wavelength. Figure 4 shows that all samples have different luminescence intensities. We predict that the difference in intensity of the luminescence spectra occurs due to different CDs molecule densities. Hui et al. (2016) stated that the intensity of the luminescence is dependent on the density of the molecules. The appearance of CDs solutions under blue laser illumination is shown in Figure 5. The cyan color appears from light emitted by CDs solutions made of green mustard stem, green mustard leaf, bintaro flesh, and bintaro skin, while the light green color comes from the light emission of CDs solutions made of pumpkin flesh and pumpkin skin.

3.3 *Energy gaps of carbon dots*

The energy gaps of CDs in this study were determined by the Tauc plot method. The Tauc plot shows the quantity hν (the energy of the light) on the abscissa and the quantity $(\alpha h\nu)^{1/r}$ on the ordinate, where α is the absorption coefficient of the material. The resulting plot has a distinct linear regime which denotes the onset of absorption. Thus, extrapolating this linear region to the abscissa yields the energy of the optical band gap of the material. Previous

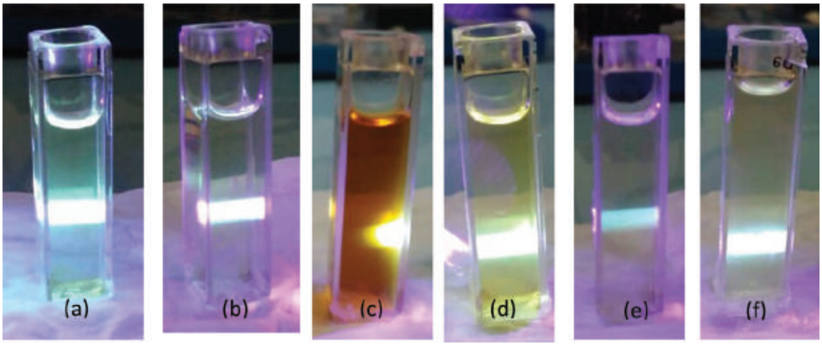

Figure 5. The appearance of carbon dots solutions made from (a) green mustard leaf, (b) green mustard stem, (c) pumpkin skin, (d) pumpkin flesh, (e) bintaro flesh, and (f) bintaro skin under blue laser illumination.

Table 1. Relation between emission wavelength and carbon dots energy gap.

Carbon dots sources	Wavelength (nm)	Gap energy (eV)
Mustard leaf	507	3.0
Mustard stem	505	2.3
Bintaro flesh	505	2.2
Bintaro skin	522	2.1
Pumpkin flesh	516	2.0
Pumpkin skin	516	1.9

research reports that the energy gap of CDs is in the range of 1.5–3.5 eV (Haitao et al., 2012). Table 1 shows the relation between the emission wavelength and the CDs energy gap, which is in the range of 1.9–3.0 eV.

4 CONCLUSION

Carbon dots from natural sources like green mustard leaf, green mustard stem, bintaro flesh, bintaro skin, pumpkin flesh, and pumpkin skin have been successfully synthesized. The cyan and green colors appear from the light emission of carbon dots made of the mentioned natural sources. Absorbance peaks of all measured samples were observed in the Ultra Violet (UV) region (230–320 nm). According to their optical properties, carbon dots obtained from this research can be utilized for bioimaging and various optical devices such as light emitting diodes and solar cells.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Optimum temperature of the amplification of the *fljB* gene of *Salmonella typhimurium*

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ABSTRACT: Fast and accurate detection of *Salmonella typhimurium* (*S. typhimurium*) is needed. This study aims to design and test the primer optimum temperature for the *S. typhimurium* flagellin gene (fljB) with the Gradient *Polymerase Chain Reaction* (PCR) technique. The in silico analysis using Professional Clone Manager program 9.2 for the primer design showed that the fljB primer pair could amplify *S. typhimurium fljB* fragments to produce amplicon with size 106 base pairs (bp). Evaluation of the primer ability of the design result and determination of the optimum temperature to produce amplicons of the right size was carried out by Polymerase Chain Reaction (PCR) Gradient. The temperature variation on PCR-Gradient is 56–61°C. The *S. typhimurium* isolate as a template for the Gradient PCR process has a concentration of 53.75 ng/μΛ with purity (A260/280) of 1.85. The results of the study generously information that the *fljB* primer provides optimal results at annealing temperatures 60°C. This is indicated by the production of a DNA band with a size of 106 base pairs in accordance with the analysis in silico and has a thickness band intensity. Based on the results obtained, it can be concluded that the optimal temperature of the *fljB* primer of *S. typhimurium* is 60°C. Furthermore, the primers and optimum temperatures obtained were used for the Real Time PCR stage in the development of sensitive, specific and faster methods of detection of food poisoning bacteria.

1 INTRODUCTION

S. typhimurium infection through food contamination is a major public health threat even in developed countries, and is better known as a foodborne disease (Won and Lee, 2017). The *fljB* gene is an abundant protein-coding on the surface of the bacterial flagellum (Lim *et al*., 2003). This gene can be used as a primer in the Polymerase Chain Reaction (PCR) method to multiply the number of DNA molecules on a particular target, by synthesizing new DNA molecules that complement with the DNA molecule target. PCR is a repetitive reaction which includes template denaturation, annealing (pairing) the pair of primers on a single strand of DNA target, and extension (elongation) which can obtain DNA amplification.

In the annealing process, one of the main factors that influenced the success of the amplification process is temperature because for the primer to attach onto the DNA strands, it needs an optimal temperature. If the temperature is too high, it will cause the amplification to fail because there is nothing that the primer will be able to attach to, and if the temperature is too low, it will make the primer attach to other sides of the genome, and the result is that the DNA formed has a low specificity. So, it is very important to find the optimum temperature of annealing for the amplification process (Rybicky, 1996).

Because annealing is a very important process, it needs an optimum temperature that will obtain maximum results for DNA in targeted area and make DNA analysis easy. By knowing the correct annealing temperature, it is hoped that it will provide high DNA quality results and able to distinguish between bacteria from others.

2 METHOD

2.1 *Primer design*

The primer design uses the sequence of the *fljB* gene of *S. typhimurium* sr. LT2 (Accession number: NC_003197) and was designed with the National Center for Biotechnology Information (NCBI) Primer-Blast software (Bustin & Hugget, 2017). The recommended primer is displayed, and then the primer is tested with Clone Manager Professional 9.2 software to determine its melting point, Guanine-Cytosine percentage (GC-percentage), hairpin, dimer and other characteristics. The selected design primer is a primer which has a length of 18–24 bases, a GC percentage of 50–60%, small dimer and hairpin numbers, a melting point of 50–65°C, and 75–200 bp of amplicon length (Bio-Rad, 2006; Thermo Fisher Scientific, 2016). The design of the fljB gene primer was synthesized in Macrogen, Korea.

2.2 *Growth of S. typhimurium bacteria*

S. typhimurium bacterial suspension from the Microbiology Laboratory Universitas Indonesia (UI) was formed in agar slants, grown on *Salmonella. Shigella* agar media (from Deben Diagnostics Limited) and incubated for 18 hours at 37°C. One colony of *S. typhimurium* that colored black on the surface of the agar was put on inoculating loop, dipped into 10 ml of Luria Bertani broth (from Deben Diagnostics Limited), and then placed in an incubation shaker at 37°C for 18 hours.

2.3 *Isolation of DNA S. typhimurium bacteria*

Amount of 1 ml of *S. typhimurium* bacterial suspension from the Luria Bertani broth was centrifuged at 7000 rpm for 10 minutes with three repetitions before DNA isolation. DNA isolation from the supernatant was carried out following the QIAamp DNA Mini Kit protocol (Qiagen, 2001). The concentration of DNA isolation results were measured and purified with Nano Drop (Nanovue Plus), and checked using electrophoresis on 0.7% agarose gel (Thermo Fisher Scientific, 2012) and an ultraviolet Trans illuminator (Vilber Lourmat). The isolated DNA was stored in a freezer at –20°C until it was ready to be used.

2.4 *Amplification of S. typhimurium using gradient PCR*

Amplification of the fljB gene in *S. typhimurium* bacteria with an isolated sample was carried out with a PCR machine (Applied Biosystem). Optimization of the primer PCR was performed with the gradient method. The annealing temperature in the optimization process was 56–61°C. The 25 µl reaction mixture contained: 12.5 µl of Dreamtaq Green PCR Master Mix (Thermo Fisher Scientific); 1 µl of the primer forward (10 µm); 1 µl of primer reverse (10 µm); 8.5 µl of nuclease free water (Qiagen); and 2 µl of template DNA. The amplification conditions were set as follows: initial denaturation at 95°C for 2 minutes following 40 cycles; denaturation at 95°C for 30 seconds; annealing at 56–61°C for 30 seconds; and elongation at 72°C for 1 minute. The amplification process ended with a final elongation at 72°C for 10 minutes.

2.5 *Electrophoresis Gel Agarose*

PCR products were electrophoresed with 2% agarose in Tris-acetate-EDTA (TAE) 1X buffer solution. A total of 7 µl of DNA from the PCR results in a temperature range of

56–62°C was mixed with 3 μl of loading dye, and then put in a well containing agarose gel. The electrophoresis process was run at 80 v, and at a current of 500 mA for 60 minutes. The appearance of DNA fragments was seen using an ultraviolet Trans illuminator (Vilber Lourmat).

3 RESULTS AND DISCUSSION

The primer bacteria of *S. typhimurium* was designed by taking pieces of *fljB* gene DNA starting from the 1046th forward base and 1032th reverse base with a target product of 106 bp. The length of each oligonucleotide was 20 bases. The primer was analyzed using the Clone Manager Professional 9.2 program.

Based on Table 1, it can be seen that the selected pair of primers was appropriate to the criteria for good primers including primer length, percentage GC, Melting Temperature (Tm), primer interaction (dimers and hairpins), primer stability, repeats, and runs.

Forward and reverse primers had the same percentage GC which was 55. The recommended percentage GC is 50–60. The result of the percentage GC of the primer design met the reference for making a primer. High GC content from the primer can cause the formation of self-dimer and secondary structure. The percentage GC will affect the bond between DNA strands. A high percentage GC will make strong bonding between DNA strands because the GC contains more bonds between nucleotides than Adenine-Thymine (AT), which will affect the Tm (Borah, 2011).

The Tm of the pair of primers was 60.5°C. Tm is the temperature when half of the double DNA will be separated (Kumari, 2016), and will affect the temperature of the DNA double helix strand denaturation and the primer annealing temperature. The primer design Tm met the program's reference. Both primers did not have a different Tm value. The general standard of the primer Tm value should have the same melting temperature (Ye, 2012), but a difference in Tm of less than 5°C is still tolerable (Hugget & O'Grady, 2014). This will guarantee the correct and specific annealing temperature in the PCR process. Tm will be the basis for determining the annealing temperature. If the annealing temperature used is less than optimum, then primer attachment in an inappropriate place will occur (Lorenz, 2012).

From the results of the in silico analysis, the dimer value at the 3' end was 2 and 1 respectively. There were 2 dimers in the forward primer and 3 dimers in the reverse primer, other than those on the 3' end. Both primers did not have hairpins, and so both primers met the good criteria for a primer. In the primary forward and reverse, it is best to avoid the formation of dimers or hairpins (Meagher, 2018; Ye, 2012). The dimer shows the hybridization between the identical primer base. If there is a dimer in the primer, the DNA polymerase can bind to the identical part and extend in both directions. This can decrease the efficiency of

Table 1 Results of the design of the gene *fljB* primer pair.

Criteria	F-*fljB*	R-*fljB*	Based on clone manager professional 9.2
Primer length	20	20	18–22
% GC	55	55	50–60
Tm (°C)	60.5	60.5	55–80
Dimer at 3' terminus	2	1	<3
Dimer other 3' end	2	3	<7
Stability (kcal)	0.3	0.2	≥1.2
Runs	3	3	<3
Repeat	None	2	<3
Hairpins	None	None	None

*F-fljB = Forward-fljB.
*R-fljB = Reverse-fljB.

the amplification even if the products are not according to what is needed. The presence of dimers at the end of 3' can inhibit the amplification process because amplification starts from the end of 3' so that it can reduce or not form PCR products (Maitriani *et al.*, 2015). The good primers did not complement each other so they did not form the hairpin structures. The hairpin form makes the primer not anneal to the DNA sequence sample (Taylor *et al.*, 1995). The same nucleotide repetitions (runs) and dinucleotides (repeats) must be avoided because they can make false priming in the primer so that the primer attachment process becomes difficult. The primer should have a repeat of no more than 4 bases (Dieffenbach *et al*, 1995; Lorenz, 2012).

The isolation of *S. typhimurium* bacterial DNA was measured by its concentration and purities by using Nano Drop (Nanovue Plus). The purification of DNA samples was measured based on the 260/280 absorbance ratio. A DNA concentration of 53.75 ng/µl was obtained with a purification (A260/280) of 1.85. DNA isolates obtained were pure enough because they were in a good purification range of around 1.8–2.0. If the ratio of absorbance produced is less than 1.8, it means that DNA isolates are still mixed with protein, and if the ratio of absorbance produced is more than 1.8, it means there is too little impurity in the form of RNA and DNA (Ye, 2012).

Electrophoresis was carried out to determine the success of the sample DNA isolation process. Based on the electrophoresis results of DNA isolates, Figure **1** shows that the DNA genome of *S. typhimurium* bacteria was successfully isolated. This is seen with the appearance of DNA bands on the electrophoregram. DNA bands in the left lane is a marker measuring 1 kb Ladder which serves as a marker of the size of an isolated DNA. Based on its size, DNA bands isolated from *S. typhimurium* appear in the uppermost area–higher than the 1 kb marker size–which shows this result is in accordance with information about the size of the genome *S. typhimurium* is 4.9×10^6 bp (McClelland, 2001).

DNA isolation results are used as templates in the amplification process. The success of PCR is influenced by the use of suitable pair primers and the annealing temperature. Therefore, annealing temperature optimization is one of the most important criteria to determine PCR success. Annealing temperature optimization must be carried out because the annealing temperature takes a role in the primer's attachment process in the target DNA template, and makes it run well. Attaching the primer to the DNA target will trigger the polymerase enzyme to catalyze the installation of complementary nitrogen bases, and in the reagent, into the template DNA so that new DNA is formed. Annealing temperature with a high temperature can inhibit the hybridization process of the template so that less PCR products are produced (Astriani *et al.*, 2014).

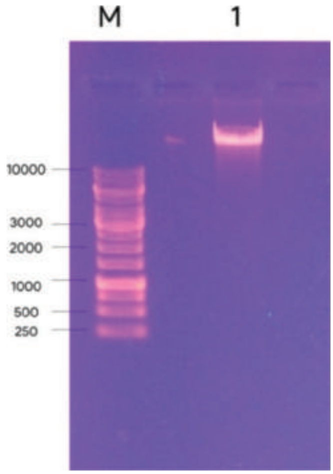

Figure 1. Gel Electrophoresis DNA isolate results of S. *typhimurium*. Line M. DNA Marker 1 kb Ladder. Line 1. The Genome of *S. typhimurium* Bacteria.

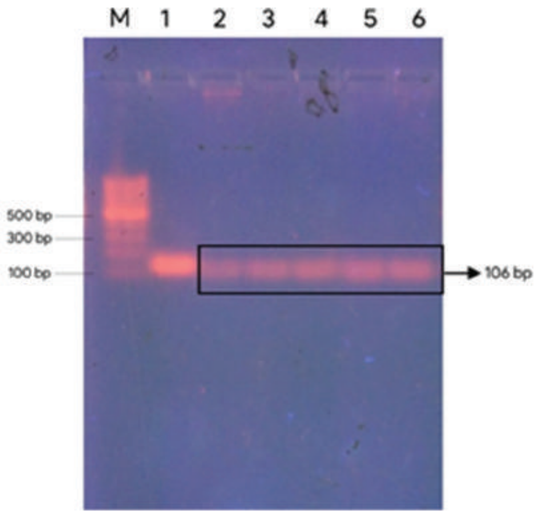

Figure 2. Electrophoresis Gel Agarose results of amplification of *S. typhimurium fljB* gene isolate fragment with an annealing temperature range of 58–62°C and a marker of 100 base pair. The detail information describe on the text.

PCR or chain polymerase reactions are a way to amplifying (doubling) a DNA fragment *in vitro* by using a particular primer (Taylor et al., 1995). Through the PCR technique, the ability of primer amplification and detection of PCR products by 2% agarose gel electrophoresis can be determined. The electrophoregram results are shown in Figure 2. Electrophoresis results showed that column 1 is a positive control in the form of the primer *S. typhimurium* with the *pef* gene that was previously designed with the 139 bp amplicon product (Nurjayadi *et al.*, 2017). Column 2 is the result of the *S. typhimurium fljB* gene PCR with 106 bp, and at an annealing temperature of 58°C. Column 3 is the result of the *S. typhimurium fljB* gene PCR with 106 bp, and at an annealing temperature of 59°C. Column 4 is the result of *S. typhimurium fljB* gene PCR with 106 bp, and at an annealing temperature of 60°C. Column 5 is the result of *S. typhimurium fljB* gene PCR with 106 bp, and at an annealing temperature of 61°C. Column 6 is the result of *S. Typhimurium fljB* gene PCR with 106 bp, and at an annealing temperature of 62°C. Column M is a marker of 100 bp.

From the electrophoresis results it can be seen that the band at an annealing temperature range of 56–62°C produces a relatively same band thickness, which in line 4 with a temperature of 60°C, the band looks a little thick compared to the others. The thick and bold band intensity indicates that the quantity of DNA formed is greater, and more primer can work optimally to amplify the DNA of *S. typhimurium* bacteria. The optimum annealing temperature for the primer can amplify the template in the PCR process in the range of 58–60°C (Dorak, 2006). Therefore, 60°C is the most optimum annealing temperature for the PCR process. Forward and reverse primer of the fljB gene has succeeded in amplifying *fljB* gene fragments with a product size of 106 bp, in accordance with the results of the *in silico* analysis from the design primer step.

4 CONCLUSION

A pair of *fljB* gene primers from the design result was able to amplify *S. typhimurium fljB* gene fragments to produce 106 bp amplicon length, according to the results of the *in silico* analysis from the Clone Manager Professional 9.2 program. Amplification of the *fljB* gene DNA using the *fljB* gene primer at an annealing temperature of 60°C. Furthermore, the primers and optimum temperatures obtained were used for the Real Time PCR stage in the development of sensitive, specific and faster methods of detection of food poisoning bacteria.

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Gibbs paradox of some thermodynamic properties in one-dimensional Gross-Pitaevskii equation

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ABSTRACT: A single condensate partition function in the canonical ensemble of the one-dimensional Gross-Pitaevskii equation has been used to construct the partition function of N noninteracting condensates. In this paper, we employed the appropriate transformation in order to make the partition function of a single condensate to be an extensive quantity by introducing a harmonic volume as the inverse cube of the average geometric trapping frequency. We found that some expressions of the thermodynamic quantities must be corrected to keep the consistency of the thermodynamic expressions based on the Gibbs paradox in the statistical mechanics. This only can be done if a set of condensates is considered as the indistinguishable macroscopic quantum oscillators with a weak nonlinearity instead of the distinguishable ones.

1 INTRODUCTION

It has been well-known that the harmonic oscillator model can be referred to study the characteristics of some systems. In quantum mechanics, the discrete eigenenergies and appropriate eigenfunctions of the harmonic oscillator can be analytically obtained by solving the time-independent Schrödinger equation, using either the ladder operators or the path integral method. Interestingly, the providing discrete energies have been used to construct the partition function in the framework of statistical mechanics and applied to seek some thermodynamic quantities of system, for example, Einstein and Debye used the model to formulate the heat capacity for solid. It means that the harmonic oscillator model can be useful to describe very well some physical systems. Note that some authors have extended the mathematical properties of harmonic oscillator model for some cases (Cordero-Soto *et al.*, 2008; Cordero-Soto, Suazo and Suslov, 2009, 2010).

In the nonlinear case, it is difficult to discuss the thermodynamics of system since there is almost no possibility of obtaining the analytical partition function. One of the possible attempts to construct the partition function is to reduce the dynamical equation of system, which resembles the harmonic oscillator. In our understanding, the most possible nonlinear equation, which obeys the above condition, is the one-dimensional Gross-Pitaevskii equation (GPE), in which the external potential so-called the trapping potential is set to the anisotropic parabolic function. This equation, which is derived by the Hartree-Fock approximation, actually describes the dynamics of a single condensate in the very low temperature, where the internal interaction is given in the nonlinear term (Stringari, 1996; Pérez-García, Michinel and Herrero, 1998; Ostrovskaya *et al.*, 2000). In fact, some authors have treated the equation as a macroscopic quantum oscillator by considering the small nonlinearity (Kivshar, Alexander and Turitsyn, 2001). This treatment therefore opens a new hope to explore the thermodynamic aspect deeply since it is possible to construct the partition function.

In our previous paper (Prayitno and Latifa, 2012), by repeating the last work of Kivshar *et al.* (Kivshar, Alexander and Turitsyn, 2001), we formulated the canonical partition function of a single condensate by treating the one-dimensional GPE as a macroscopic quantum oscillator. However, to follow up the discussion further on the thermodynamics, we get difficulties to determine the thermodynamic quantities since the volume is not clearly provided. To overcome the above problem, the new definition of volume is necessary. Interestingly, Romero-Rochín has introduced a new definition of volume called the harmonic volume by stating that the real volume is proportional to the inverse cube of the average geometric trapping frequency when deriving the partition function to study the thermodynamic aspects through the grand canonical ensemble in the case of Bose-Einstein condensation (BEC) (Romero-Rochín, 2005a, 2005b), see also Ref. (Romero-Rochín and Bagnato, 2005). By pursuing the above method, we scaled the partition function for a single condensate through the scaling transformation to make it become the extensive quantity. In fact, some papers also explored the similar idea to provide some thermodynamics quantities in the case of BEC (Sandoval-Figueroa and Romero-Rochín, 2008; Romero-Rochin, 2010). In addition, by using the different approaches, some papers have also been published previously to investigate the thermodynamics quantities in BEC (Giorgini, Pitaevskii and Stringari, 1997; Kirsten and Toms, 1998; Gerbier *et al.*, 2004; Yukalov, 2006, 2011).

To formulate the thermodynamic quantities, we have to deal with the definition of the extensive and the intensive quantities. Even though we succeed to achieve the extensive partition function for a single condensate, we obtain the inconsistency when formulating some thermodynamic potentials that should be extensive too. It comes from the treatment that a set of condensates is considered as the distinguishable macroscopic quantum oscillators with a weak nonlinearity, thus creating the Gibbs paradox. As a direct consequence, the second law of thermodynamics will be violated. In this paper, we give some quantities that possess the paradox and the resolution. The rest of this paper is organized as follows. We construct the partition function for N condensates in Sec. 2 by imposing some conditions. In Sec. 3, we apply our previous result to construct some thermodynamic quantities and reformulate the former thermodynamic potentials, which achieve the Gibbs paradox. We give our conclusions in Sec. 4 based on our final results.

2 METHOD

It has been assumed that a Bose-Einstein condensate (BECs) can be considered as a macroscopic quantum oscillator with a weak nonlinearity whose eigenenergies experience correction based on the very small nonlinearity. This assumption yields a single condensate partition function, which can be written as (Prayitno and Latifa, 2012)

$$Z = \sum_{n=0}^{\infty} e^{-\left\{(n+1/2)\hbar\omega_z - \sigma|B_n|^2 V_{nnnn}\sqrt{m\omega_\perp\sqrt{\lambda}/\hbar}\right\}/kT} \tag{1}$$

where $\lambda = \omega_z^2/\omega_\perp^2$ is the very small parameter describing the cigar-shaped trap, m is the mass of atom, σ is the negative or positive dimensionless parameter, B_n is the expansion coefficient, and V_{nnnn} emerges from the nonlinear term

$$V_{nnnn} = \int_{-\infty}^{\infty} \phi_n(z)\phi_n(z)\phi_n(z)\phi_n(z)dz \tag{2}$$

with $\phi_n(z)$ is a set of the dimensionless normalized eigenfunctions of the quantum oscillator, the detailed experimental results using the BECs can be found in Refs. (Cataliotti *et al.*, 2001; Gupta *et al.*, 2002; Khaykovich *et al.*, 2002; Strecker *et al.*, 2002; Janis, Banks and Bigelow, 2005; Wang *et al.*, 2005). In statistical mechanics, it is clear that Eq. (1) is not the extensive quantity because the partition function does not contain the extensive quantity. Note that the temperature T, in this case, is the intensive quantity. To solve the problem, we first transform Eq. (1) through the dimensionless parameter by the following relationship

$$Z \rightarrow \left(\frac{\omega_\perp^2 \omega_z}{\omega^3} \right) Z \tag{3}$$

where ω denotes the average geometric frequency. In this case, the subscript in ω refers to the direction, along which the quantum oscillator propagates. Since the dimensionless parameter can be set equal to 1, we claim that the brought physical quantities are unchanged, the relation among ω, $\omega_\perp$, ω_z can be found in Refs. (Yukalov, Yukalova and Bagnato, 1997; Dalfovo *et al.*, 1999).

In his papers, Romero-Rochín has proposed that the inverse cube of average geometric trapping frequency, ω^{-3}, can be accepted as a thermodynamic variable, which is related to the occupation gas in an available volume (Romero-Rochín, 2005a, 2005b; Romero-Rochín and Bagnato, 2005; Sandoval-Figueroa and Romero-Rochín, 2008; Romero-Rochin, 2010). It means that the available volume can be replaced with this quantity by introducing a new definition of volume, namely the harmonic volume, which is an extensive quantity. So, the pair conjugate of the harmonic volume, which is an intensive quantity, is called harmonic pressure (Romero-Rochín, 2005a, 2005b; Romero-Rochín and Bagnato, 2005; Sandoval-Figueroa and Romero-Rochín, 2008; Romero-Rochin, 2010). Let's define the harmonic volume as $\Omega = \omega^{-3}$, thus the partition function can be expressed as

$$Z = \Omega \omega_\perp{}^2 \omega_z \sum_{n=0}^{\infty} e^{-\left\{(n+1/2)\hbar\omega_z - \sigma |B_n|^2 V_{nnnn} \sqrt{m\omega_\perp \sqrt{\lambda}/\hbar}\right\}/kT}. \tag{4}$$

It is clear that the partition function in Eq. (4) becomes an extensive quantity since it holds $Z \rightarrow 2Z$ if the transformation $\Omega \rightarrow 2\Omega$ is carried on. Therefore, the total partition function for the system containing N noninteracting condensates is given by

$$Z_t = Z^N \tag{5}$$

where we initially assume that a set of N noninteracting condensates is considered as a set of N distinguishable oscillators since a set of oscillators is usually treated as a set of distinguishable particles in statistical mechanics.

3 RESULT AND DISCUSSION

Now, we try to use Eq. (5) to derive one of the thermodynamic potentials, i.e., enthalpy. In terms of N, Ω, and T, the enthalpy has form

$$H = kT\left(\Omega \frac{\partial \ln Z_t}{\partial \Omega} + T \frac{\partial \ln Z_t}{\partial T} \right). \tag{6}$$

Substituting Eq. (5) into Eq. (6) and using Eq. (4), we get

$$\begin{aligned} H = NkT + N\sum_{n=0}^{\infty}\left[\left(n+\frac{1}{2}\right)\hbar\omega_z - \sigma|B_n|^2 V_{nnnn}\sqrt{m\omega_\perp\sqrt{\lambda}/\hbar}\right] \\ \times \exp\left(\left\{-\left(n+\frac{1}{2}\right)\hbar\omega_z + \sigma|B_n|^2 V_{nnnn}\sqrt{m\omega_\perp\sqrt{\lambda}/\hbar}\right\}/kT\right). \end{aligned} \tag{7}$$

If we employ the following transformations, $N \rightarrow 2N$ and $\Omega \rightarrow 2\Omega$ respectively, we will find $H \rightarrow 2H$. The transformation result is consistent since H is indeed extensive, thus the enthalpy needs no correction.

Later, we try to check the Gibbs free energy, which is given in terms of N, Ω, and T, by

$$G = kT^2\Omega^2 \frac{\partial}{\partial\Omega}\left(\frac{\ln Z_t}{\Omega}\right). \tag{8}$$

Inserting Eq. (5) into Eq. (8) and using Eq. (4), we obtain

$$G = NkT^2 - NkT^2 \ln\left[\Omega\omega_\perp{}^2\omega_z \sum_{n=0}^{\infty} \exp\left(\left\{-\left(n+\frac{1}{2}\right)\hbar\omega_z + \sigma|B_n|^2 V_{nnnn}\sqrt{m\omega_\perp\sqrt{\lambda}/\hbar}\right\}/kT\right)\right]. \tag{9}$$

After transforming the variables $N \to 2N$ and $\Omega \to 2\Omega$ respectively, we get

$$G \to 2G - 2NkT^2 \ln 2. \tag{10}$$

Since the Gibbs free energy is an extensive quantity, so in this case the function experiences the Gibbs paradox. We seek for the resolution by only pursuing the textbook-like treatment in statistical mechanics. Since this problem is similar to the ideal gas problem, the Gibbs paradox problem can only be solved if we treat the condensate as an indistinguishable oscillator, thus replacing with

$$Z_t = \frac{1}{N!} Z^N. \tag{11}$$

In this case, we also impose a condition related to N. If we assume that N is so large, then by using the Stirling's formula, we approximate

$$\frac{1}{N}\ln N! \cong \ln N - 1. \tag{12}$$

By substituting again Eq. (11) into Eq. (8) and imposing Eq. (12), we obtain

$$G = NkT^2 - NkT^2 \ln\left[\frac{\Omega}{N}\omega_\perp{}^2\omega_z \sum_{n=0}^{\infty} \exp\left(\left\{-\left(n+\frac{1}{2}\right)\hbar\omega_z + \sigma|B_n|^2 V_{nnnn}\sqrt{m\omega_\perp\sqrt{\lambda}/\hbar}\right\}/kT\right)\right]. \tag{13}$$

Now, we easily see that the Gibbs free energy in Eq. (13) has become extensive since after transforming $N \to 2N$ and $\Omega \to 2\Omega$, we get $G \to 2G$.

Next, let's check another thermodynamic potential, i.e., the Helmholtz free energy, which has form

$$F = -kT \ln Z_t. \tag{14}$$

Then, by substituting Eq. (5) into Eq. (14), we obtain

$$F = -NkT \ln\left[\Omega\omega_\perp^2\omega_z \sum_{n=0}^{\infty} \exp\left(\left\{-\left(n+\frac{1}{2}\right)\hbar\omega_z + \sigma|B_n|^2 V_{nnnn}\sqrt{m\omega_\perp\sqrt{\lambda}/\hbar}\right\}/kT\right)\right]. \tag{15}$$

Observing the formulation above, we directly conclude that the Helmholtz free energy also sustains the Gibbs paradox since after replacing $N \to 2N$ and $\Omega \to 2\Omega$, we get $F \to 2F - 2NkT\ln 2$. By following the previous procedures, we resolve the problem by reformulating the Helmholtz energy as

$$F = -NkT\left\{1 + \ln\left[\frac{\Omega}{N}\omega_\perp^2\omega_z \sum_{n=0}^{\infty} \exp\left(\left\{-\left(n+\frac{1}{2}\right)\hbar\omega_z + \sigma|B_n|^2 V_{nnnn}\sqrt{m\omega_\perp\sqrt{\lambda}/\hbar}\right\}/kT\right)\right]\right\}. \tag{16}$$

Repeating the above procedures, one can check singly the other thermodynamic quantities, which experience Gibbs paradox. In our notes, there are two other quantities yielding the Gibbs paradox, i.e., the entropy and the chemical potential, while the internal energy and its derivative quantities, such as the heat capacity, do not.

4 CONCLUSION

We have presented several quantities experiencing the Gibbs paradox and solved the problem by treating a set of condensates as a set of indistinguishable oscillators. To reach our goal, we initially make the condensate partition function to be extensive by defining the harmonic volume associated with the inverse-cube of the average geometric trapping frequency. In this case, we perform the scaling transformation to the partition function with the dimensionless parameter, in which the inverse cube of average geometric frequency is included.

First of all, using the expression of the partition function of N distinguishable noninteracting condensates, we obtain the inconsistency of some thermodynamic expressions related to the extensive or the intensive quantities. It suggests us to replace the distinguishable condensates with the indistinguishable ones. It can be proven that the derivative quantities, which are derived from the paradox-experienced thermodynamic functions, must also be corrected.

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Co-electrodeposition of Ni/Si_3N_4 composite coatings

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ABSTRACT: An investigation has been undertaken to study the properties of co-electrodeposited Ni/Si_3N_4 composite coatings. As a preliminary study, the effect of Si_3N_4 powder concentration variation (10–30 g/L) on Ni/Si_3N_4 composite coating properties was investigated. The surface morphology and structure were characterized by using Scanning Electron Microscopy (SEM) and X-ray diffraction, respectively. The coating hardness was tested by using the Vickers hardness test. The results showed that coating morphology and structure were improved as Si_3N_4 concentration increased and eventually enhanced coating hardness. The results showed that Si_3N_4 particles were successfully co-electrodeposited to form a Ni/Si_3N_4 composite coating. The coating surface was compact and no microcracks were observed. It was found that Si_3N_4 particles were dispersed and crystalized within the composite. In general, the increase in Ni/Si_3N_4 composite coating hardness was due to Si_3N_4 particle dispersion and Ni grain refining.

1 INTRODUCTION

Nickel is an attractive engineering material because of its high wear and corrosion resistance, and is commonly applied as a thin film or coating (Kundu et al., 2014). Nickel has high corrosion resistance especially at high temperature applications due to the formation of NiO (Geng et al., 2003; Gregoire et al., 2018). Nickel is usually utilized as metal matrix in composite coating by using electrodeposition. To improve its mechanical properties, some hard particles such as nitride particles as a reinforced particle, can be introduced into a nickel matrix composite coating (Budi et al., 2017; Budi et al., 2016; Ma et al., 2018).

Among nitride particles, Si_3N_4 has been considered as a reinforcement in composite coatings because of its high melting point, hardness, wear and corrosion resistance (Lee et al., 2015; Li et al., 2018; Lu et al., 2013;). The cooperation of Si_3N_4 particles in Al/Si_3N_4 composites leads to an increase in its density and hardness (Sharma et al., 2015). The increase of Si_3N_4 content in Cu/Si_3N_4 composite coatings improves its microhardness (Robin et al., 2011). It has been reported that by reducing Si_3N_4 reinforced particle size, an increase in the corrosion resistance of Ni/Si_3N_4 composite coatings occurs, but none report on its hardness (Khazrayie & Aghdam, 2010).

In this study, the effect of Si_3N_4 concentration on the structure and mechanical properties of the co-electrodeposition of Ni/Si_3N_4 composite coatings, was investigated.

2 METHOD

The chemical composition bath for the co-electrodeposition of Ni/Si_3N_4 composite coating was composed of 0.38 M $NiSO_4{\cdot}6H_2O$, 0.17 M $NiCl_2{\cdot}6H_2O$, 0.49 M H_3BO_3, 0.2 g/L Sodium Dodecyl Sulfate (SDS) and various Si_3N_4 concentrations of 10, 20 and 30 g/l. The compound was mixed by using aquades and stirred by using magnetic stirrers for 24 hours. Tungsten carbide bars of $2 \times 5 \times 33$ mm in dimension were used as a substrate (or working electrode in an electrochemical cell), while Pt and AgCl wire were used as counter and reference electrodes, respectively. Before the process, the substrates were ground with sandpaper, then washed by detergent, and subsequently cleaned by an ultrasonic cleaner. Finally, the substrate was dried and cleaned with alcohol. The electrodeposition process was conducted by using a potentiostat system at a fixed current of 2 mA for 15 minutes. The samples characterization was performed by using Scanning Electron Microscopy and Energy Dispersive Spectroscopy (JEOL-JED 2300). An X-Ray Diffractometer (Shimadzu 7000; Cu Kα, $\lambda = 1.54$ Å, 40 kV, 30 mA) and a Micro Vickers hardness tester (Leco LM 800 AT) were also used.

3 RESULTS AND DISCUSSION

3.1 *Surface morphology*

The Scanning Electron Microscopy (SEM) image on surface morphology of the co-electrodeposited Ni/Si_3N_4 composite coatings on tungsten carbide at different Si_3N_4 concentrations are shown in Figure 1. From the macro view point, no microcracks were observed except for the sample which was electrodeposited at a Si_3N_4 concentration of 20 g/l. However, overall the composite crystal was compact, had a rough surface, and a coarse grain. But the coating surface still contained some pores.

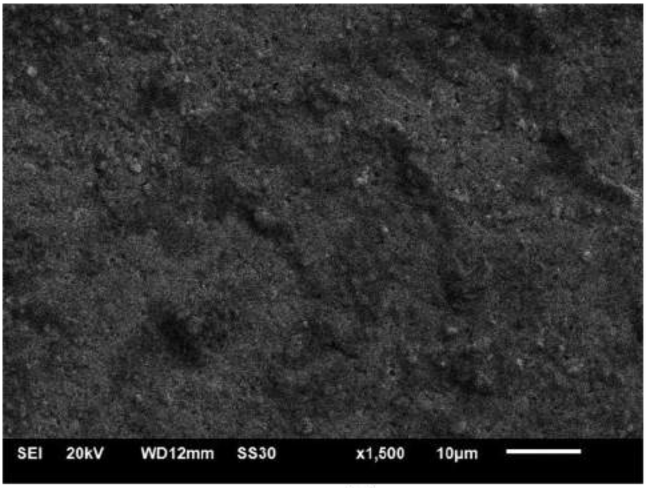
It is known that nickel is a porous metal which makes it have excellent mechanical properties at a lower weight (Kamaraj et al., 2017). The porosity formed during the electrodeposition process was due to the kinetic mechanisms of electrochemical deposition, nucleation and crystal growth. The crack (defect) found on the coated surface was due to the reduction process of nickel oxide by hydrogen gas (Skrypnika & Matvienko, 2017).

3.2 *Composition*

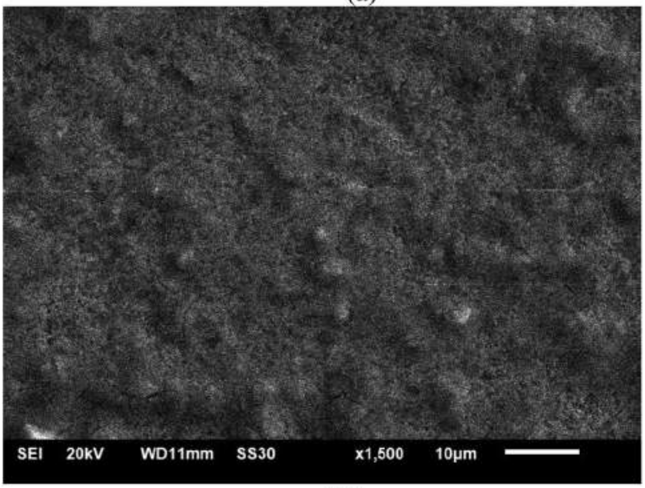
The EDS (Energy Dispersive Spectroscopy) composition of co-electrodeposited Ni/Si_3N_4 composite coating at different Si_3N_4 concentrations is presented in Figure 2 and Table 1. The different atomic percentages of Ni, Si, N and Was substrate elements, were observed in the composite at different Si_3N_4 concentrations (Table 1). Ni as a matrix composite, was indicated by its large quantity in the coating. However, a low quantity of Ni was observed at a Si_3N_4 concentration of 20 g/l. It was reported that the metal matrix ion (Ni^{2+}) and nitride particles were deposited under the electric field and fluid force (Ma et al., 2018). Contrary to this, the current density did not influence the incorporated particle, and the decreased particle content in the composite as the particle concentration increased, was due to a collision effect (Robin et al., 2011). In this study, the increase in Si content as the Si_3N_4 concentration increased, indicated that the Si_3N_4 successfully co-electrodeposited as a Ni/Si_3N_4 composite coating. At a Si_3N_4 concentration of 20 g/l, the Ni content decreased drastically. This might have been due to competition between Ni metal ions flux and nitride particles flux on the substrate surface (cathode). As Si_3N_4 concentration is increased, the flux of the Ni metal ion decreases.

3.3 *Crystal structure*

The XRD pattern of the Ni/Si_3N_4 composite coatings is shown in Figure 3. Ni (111), (002) and (022) peaks were observed at $2\theta = 44.36°$; 51.75° and 77.03°, respectively. Meanwhile, Si_3N_4 (020), (011), (120), (140), (411) and (212) peaks appeared at $2\theta = 26.59°$, 33.41°, 35.53°, 64.09°, 72.79° and 75.47°, respectively. In general, the peak intensity for nickel was very low compared with Si_3N_4 intensity peaks, indicating the refinement of the Ni crystal. Therefore, co-electrodeposition of Si_3N_4 particles has inhibited Ni grain growth and a similar result was also observed for the other system (Robin et al., 2011). It has been reported that the Si_3N_4 particle have an amorphous nature indicated by a low intensity peak (Barshilia et al., 2006) however, in this study Si_3N_4 intensity peaks were higher than Ni intensity peaks indicating that the Si_3N_4 particles had crystalized and grown. A significant growth of Si_3N_4 (020) peak is observed as Si_3N_4 concentration is increased from 10 g/L to 20 g/L.



(a)



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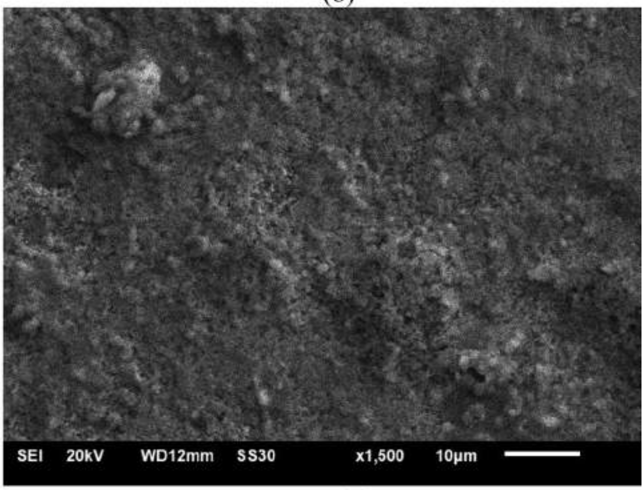

(c)

Figure 1. Scanning Electron Microscopy (SEM) image of Ni/Si_3N_4 composite coatings at different Si_3N concentrations: (a) 10 g/L; (b) 20 g/L; and (c) 30 g/L.

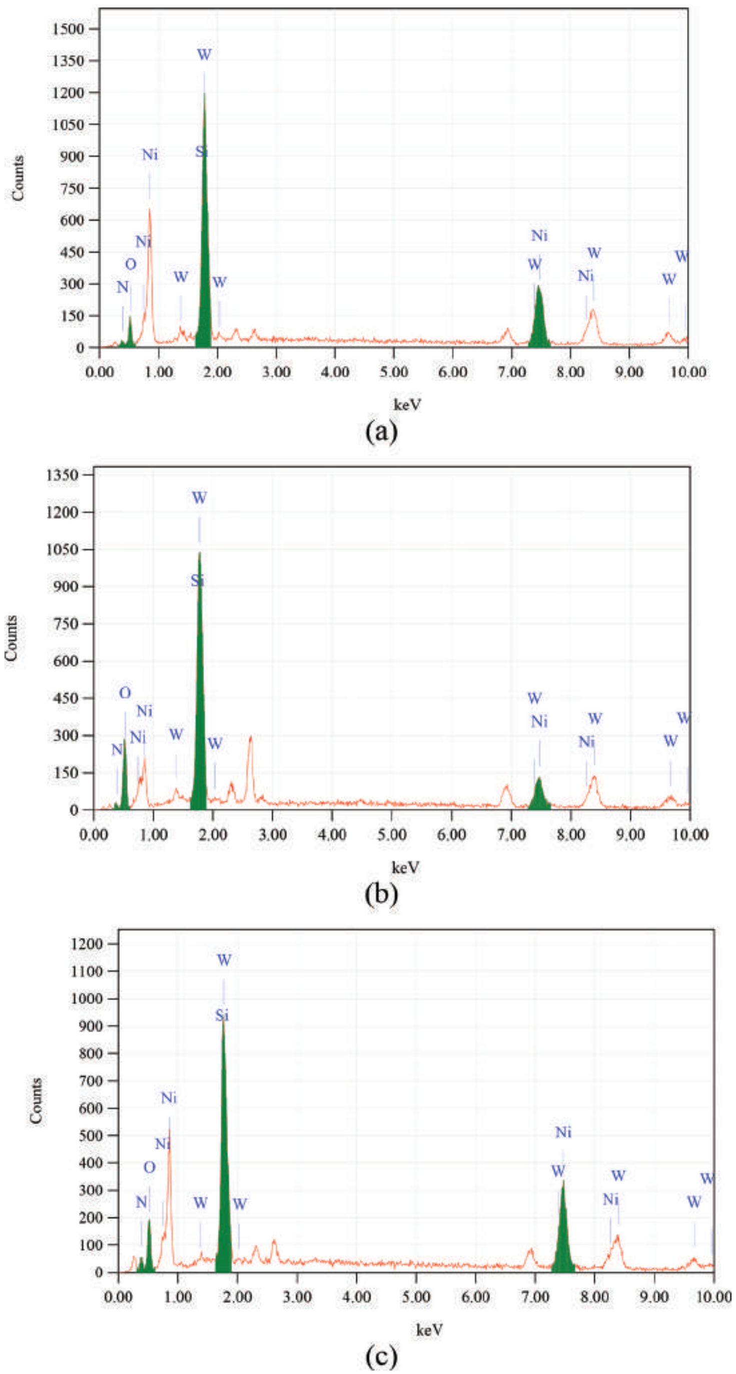

Figure 2. Energy Dispersive Spectroscopy (EDS) composition of Ni/Si_3N_4 composite coatings at different Si_3N_4 concentrations: (a) 10 g/L; (b) 20 g/L; and (c) 30 g/L.

The XRD pattern of samples electrodeposited at 10 g/L Si_3N_4 is slightly different compared to others, especially the presence of the amorphous phase at a low angle due to unreacted elements of the composite (Real et al., 2018). As the Si_3N_4 concentration is increased, the amorphous phase disappears.

Table 1. Energy Dispersive Spctroscopy (EDS) composition of Ni/Si_3N_4 composite coatings at different Si_3N_4 concentrations.

	Composition (atomic %)		
Element	10 g/L	20 g/L	30 g/L
N	30.80	23.81	30.66
O	38.21	61.21	43.66
Si	2.59	3.23	6.76
Ni	15.91	4.51	13.03
W	12.49	7.23	5.90

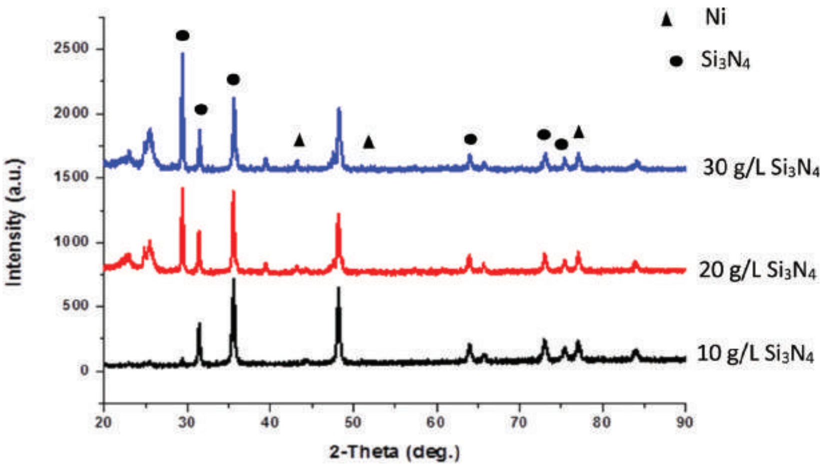

Figure 3. X-Ray Diffraction (XRD) pattern of Ni/Si_3N_4 composite coatings at different Si_3N_4 concentrations: (a) 10 g/L; (b) 20 g/L; and (c) 30 g/L.

Table 2. Microhardness of the Ni/Si_3N_4 composite coatings.

Si_3N_4 concentration (g/L)	Microhardness (HV)
10	1390.6
20	1018.23
30	1836.3

3.4 *Microhardness*

The microhardness test result of the Ni/Si_3N_4 composite coatings is presented in Table 2. It shows that their microhardness has varying values as Si_3N_4 concentration is increased. An increase in coating microhardness with increasing Si_3N_4 concentration is attributed to Ni grain refining due to Si_3N_4 dispersion strengthening. While, a decrease in coating microhawrdness with increasing Si_3N_4 concentration (as indicated by a sample electrodeposited at 20 g/l) might be attributed to the high residual stress at the coating interface (Liu et al., 2017). A similar phenomenon was also observed for another type of metal matrix and another synthesis method (Kumar et al., 2016; Robin et al., 2011). The addition of Si_3N_4 particles into the composite coating may resist dislocation and reduce plastic deformation.

4 CONCLUSION

Co-electrodeposition of Si_3N_4 particles into the Ni coatings to form Ni/Si_3N_4 composite coatings has been successfully developed. The increase in Ni/Si_3N_4 composite coating microhardness is attributed to Ni grain refining due to Si_3N_4 particle dispersion within the coating.

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In vitro germination of wild banana *Musa acuminata* Colla var. *microcarpa* (Becc) after storage periods at different temperatures

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ABSTRACT: *Musa acuminata* Colla var. *microcarpa* (Becc), is one of fifteen types of wild bananas in Indonesia. The storage of bananas is difficult because banana seeds are inside and are a fast decaying fleshy part of the fruit. Germination of intact seeds either fails to germinate or has a low percentage of germination because there is an incompatibility with seed formation. This study aimed to find the ability for wild banana germination after storage through embryo culture. The banana embryos were cultured on a Murashige and Skoog (MS) medium with 2.25 mg/l^{-1} of 6-benzyladenine and 0.175 mg/l^{-1} of indole-3-acetic acid. The total number of embryos inoculated was 1,800. This study showed that storage of bananas at three different temperatures for a 60 days period, made the embryo unable to germinate. Most of the embryos germinated in a storage period of 4 to 10 days, whereas 76% germinated when stored at cold temperatures for 30 days. For banana seeds stored at different temperatures for 4 to 10 days, 70–76% of the embryos germinated. For banana seeds stored at cold temperatures for a 30 days period, 84% of the embryos germinated, and for a 60 days period, 68%. This research shows that the best short-term storage of wild banana seeds was in a cold temperature (1 to 5°C) for a 30 days period. The germinated embryos of wild banana were then multiplied in MS medium for four months to produce shoots and calli before acclimatization in a greenhouse.

1 INTRODUCTION

Banana and plantain (*Musa* spp) are a giant monocot plant belonging to the family *Musaceae*. Bananas grow in tropical and subtropical countries at a temperature of 20°C, above and below the equatorial line (Pua, 2007). Bananas consist of many cultivars and there are currently around 1,000 banana cultivars and 50 local races (landraces) (Heslop-Harrison & Schwarzacher, 2007). In Indonesia, around 200 local banana cultivars and wild varieties have been planted in almost all areas at different heights and in various types of soil (Nasution, 1991). Cultivated bananas, plantains and fiber-producing banana species (*Musa textilis* Nee) are derived from the intraspecific and or interspecific hybridization of the wild banana *Musa acuminata* Colla and *Musa balbisiana* Colla (Ploetz et al., 2007; Sipen et al., 2011; Valmayor et al., 2000). The center of diversity and the hybrids of *Musa acuminata* are in Malaysia and Indonesia (Asif et al., 2001), while hybrids of *Musa balbisiana* have been predicted to have originated from India.

Musa acuminata Colla var. *microcarpa* (Becc), is one of fifteen types of wild bananas in Indonesia. This banana has a local Indonesian (vernacular) name: forest banana or monkey banana (Nasution, 1991). Wild bananas are a diploid plant (2n = 2x), have fertile pollen which can be cross-pollinated with other diploid bananas, and are relatively free of disease (Heslop-Harrison & Schwarzacher 2007; Ploetz et al., 2007; Uma et al. 2012. Great diversity in wild and cultivated bananas (*Musa* spp) can be found from Aceh (Sumatera) to Papua

(International Network for the Improvement of Banana and Plantain & Central Research Institute for Horticulture, 2002). *Musa* germplasm can also be found in East Kalimantan, Maluku and Lesser Sunda Islands (Hermanto et al., 2014, and new varieties of wild banana have reportedly been found in Sulawesi (Sulistyaningsih et al., 2014). The variety of wild bananas in Indonesia shows that the genetic diversity in these species is very high, making wild bananas useful as a source of germplasm to assemble superior varieties. The existence of wild bananas needs to be conserved so that a source of plant genetic diversity can be maintained.

Germplasm storage methods depend on the nature of germplasm material (seeds or non-seeds) (Imarhiagbe et al., 2016). Banana seeds are naturally orthodox (storable) seeds. They can be stored for a long time under low humidity and low temperatures (Imarhiagbe et al., 2016). Although banana seeds can be germinated immediately after extraction, the seeds show secondary dormancy after storage (Fortescue & Turner, 2011). Previous studies on seed germination of wild bananas at the time of harvest and post-harvest at optimal conditions, have been carried out on *Musa velutina* Wendl. & Drude (Nagano et al., 2008), *Musa ornata* from Mexico (Burgos-Hernandez et al., 2014), and on *M. acuminata* subsp. *burmannica* Simmonds from India (Vineesh et al., 2015).

Wild bananas are difficult to germinate (Nagano et al., 2008; Roy et al., 2006; Uma et al. 2012. At least 3 to 6 weeks is required to initiate seed germination in soil. Germination occurs over a 3 to 15 week period and often provides a low percentage of growth (Uma et al., 2012. This low growth percentage occurs because the embryo may be in an abnormal condition that does not allow it to grow. Germination of the banana depends on the ripening of the fruit at harvest, and the physiological age of the seed (Harry et al., 2010; Rashid et al., 2013; Reed, 2005

Germination is also inhibited by physical barriers, such as impermeability of seeds, chemical barriers by dormancy induced plant growth, incompatibility of normal seed formation, damaged endosperm, storage period of the seeds (Nagano et al., 2008; Uma et al., 2012, and difficulty with cross-pollinating seeds (Harry et al., 2010; Rashid et al., 2013). Germination of wild bananas through embryo culture is one of the techniques used to increase seed germination so that the potential resource loss of banana genetics can be prevented. This study aimed to find the ability for wild banana seed germination through embryo culture after storage in different treatments.

2 METHOD

This study used the *Musa acuminata* Colla var. *microcarp*a (Becc.) Nasution, a seeded wild banana from the Aripan area, Solok, West Sumatra, Indonesia. This study was comprised of three factors: the plant storage organ (fruit and seeds); storage temperature (–20 to –25°C, 1 to 5°C, and 32 to 40°C); and storage period (4 to 10, 30, and 60 days). The experimental design used a factorial completely randomized design, and the number of treatments was 18 with 20 replications. The total number of embryos planted was 1,800.

2.1 *Storage of wild bananas at different temperatures and storage periods*

In this previous study, the explanted banana fruit seeds were stored at a freezing temperature, a cold temperature, and at room temperature. This previous study showed that banana fruit stored at room temperature (30°C) is not a suitable temperature for banana storage. The objective of the research was to find the effectiveness of the fruit and seed of the banana as a storage organ, and to achieve a good sterilization technique for fruit and seeds of bananas for an *in vitro* embryo culture. Fruits and seeds of wild bananas were stored at freezing temperatures of –20 to 25°C, cold temperatures of 1 to 5°C, and above room temperatures of 32 to 40°C). They were also stored for 3 different time periods: 4 to 10 days; 30 days; and 60 days. The parameters observed were conducted qualitatively, including fruit phenotype after storage, and the best sterilization techniques to obtain aseptic embryo cultures.

2.2 *Sterilization technique and germination of wild bananas after storage*

Banana fruit and fertile seeds that were stored in different temperatures and storage periods were grown *in vitro* through the embryo culture technique. Seeds of the bananas were separated from their pulp by washing in rice husk ash (carbonized rice husk), and then in tap water. Washed seeds were transferred to a beaker glass containing water for 30 minutes. Only sunken seeds were used because most of the floating seeds were generally devoid of the embryo or endosperm.

Sterilization of the treated seeds was undertaken in sterile conditions in a transfer box. Banana seeds that were stored for 30 days were soaked with 70% alcohol for 10 minutes followed by 100% sodium hypochlorite for 10 minutes. The banana seeds were then rinsed with sterile distilled water 4 to 5 times (the first sterilization technique). Banana seeds that were stored for 60 days were soaked with 1–2% mercuric chloride for 10 to 15 minutes followed by 70% alcohol for 10 minutes, then 100% sodium hypochlorite for 10 minutes. The sterile seeds were then soaked in sterile distilled water for 60 to 120 minutes, then dried using sterile filter paper (second sterilization technique). The banana seeds were placed in a sterile petri dish before the embryo was isolated. These two novel techniques sufficiently reduced the embryo contamination by 90–100%.

Embryos were extracted under a transfer box and were cultured in Murashige and Skoog salts supplemented with 2.25 mg/l^{-1} 6-benzyl adenine (BA) and 0.175 mg/l^{-1} indole-3-acetic acid (IAA). The embryos, after initiation, were cultured in a dark culture room at temperatures of 16 ± 1°C for 1 to 2 weeks and then transferred to a lighter culture room. The embryos were observed for percentage germination of shoot and calli formation. The experiments were repeated for twenty replications and analyzed statistically by descriptive statistics.

3 RESULTS AND DISCUSSION

3.1 *Wild banana fruit and seed performance after a storage period with different temperatures*

The storage of banana fruit and seeds at various temperatures and periods was conducted to determine the viability of banana seeds after the storage period. The results are shown in Figure 1. The bananas stored at room temperature (30°C) showed that the color of the banana skin turned from green to dark brown. The banana peel and skin were also covered with a fungus (Figure 1b). In the next experiment, the temperature was increased to the range 32 to 40°C. The fruit stored at these temperatures did not show any fungal growth, but the fruit became very dry, shrunk in size and the fruit color turned black. This indicated that the temperature range of 32 to 40°C was not a good temperature for banana fruit storage.

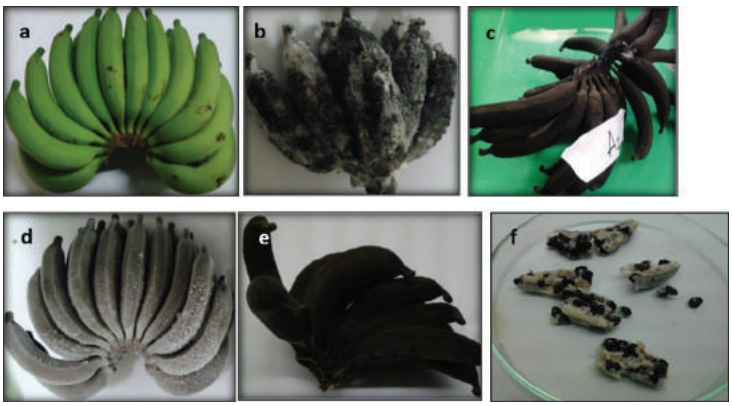

Figure 1. Performance of wild bananas (*Musa acuminata* Colla var *microcarpa*) before and after storage: (a) fruit after harvest; (b) stored at room temperature (30°C) for 2 weeks; (c) stored at above room temperature (32 to 40°C); (d) storage at freezing temperatures (–20 to –25°C); (e) storage in cold temperatures (1 to 5°C); and (f) banana seeds at room temperature.

Most of the fruit and seeds stored for 30 and 60 days at freezing and cold temperatures showed an alteration in performance. For the fruit stored at freezing temperatures (–20 to –25°C), the fruit size was relatively large, and the skin color changed from green to dark brown; the seeds also swelled. The storage of fruit at freezing temperatures suggests fruit damage occurred due to chilling injury (Figure 1d). According to Mangrich and Saltveit (2000), this is a physiological disorder that occurs in plants sensitive to temperatures below 12°C. Fruit and seeds stored at cold temperatures (1 to 5°C) shrink and turn blackish-brown (Figure 1e). Oxidative browning is a common occurrence and is often a severe problem for plant cells. This brown pigment occurs because of the accumulation of a phenolic compound. It is a chemical process and produces a brown pigment called melanin (Jones & Saxena, 2013).

Storage of plant material at temperatures of 0 to –5°C is used for species that are tolerant to cold temperatures, but for plant species that are sensitive to cold temperatures, storage is at temperatures ranging from 0 to 15°C (Engelman, 1991; Kaviani, 2011). This experiment showed that fruits stored at above room temperature, freezing and cold temperatures for 30 days indicated that the banana fruit is sensitive to cold temperatures. Seed storage is a common method for genetic conservation of plants. Banana seeds are naturally orthodox seeds and have various dormancy types (Fortescue & Turner, 2011). Orthodox and sub-orthodox seeds could be stored at temperatures from –15 to –20°C (for those tolerant to cold temperatures) or 0 to –5°C (for subtropical and tropical species) (Kaviani, 2011). Banana seeds could germinate immediately after extraction, but the seeds showed secondary dormancy after storage (Uma et al., 2011). This experiment showed that wild banana seeds stored at above room temperatures, cold temperatures, and freezing temperatures did not show changes in performance of seeds (Figure 1f). According to Nagano et al. (2008) storage of banana seed can promote the germination of dormant seeds and immature seeds

3.2 *Effects of the period of fruit and seed storage on in vitro embryo germination of wild bananas*

The germination of wild bananas was carried out through an *in vitro* embryo culture technique after storage. At the initiation stage, it showed that for most seeds stored for 60 days at freezing temperatures of –20 to –25°C, their embryos appeared to swell. Seeds stored in cold temperatures of 1 to 5°C) had an embryo size relatively no different from embryos that had been inoculated at 4 to 10 days after harvest. Whereas at temperatures of 32 to 40°C, the embryo shrank. The embryo was then germinated on the medium containing 2.25 mg/l^{-1} BA and 0.175 mg/l^{-1} IAA (Indrayanti et al., 2011; 2012).

The ability to germinate wild banana embryos after storage was determined by calculating germination potential. Wild banana seed germination is determined by the number of normal germinating embryos characterized by the emergence of a radicle. Germination is a measure of potential viability with the formula for the number of normal germinating embryos per number of embryos planted (Sadjad et al., 1999). The results of this study are shown in Figures 2 and 3 and Table 1. The effect of fruit stored at freezing and above room

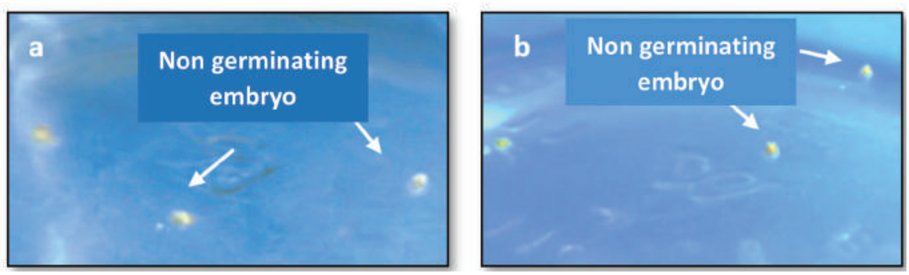

Figure 2. Non-germinating embryos: (a) after the seeds were stored at –20 to –25°C for 30 days ($S_2T_1P_1$); and (b) after the fruit was stored at 32 to 40°C for 60 days ($S_1T_3P_2$).

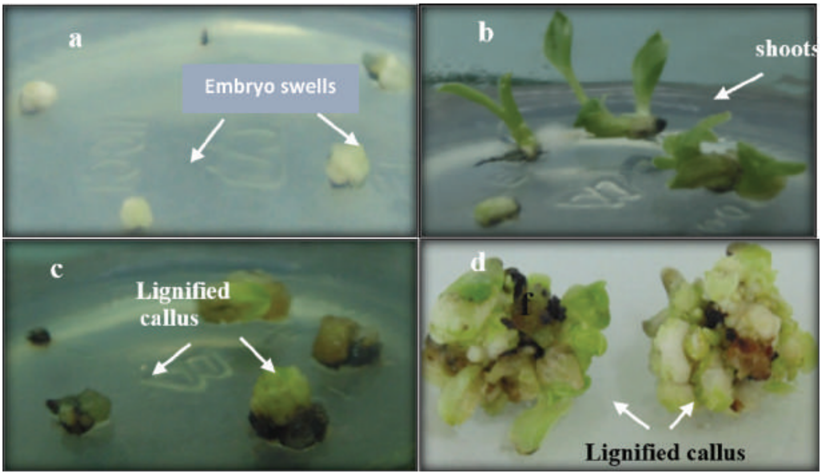

Figure 3. Embryo growth to shoot after the seeds are stored at a temperature of 1 to 5°C for 30 days ($S_1T_2P_1$): (a) 14 days after initiation; and (b) 60 days after initiation. The growth of the embryo became callused after the fruit is stored at a temperature of 1 to 5°C for 4 to 10 days ($S_1T_2P_0$) in 30 days (c) and 60 days (d) after initiation.

Table 1. Percentage of embryo germination of wild bananas after storage at various temperatures and periods after 30 days of culture.

Storage organ	Temperature (°C)	Storage period (days)	Code of treatment	Percentage of embryo germination (%) after 30 days of culture
Fruit	–20 to –25	4 to 10	$S_1T_1P_0$	70
Fruit	1 to 5	4 to 10	$S_1T_2P_0$	74
Fruit	32 to 40	4 to 10	$S_1T_3P_0$	64
Fruit	–20 to –25	30	$S_1T_1P_1$	0
Fruit	1 to 5	30	$S_1T_2P_1$	76
Fruit	32 to 40	30	$S_1T_3P_1$	0
Fruit	–20 to –25	60	$S_1T_1P_2$	0
Fruit	1 to 5	60	$S_1T_2P_2$	0
Fruit	32 to 40	60	$S_1T_3P_2$	0
Seed	–20 to –25	4 to 10	$S_2T_1P_0$	70
Seed	1 to 5	4 to 10	$S_2T_2P_0$	66
Seed	32 to 40	4 to 10	$S_2T_3P_0$	76
Seed	–20 to –25	30	$S_2T_1P_1$	0
Seed	1 to 5	30	$S_2T_2P_1$	84
Seed	32 to 40	30	$S_2T_3P_1$	0
Seed	–20 to –25	60	$S_2T_1P_2$	0
Seed	1 to 5	60	$S_2T_2P_2$	68
Seed	–20 to –25	60	$S_2T_3P_2$	0

temperature for 30 to 60 days on seed germination was that all the embryos did not germinate (Figure 2a–b). At those two temperatures, the embryo of the wild banana *Musa acuminata* Colla var. *microcarpa* germinated only at the storage period of 4 to 10 days and their germination percentages were 64–74% (Table 1 and Figure 3a–d). Germination is a physiological reaction; the ability of the embryo to germinate depends on specific temperatures and is related to starch digestion by amylase (Nagano et al., 2008).

Temperature during seed storage affects embryo development (Nagano et al., 2008). This study showed that there was no embryo germination after fruit storage for 60 days at all temperature treatments, after 30 days storage at freezing temperatures, and above room temperature (Table 1). Among these various temperature treatments, embryos germinated mostly at a temperature of 1°C to 5°C for all storage periods with their germination percentages invariably being 68–84% after 30 days of culture on the Murashige Skoog medium. The highest percentage of embryo germination (84%) was produced from seeds stored for 30 days. In the wild banana (*Musa acuminata* subsp. *burmannica*), the percentage seed germination ranged from 84.12% to 88.5% under *in vitro* conditions and 4 weeks after culture (Vineesh et al., 2015). The zygotic embryos of wild bananas from Mexico, *Musa ornata* Robx, took 21 days to germinate (Burgos-Hernandes et al., 2014).

The developed embryo from stored seeds is still able to germinate (68%) until 60 days of expandable storage, although the number of days to germination increased (16 to 17, see Figure 4). According to Nagano et al. (2008), seed storage can promote the germination of dormant and immature seeds. Embryos grown from 30 days of fruit storage need 24 to 25 days to germinate, and their germination percentages were 76%. This occurs because of the activation of inhibitory compounds, at the stage of embryo maturation, which causes seed dormancy (Reed, 2005; Roy et al., 2006; Uma et al., 2011). All germinated seedlings grew and developed normally.

The number of days to germination is the average of the time the embryo grows a normal sprout. Most of the embryos stored for 4 to 10 days germinated at 8 to 9 days after culture with the percentage germinating being 6–12% (Figure 4). For the fruit of the bananas stored at 1 to 5°C for 30 days of storage, embryos germinated at 18 to 19 days after culture (13%). For banana seeds stored at 1 to 5°C for 30 days of storage, embryos germinated 16 to 17 days after culture (11%), while for banana seeds stored for 60 days, the embryos germinated 24 to 25 days after culture (11%, see Figure 4). This study shows that *Musa acuminata* Colla var *microcarpa* stored for 60 days has a faster germination time than *Musa veluntina* Wendl. & Drude. Seeds of *Musa velutina* stored for 60 days took 42 days to germinate, but seeds stored for 4 to 8 months germinated in 14 to 21 days (Nagano et al., 2008). Lee et al. (2018) reported that for *Thalictrum uchiyamae* (Ranunculaceae), a species of herbaceous perennial, the physiological dormancy of the embryo was broken by a cold temperature of 5 °C for 60 days, but warm temperatures (15°C to 20°C) were required to promote embryo elongation after the physiological dormancy was broken.

The percentage of embryos to germinate is at its maximum at the temperature storage range of 1 to 5°C (cold temperature) for 30 days of storage (84%). As the temperature declines to freezing temperatures or advances at above room temperatures, the percentage of embryos to germinate decreases and the number of days to germination increases. Bananas

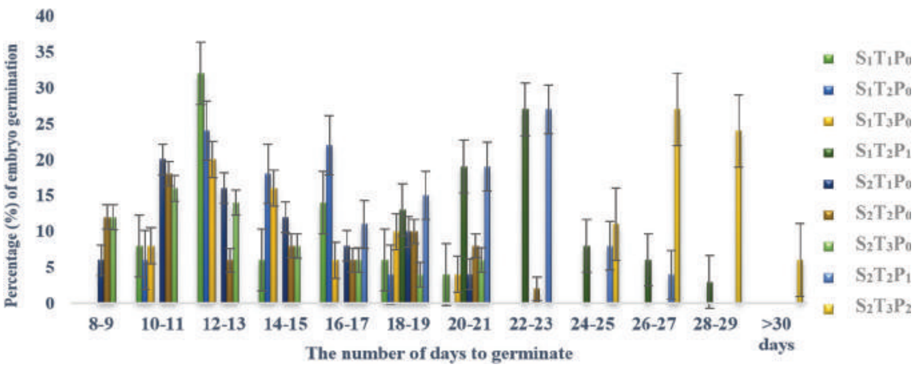

Figure 4. Days of emergence and percentage of embryo germination of wild bananas *Musa acuminata* Colla var. *microcarpa* (Becc.) at 8 to 30 days after culture. S_1 = fruit storage, S_2 = seed storage, T_1 = temperature –20 to –25°C, T_2 = temperature 1 to 5°C, S_3 = temperature 32 to 40°C, P_0 = 4 to 10 days of storage, P_1 = 30 days of storage, and P_2 = 60 days of storage.

are sensitive to low temperatures. The fruit will suffer damage after a storage period below 10 to 15°C (Mangrich & Salveit, 2000), 11 to 20°C (Hardaningsih & Alfi, 2010) or 11.5 to 13°C (Wang, 1991), with a critical temperature of 13°C. This damage occurs due to physiological disturbances where the color of the fruit will become decolorized. Therefore storage at freezing temperatures (–20 to –25°C) causes chilling injuries. Seeds stored in freezing conditions for 30 to 60 days showed damage to the embryo and caused dormancy.

According to Fortescue and Turner (2011), banana seeds show secondary dormancy after storage. In this experiment, the fruit and seeds were stored at freezing temperatures causing the seeds' water content to become high. The duration of storage for 60 days can cause a decrease in the moisture content of the seeds which is closely related to the evaporation process of seeds during the storage period. Germination of ginger seeds (*Zingiber officinale* Rosc.) showed similar results in that the viability of the embryos decreased after being stored for 60 to 90 days (Sukarman et al., 2007). This study showed that improperly stored banana fruit and seeds at freezing temperatures (–20 to –25°C) and above room temperature (32 to 40°C) was, in contrast, not the right method for banana storage. The number of days needed to germinate and the total percentage of wild banana germination showed that temperature, and prolonged duration of storage organs, can critically affect the ability of the embryo to germinate in a culture medium. To prolong the duration of wild bananas, their seeds should be stored at a temperature of 1 to 5°C for 30 to 60 days.

3.3 *Effect of various storage conditions to in vitro shoots and calli growth of wild bananas*

The embryos that were germinated in the MS medium, partially grew into shoots or calli (Figure 3b–d). The banana shoots and calli were subcultured at regular intervals every month in a fresh media. The number of shoots and calli were recorded 1 to 4 months after culture. At this stage, leaf plumula will grow to shoots, and the radicle will develop into roots. The effect of various storages on the number of *in vitro* shoots at 120 days after culture showed that embryos developed from fruit stored for 4 to 10 days at a cold temperature (1 to 5°C) had the highest number of shoots (5.00 ± 0.5). There was no significant difference in the number of shoots from seeds stored at cold temperatures for 4 to 10 days (4.60 ± 0.83) and 30 days of storage (4.60 ± 0.34, see Table 2). The lowest number of shoots produced from fruits stored at above room temperature (32 to 40°C, 1.90 ± 0.41, and see Table 2). This study shows that cold temperatures (1 to 5°C) are an optimum temperature for seed storage.

According to Burgos-Hernandez (2014), the differences in the width of the water channel in banana seeds may result in differences in the ability of cells to form shoots. In *Musa acuminata* it has been reported that fresh seeds have a narrower water channel than dry seeds, so the uptake of water is higher for dry seeds (Puteh et al., 2011). The high percentage of germination (84%) and the high number of shoots (5.00 ± 0.78) produced from seeds stored at cold temperatures could be a good indicator for the success of plants in the acclimatization phases.

Table 2. Effect of various storage conditions on the average number of *in vitro* wild banana shoots 30 to 120 days after culture.

	The average number of shoot growth in 30 to 120 days							
Storage conditions	30	± SE	60	± SE	90	± SE	120	± SE
Fruit, freezing temp, 4–10 days of storage	2.20	0.39	2.50	0.37	2.70	0.40	3.20	0.33
Fruit, cold temp, 4–10 days of storage	2.88	0.40	2.88	0.40	3.63	0.32	5.00	0.78
Fruit, above room temp, 4–10 days of storage	1.90	0.41	1.90	0.41	1.90	0.41	1.89	0.45
Fruit, cold temp, 30 days of storage	3.20	0.13	3.20	0.13	3.20	0.13	3.40	0.22
Seed, freezing temp, 4–10 days of storage	2.71	0.29	2.71	0.29	2.63	0.26	2.86	0.51
Seed, cold temp, 4–10 days of storage	2.60	0.34	2.70	0.37	3.70	0.54	4.60	0.83
Seed, above room temp, 4–10 days of storage	1.60	0.22	2.10	0.23	2.10	0.23	2.30	0.21
Seed, cold temp, 30 days of storage	3.60	0.22	3.50	0.27	4.50	0.34	4.60	0.34

Table 3. Effect of various storage conditions on the average number of *in vitro* calli of wild bananas in 30 to 120 days after culture.

	The average number of callus growth in 30 to 120 days							
Storage condition	30	± SE	60	± SE	90	± SE	120	± SE
Fruit, freezing temp, 4–10 days of storage	1.83	0.40	1.70	0.26	2.00	0.26	2.11	0.26
Fruit, cold temp, 4–10 days of storage	1.33	0.21	1.80	0.29	2.20	0.25	2.29	0.29
Fruit, above room temp, 4–10 days of storage	1.00	0.00	1.67	0.67	1.67	0.67	1.67	0.67
Fruit, cold temp, 30 days of storage	2.30	0.30	2.30	0.30	2.50	0.27	2.80	0.29
Seed, freezing temp, 4–10 days of storage	1.83	0.48	2.11	0.42	2.89	0.42	2.56	0.41
Seed, cold temp, 4–10 days of storage	1.33	0.21	2.10	0.28	3.50	0.40	3.50	0.40
Seed, above room temp, 4–10 days of storage	1.25	0.25	2.43	0.30	3.00	0.38	3.00	0.38
Seed, cold temp, 30 days of storage	2.00	0.30	2.10	0.28	2.10	0.28	2.10	0.28

In this study, some of the embryos of wild bananas that had undergone germination were producing calli. Calli are parenchymal cells that divide abnormally during mitosis under tissue culture processing. There are two types of calli: friable, lignified/hard. Friable calli have a good genetic potential to differentiate and redifferentiate to form a plantlet after passing physiological and biochemical change (Akinyosoye et al., 2015), and through indirect organogenesis or embryogenesis. In this study, the embryo which germinated after storage produced lignified and hard calli (Figure 3c–d). Lignin is a polymer of aromatic subunits derived from phenylalanine that strengthens and waterproofs specialized plant cells. Lignification is part of the normal differentiation and functioning of specific cell types. It also triggers a response to various abiotic and biotic stresses in cells that would not alternatively be lignifying (Barros et al., 2015).

The effect of various storage methods on calli formation shows that embryos developed from seeds stored at cold temperatures and seeds stored at above room temperatures for 4 to 10 days, have the same number of calli (3.50 ± 0.40 and 3.00 ± 0.38, see Table 3). The lowest number of calli were produced from embryos developed from fruit stored at above room temperature (1.67 ± 0.67). The differences in embryo germination of the *Musa* species may be a reflection of different degrees of embryo dormancy after storage, and possibly because of the lack of gibberellic acid, and there are lots of plant inhibitors in the seed embryos.

4 CONCLUSIONS

Banana fruit and seeds stored at freezing temperatures and above room temperatures for 60 days were not the right method for banana storage. The most effective temperature for seed storage is in cold temperatures. At these temperatures, the wild banana *Musa acuminata* Colla var. *microcarpa* (Becc.) can be stored for two months. This research shows that the best short-term storage of wild banana seeds was in a cold temperature (1 to 5°C) for a 30 days period. In this study, the embryo which germinated after storage and developed shoots, also produced lignified and hard calli.

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Reversible antifertility effects, and morphometry of testis and epididymides in male DDY mice after being given aqueous neem seed extract (*Azadirachta indica* A. Juss)

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ABSTRACT: Neem has been well known as herbal medicine because of it is beneficial properties, such as antihyperglycemic, antifungal, spermicide especially in herbal contraception. The aim of this study was to observe antifertility and morphometry of reproductive organs of male mice, such as fertility and weight of testis and epididymides. The mice were orally administered the aqueous neem seed extract with doses of 0.00, 0.25, and 0.50 mg/kg body weight for 36 days and then treatment was stopped for 36 days. This experiment used a completely randomized design and data was analyzed by *Tukey's* tests. The results showed a reduction in fertility, and reduce testicular weight, was reversible, but did not decrease testicular morphometry and epididymides. However, fertility and reversibility of reproductive organs gave significantly different ($p < 0.05$). After 36 days of withdrawal of treatment, the reproductive organs of male mice recovered to the control group. Morphometric results of the testis, and epididymides of treated mice were not significantly different ($p > 0.05$). Conclusion, aqueous neem seed extract caused antifertility and reversible alterations in the male reproductive organs of mice, and has the potential to be male contraceptive.

1 INTRODUCTION

Herbal treatments have grown rapidly in the world in the last few decades. The use of plants as traditional medicines is increasing and gaining popularity in all developed and developing countries. This is due to the presence of active ingredients, such as alkaloids, phenolics, tannins and flavonoids which are active pharmacological compounds. Phytochemicals contain primary and secondary compounds (Hannah & Krishnakumari, 2015). Even the World Health Organization established a task force to research plants for fertility regulation with the aim of finding new non-steroidal oral contraceptive agents (Sathiyaraj et al., 2010).

Some plant products can inhibit male and female fertility and can be developed into contraception (Joshi et al., 2011). Men are becoming a new focus for the development of contraception (Thakur et al., 2010). The ideal male contraceptive, among others, is being easily available, inexpensive, safe to use, without side effects, does not affect libido, and is reversible (Mathew & Bantwal, 2012). The current method for male contraception is anti-spermatogenesis agents that: (a) suppress the production of spermatozoa; (b) interfere with the maturation of spermatozoa, and (c) block the transport of spermatozoa. Traditional male contraceptive methods currently available are condoms and vasectomy. Male fertility, especially in spermatogenesis, can be manipulated by a variety of varied mechanisms that are reversible (Thakur et al., 2010).

There are several antifertility medicinal plants. One of the plants that can be used is neem (*Azadirachta indica*). Neem has long been used as a medicine in the Ayurvedic system. Various parts of this plant can be used for the treatment of different diseases (Sathiyaraj et al., 2010).

Neem is one of the plants that can be used as a male contraceptive drug and neem extract can also be used as an antifertility agent (Gbotolorun et al., 2008). Neem contains various components of chemical compounds, such as flavonoids, tannins, alkaloids, steroids, triterpenoids, phenols, carotenoids, steroids and ketones (Hashmat et al., 2012). Among these compounds, antifertility properties can be found. Antifertility compounds work, in principle, in two ways: through cytotoxic or cytostatic effects; and through hormonal effects that inhibit the rate of sex cell metabolism by disrupting hormone balance (Asif, 2013). The benefits of neem as a natural herbal contraceptive drug have been investigated as an antiandrogenic (Pastuszewska et al., 2006), as an antifertility compound (Asif, 2013), as an instigator of reduced fertility (Tiwari et al., 2014), and as a contraceptive (Nishan & Subramanian, 2014).

Neem contains various types of active compounds, namely flavonoids, glycosides, alkaloids, and saponins (Yehia, 2016). Bioactive compounds such as triterpenoids contained in plants have antifertility agents. High alkaloid content in plants can increase the concentration of estradiol and prolactin, which can inhibit the gonadotrophic action of the testis and the fertility of male animals, suppress spermatogenic activity, and cause infertility (Pastuszewska et al., 2006). Flavonoids cause antispermatogenic effects by decreasing the quality of spermatozoa (Srivastav et al., 2010).

Flavonoids can inhibit many oxidation reactions, both enzymes, and non-enzymes. The inhibition of enzymatic reactions in the body will inhibit a number of cell development processes in the body, including sex cells during gametogenesis. Saponins can reduce motility, viability, and morphology of spermatozoa, and do not cause toxic effects (Joshi et al., 2011). But on the other hand, the neem has a bitter taste. Its pulp is due to the presence of triterpenoids, especially azadirachtin (Adjorlolo et al., 2016). Neem also contains high crude fiber. Plants with high crude fiber content have low digestibility. This is because the tissues have undergone a lignification process so that lignicellulose and lignohemelulose are formed (Walugembe, 2013).

The testis have a function, namely as a place for spermatogenesis and androgen production. Testicles and are very important genital and reproductive tract glands in producing spermatozoa (Cheah & Yang, 2011). It is necessary to examine whether the seeds of the neem affect body weight, morphometry of the testis and reversibility of testicular and epididymides morphometry after treatment. The purpose of this study was to evaluate the reversibility and morphometry of the testis and epididymides after treatment with aqueous neem seed extract.

2 METHOD

The study was conducted in the Laboratory Animal Management Unit of the Faculty of Veterinary Medicine of Bogor Agricultural University, Indonesia. The evaluation of reversibility and morphometry of testis and epididymides was carried out in the Laboratory of Rehabilitation and Reproduction in the Department of Clinical Reproduction and Pathology of the Veterinary Faculty of Bogor Agricultural University.

Neem seeds were obtained from the testing laboratory of the Bogor Spice and Medicinal Crops Research Institute (Balittro) in Indonesia. The raw material was dried using an oven with a temperature of 60°C, milled to a powder, then macerated and made into an extract using an aqueous solvent.

2.1 *Research ethics*

This research has received approval (ethical clearance) from the Animal Ethics Commission of the Faculty of Veterinary Medicine of the Bogor Institute of Agriculture, with an Animal Ethics Approval Certificate Number of 038/SKEH/SKE/VI/ 2015.

2.2 *Preparation of experimental animals*

The study was conducted experimentally with a completely randomized design and four replications. The experimental animals used were 36 male DDY mice aged 12–14 weeks and with a body weight of 20–30 g. Mice were obtained from the Food and Drug Supervisory Agency Jakarta). Mice were acclimatized for two weeks, fed with pellets (PUR 512 BG @ Charoen Pokphand Indonesia) and drank *ad libitum*. Animals were grouped randomly by dividing them into five groups, each group consisting of four mice.

2.3 *A sampling of experimental animals and group of treatment with aqueous neem seed extract*

Group I (Control/C1) without treatment, groups II and III (s1-1, s2-1), IV and V (S1-1, S2-1) were treated with neem seed extract with doses of 0.25 and 0.50 mg/kg body weight (bw). The extract was provided for 36 days. Then stopped and maintained until the 72nd day (after 36 days of stopping the extract). The extract treatment was carried out orally with 0.5 ml/day in the morning between 06.00 and 07.00.

To know the effect of reversibility and morphometry, mice in both groups were killed by carrying out intraperitoneal anesthesia using ketamine 1.5 mg/kg bw and xylazine at a dose of 0.3 mg/kg bw, followed by dislocation of the os axis. Next, it is applied to the ventral abdomen to take the testis and epididymides. Parameters observed included body weight, morphometry, and reversibility of male mice testis and epididymides. Weighing was carried out using the Ohaus analytical scale. The length and width of the testis and epididymides were also measured using the Mitutoyo brand thrust term.

Data from results of were analyzed using the analysis of variance (ANOVA). If there was a difference between treatments, then *Tukey's* test was used with 95% confidence level. Data was processed using SAS Version 9 statistical software.

3 RESULT AND DISCUSSION

3.1 *Mice body weight before and after treatment, and after recovery*

The results of the ANOVA from the body weight of mice is presented in Table 1. The results show that the body weight of the mice in the control and treatment groups had increased. Weight gain in control mice was higher ($p < 0.05$) if compared with the treatment group. For the recovery group, after 36 days of stopping the extract, the weight remained the same ($p > 0.05$).

3.2 *Weight, length, width of testis morphometry after treatment and after recovery (reversibility)*

The results of various measurements of the weight of testis of the treated mice showed a significant decrease ($p < 0.05$), but the length and width of the testis did not show a significant difference with the control group ($p > 0.05$). These results are presented in Tables 2 and 3.

The results of the various measurements of testis weight of treated mice showed a significant decrease ($p < 0.05$), but the length and width of the testis did not show a significant difference with the control group ($p > 0.05$). Right and left testis were the same size.

3.3 *Epididymides weight and length after treatment, and after reversibility*

The results of various measurements of epididymides weight and length of treated mice did not show significant differences with the control group ($p > 0.05$), in Table 4.

Table 1. Body weight of male mice after being given neem seed extract and reversibility.

Treatment	Initial body weight	Weight gain	Final body weight
C	30.20 ± 1.23^{a}	5.72 ± 1.29^{a}	35.92 ± 2.52^{a}
s1-1	29.80 ± 1.23^{a}	3.12 ± 1.46^{b}	32.92 ± 2.51^{ab}
s2-1	28.40 ± 1.42^{a}	2.92 ± 1.62^{b}	31.32 ± 2.64^{ab}
S1-2	29.80 ± 1.14^{a}	5.10 ± 1.11^{a}	34.90 ± 2.15^{a}
S2-2	28.40 ± 1.09^{a}	5.08 ± 1.13^{a}	33.48 ± 2.24^{a}

Note: Different letters on the same line show significant differences ($p < 0.05$). The aqueous neem seed extract was administered in doses of: 0.25 and 0.50 mg/kg bw (C = Control, s1-1 and s2-1 = seeds (s)); 0.25 and 0.50 mg/kg bw for 36 days (S1-2 and S2-2 = Seeds (S); 0.25 and 0.50 mg/kg bw for 36 days, then 36 days of stopping the extract.

Table 2. Testis weight of male mice after neem seed extract administration and reversibility.

	Testis weight (mg)		
Treatment	Left	Right	Average
C	0.18 ± 0.04^{a}	0.17 ± 0.04^{a}	0.18 ± 0.04^{a}
s1-1	0.15 ± 0.02^{b}	0.15 ± 0.02^{b}	0.15 ± 0.02^{b}
s2-1	0.15 ± 0.01^{b}	0.15 ± 0.02^{bc}	0.15 ± 0.02^{b}
S1-2	0.16 ± 0.02^{a}	0.16 ± 0.02^{a}	0.16 ± 0.021^{a}
S2-2	0.16 ± 0.01^{a}	0.16 ± 0.01^{a}	0.16 ± 0.019^{a}

Note: Different letters on the same line show significant differences ($p < 0.05$).

Table 3. Averages testis length and width of male mice after administration of aqueous neemseed extract and reversibility.

	Testis					
	Length (cm)			Width (cm)		
Treatment	Left	Right	Aaverage	Left	Right	Average
C	1.13 ± 0.15^{a}	1.00 ± 0.17^{a}	1.10 ± 0.18^{a}	0.53 ± 0.11^{a}	0.48 ± 0.13^{a}	0.53 ± 0.12^{a}
s1-1	1.10 ± 0.14^{a}	1.00 ± 0.16^{a}	1.03 ± 0.21^{a}	0.48 ± 0.13^{a}	0.45 ± 0.14^{a}	0.47 ± 0.14^{a}
s2-1	1.10 ± 0.13^{a}	1.00 ± 0.18^{a}	1.03 ± 0.12^{a}	0.48 ± 0.17^{a}	0.45 ± 0.17^{a}	0.47 ± 0.18^{a}
S1-2	1.15 ± 0.16^{a}	1.00 ± 0.10^{a}	1.08 ± 0.12^{a}	0.48 ± 0.13^{a}	0.49 ± 0.11^{a}	0.49 ± 0.13^{a}
S2-2	1.08 ± 0.19^{a}	1.13 ± 0.09^{a}	1.10 ± 0.16^{a}	0.50 ± 0.18^{a}	0.45 ± 0.12^{a}	0.48 ± 0.08^{a}

Note: Different letters on the same line show significant differences ($p < 0.05$).

Table 4. Averages epididymides weight and length of male mice after administration of aqueous neem seed extract and reversibility.

	Weight (mg)			Length (cm)		
Treatment	Left	Right	Average	Left	Right	Average
C	0.05 ± 0.002^{a}	0.04 ± 0.001^{a}	0.045 ± 0.002^{a}	6.51 ± 0.73^{a}	6.50 ± 0.64^{a}	6.50 ± 0.71^{a}
s1-1	0.04 ± 0.001^{a}	0.04 ± 0.001^{a}	0.040 ± 0.001^{a}	6.39 ± 0.63^{a}	6.37 ± 0.68^{a}	6.38 ± 0.59^{a}
s2-1	0.04 ± 0.001^{a}	0.04 ± 0.001^{a}	0.040 ± 0.002^{a}	6.31 ± 0.62^{a}	6.17 ± 0.43^{a}	6.24 ± 0.52^{a}
S1-2	0.04 ± 0.002^{a}	0.04 ± 0.002^{a}	0.040 ± 0.001^{a}	6.35 ± 0.63^{a}	6.45 ± 0.64^{a}	6.40 ± 0.65^{a}
S2-2	0.04 ± 0.002^{a}	0.04 ± 0.002^{a}	0.040 ± 0.003^{a}	6.48 ± 0.55^{a}	6.45 ± 0.54^{a}	6.47 ± 0.64^{a}

Note: Different letters on the same line show significant differences ($p < 0.05$).

Table 5. Fertility of female mice mated with male mice given aqueous neem seed extract.

	Parent			Offspring		
Treatment	Bw	Σ offspring	Fw	Rf	Fa	Lf
C	33.5 ± 2.35^a	10.0 ± 1.65^a	1.7 ± 0.03^a	0.0 ± 0.0	0.0 ± 0.0	10.0 ± 1.12^a
S1–2	32.0 ± 1.57^a	6.8 ± 1.21^a	1.7 ± 0.04^a	0.0 ± 0.0	0.0 ± 0.0	6.75 ± 0.89^a
S2–2	31.0 ± 2.45^a	7.8 ± 1.12^a	1.7 ± 0.03^a	0.0 ± 0.0	0.0 ± 0.0	7.75 ± 1.23^a

Notes: Bw = Body Weight, Fw = Fetal Weight, Rf = Resorption of Fetus, Fa Fetal Abnormality, and Lf = Living Fetus. Note: different letters on the same line show significant differences ($p < 0.05$).

Table 6. Reversibility, length of pregnancy and number of mice after administration of aqueous neem seed extract and recovery period (reversibility).

Treatment	Reversibility (days)	Length of pregnancy (days)	Number of off spring
C	6.75 ± 1.03^a	21.0 ± 0.0^a	10.0 ± 1.08^a
S1-2	7.50 ± 0.96^a	21.0 ± 0.0^b	6.75 ± 1.90^a
S2-2	7.75 ± 0.63^a	21.0 ± 0.0^d	7.75 ± 0.53^a

Note: different letters on the same line show significant differences ($p < 0.05$).

3.4 *Fertility of male mice*

To evaluate the reversible effect of aqueous neem seed extract or not, treated mice weremated with female mice. Furthermore, litter size, the weight of the offspring, and abnormalities found in the fetus were calculated.

The results of fertility variance of female mice mated with treated mice showed that there was significant decrease ($p < 0.05$) in the number and weight of offspring and mice treated with neem seed extract. There were no significant differences in female body weight, fetal resorption, and fetal abnormalities ($p > 0.05$). These results are presented in Table 5.

Base on the data of litter size, it can be seen that the administration of neem seed extract of 0.25 and 0.50 mg/kg bw showed lowered the litter size if compared with control group ($p < 0.05$). But aqueous neem seed extract at doses of 0.25 and 0.50 mg/kg bw could reduced litter size, although results did not show significant difference with control group ($p > 0.05$).

3.5 *Reversibility of male mice*

The results of the variance of average reversibility, length of pregnancy and number of offspring from female mice mated with treated mice showed that there was significant decrease ($p < 0.05$) in reversibility, length of pregnancy and number of offspring, are presented in Table 6.

4 DISCUSSION

Increased body weight in mice after administration of extract was lower than the control group. This can be interpreted as that during the administration of the extract, the mice were under pressure to increase weight. After administration was stopped, the mice gradually experienced the same growth as a control group. The increase in body weight compared to the control group is thought to be due to the content of bioactive compounds in neem seeds. The compounds thought to have an effect on weight loss are tannins and alkaloids. Tannin compounds have the effect of being able to precipitate proteins that are on the surface of the small intestine because they are easily bound to proteins, thereby reducing food absorption and thus obesity can be inhibited (Gulewicz et al., 2014).

Apart from the effect of tannin, the decrease in body weight of mice can also be caused by the alkaloid content in the extract. According to Koo and Noh (2007), alkaloid compounds are thought to inhibit pancreatic lipase enzyme activity. Lipase enzymes hydrolyze the bonds of fat esters to alcohol and fatty acids. The activity of the lipase enzyme will increase the absorption of fatty acids. Conversely, if the lipase enzyme activity is inhibited, fat absorption is reduced so much that fat is wasted through feces, and so results in food absorption being greatly reduced, causing the highest decrease in body weight for the mice (Gulewicz et al., 2014).

The decrease in testis weight that occurred in the treatment group was thought to be due to flavonoid content. Flavonoid compounds have androgenic properties that can inhibit *Interstitial Cell Stimulating Hormone* (ICSH) and so induce Sertoli cells to produce an *Androgen Binding Protein* (ABP) which functions to bind testosterone and induce spermatogenesis (Nandwa, 2014). High levels of testosterone in the blood that is not bound to ABP will cause negative feedback to the anterior pituitary, which stops the release of *Follicle Stimulating Hormone* (FSH) and *Luteinizing Hormone* (LH), causes reduced testosterone secretion by the Leydig cells in the testis. If the testosterone in the Leydig cells is reduced, it will result in an impaired meiotic division, so that the formation of spermatids and will also be disrupted. This will also cause a decrease in the number of sperm, and it will also affect the mass of the testis.

The tannin content was also estimated to cause smaller testicular weight in the treatment group. Tannin compounds contained in the extract can precipitate proteins that are on the surface of the small intestine. Regenerating cells desperately need proteins including cells inside the testis. If the cells in the testis lack protein, then the cell regeneration process will be hampered, which results in reduced testicular weight (Olasantan et al., 2015).

Based on the results obtained, the magnitude of the testis weight did not affect the length and width of the testis. This is caused by the optimal utilization of the capacity of seminiferous tubules in the testis; by not increasing the size of the testis, it will increase testicular weight and volume only (Amann, 1970). This study showed that testicular morphometry was not affected by the extract given, but the testicular weight was influenced by the administration of extract, so the activity of testicles is reduced or disturbed, and this must be proven by the number of spermatozoa produced by mice. These results indicate that the function of the epididymides is not disturbed by the administration of neem seed extract. The epididymides is the channel for spermatozoa maturation. In cauda epididymides, spermatozoa become motile and have the ability to fertilize the ovum (Kunkitti, 2016).

5 CONCLUSION

Aqueous neem seed extract can reduce the weight of testis, but does not decrease morphometry of the testis and epididymides, and can reduce the fertility of male mice. Neem seed extract has a reversible effect on the weight and morphometry of the testis after 36 days of stopping the extract, and it's has the potential to be natural herbal antifertility drugs.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Harvesting chlorella sp by electrocoagulation

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ABSTRACT: The aim of this study was to evaluate the harvesting of the microalgae chlorella sp by electrocoagulation using aluminum and iron plate as electrodes. The experiment was done using the batch method and used 1 liter of microalgae for each treatment, with a direct current that variated between 9, 12 and 15 volts, pH that variated from 9 to 11, and an operation time from 10 to 40 minutes. The results of the treatments were remarkably good and the efficiencies to Total Suspended Solids (TSS) as the amount of microalgae removed reached 51.55% using a current density of 8.3 mA cm^{-2} potential 15 volt, pH 11 for 30 min. The energy consumption at these optimal conditions was very low (0.163 $kWhm^{-3}$). The proximate analysis of the chlorella biomass showed an ash content of 32.45%, fat content of 1.62%, water content of 15.32%, carbohydrate content of 32.15%, protein content of 34.86%, lipid content of 0.89%, carotenoid content of 37% and total choropil of 1.4%.

1 INTRODUCTION

Chlorella sp is a group of small-sized plants that usually live in fresh and marine waters. Chlorella sp contains nutrition that is very suitable for use as feed for fish larvae. If chlorella sp is used as food for fish larvae, it is usually given directly from the culture medium. This culture medium contains ammonia, organic matter and high soluble solids, which can kill the fish larvae. To prevent the death of the fish larvae, chlorella sp should be given in a pure form without including the culture medium.

Various methods have been developed in order to get pure chlorella sp, such as centrifugation, sedimentation, filtration and flocculation (Matos et al., 2013). All of these methods require a large amount of electrical energy. For centrifugation, electrical energy of 8 kWh / m^3 is required (Danquah et al., 2009), while filtration techniques only require 0.4 kWh/m^3, although this type of technique increases operational costs because the screen filters need to be replaced periodically (Uduman et al., 2010). Meanwhile, flocculation requires a coagulant that is expensive, but its energy needs are few (Uduman et al., 2010). The most commonly used flocculants include cationic polymer flocculant (Wang et al., 2014), polyaluminum chloride, ferric chloride, aluminum chloride (Lam et al., 2015), chitosan (Delrue et al., 2015), nano chitosan particles, (Farid et al., 2013), nanomagnetite (Chun et al., 2016), and Moringa oleifera fruits (Hamid et al., 2016).

Researchers continue to work on energy efficient harvesting methods, given that the cost of harvesting micro-genes reaches 20–30% of the total production cost (Vandamme, et al., 2013). Therefore, energy saving during process harvesting is an attempt to save on production costs. The results of the literature review indicate that the electrocoagulation technique is an effective and efficient technique for harvesting microalgae because it requires little energy (Alfafara et al., 2002). According to Shuman et al. (2014), the advantages of the electrocoagulation-flocculation technique are (i) the process is simple, (ii) additional treatment is not required, (iii) the area for large electrocoagulation.

The results showed that, with the addition of flocculants, energy requirements can be derived to 0.1 kWh/m^3. The results of the research by Poelman et al. (1997) showed that using the electrocoagulation method without using a coagulant required energy equal to 0.3 kWh /m^3 with a yield of 95%. Therefore the electrocoagulation technique can also be used to harvest microalgae. The advantages of electrocoagulation techniques are that they are energy efficient, environmentally friendly, safe, and multi-functional (does not require ion enhancement materials) (Uduman et al., 2011).

There are various factors that affect the effectiveness of electrocoagulation techniques for harvesting biomass from microalgae, such as electrode material, electrode spacing, the amount of electricity needed, time, temperature, pH, conductivity and size of microalgae (Gao et al., 2010). In addition, there is the influence of the electrocoagulation method on time. Pearsall et al. (2011) reported that using a batch process takes longer than using a continuous process. The same results were also produced by Kim et al. (2012).

Vandamme et al. (2011) reported that the higher the conductivity of the microalgae, the less energy is needed. Based on the results of his study on the effect of the microalgae medium on the use of electrical energy, this shows that marine microalgae only requires electrical energy of 0.2 kWh/m^3 with 80% coagulation efficiency.

In addition, the number of electrodes used also affects the time taken for electrocoagulation. The results of Sutanto's study (2011) showed that by using 2 electrodes, it took 90 minutes to reduce Total Dissolved solids (TDS) and TSS by 98%, but by using 4 electrodes it only took 70 minutes to obtain a 99% decrease in TDS and TSS levels.

The process of separating the biomass from the culture media is an important factor in determining the cost and quality of the product. The method of harvesting using electrocoagulation techniques is expected to be a solution to the risks faced by using harvesting methods that use chemicals, as well as being an efficient method. For the purposes of this study, the influence of the most important operating variables of the electrocoagulation process on harvesting efficiency will be evaluated and the power requirements will be estimated. The respective effects of the various factors on microalgae harvesting using electrocoagulation will be assessed, along with the impact of electrocoagulation on microalgal lipids, protein, chlorophyll and carotenoids. Finally, the objective of the research is to increase the amount of biomass harvested, reduce energy costs, and shorten the amount of time taken. This study used 5 electrodes at a distance of 1 cm from each other.

2 MATERIALS AND METHOD

2.1 *Cultivation of chlorella sp*

As much as 15 L of seawater 15 ppt sterilized by autoclave for 120 minutes with a temperature of 121ºC. The autoclave capacity was 5 L per 120 minutes. A volume of 0.6 L of sterile seawater with 25 ppt salinity was put into an Erlenmeyer with a 2 L capacity that contained 0.3 L of chlorella sp seeds. The Erlenmeyer was covered with aluminum foil and then tied with rubber, leaving a small hole in the center of the aluminum foil to insert an aerator hose. The chlorella sp. was cultured in a sterile room and aerated for 24 hours a day for 5 days until 18 L of Chlorella sp was produced. After being cultured, the growth of the chlorella sp. was observed every day. The chlorella sp was continuously aerated in a sterile room until it was ready to be harvested. During cultivation, ZA fertilizer was given, Urea, TSP with a ratio of 2: 2: L. A pH meter was used to calculate the pH and the salinity was calculated by using a MASTER refractometer. The chlorella sp cell growth curve was observed by measuring the cell density, which was then calculated. The measurement was done by taking a 1 mL sample every day. The calculation of cells per day, using an Hemocytometer, was then observed under a LEICA ICC 50 HD camera microscope. The cells seen on the microscope were manually calculated by the number of cells, then the total number of cell densities was calculated using the formula:

$$D=\left\{\frac{N_1+N_2}{2}\times\frac{\left(25\times10^4\right)}{n}\right\}\times DF \tag{1}$$

D: Number of cells,
N1: The amount of microalgae in the upper plane of the Hemocytometer,

N2: The amount of microalgae in the area below the Hemocytometer,
n: Number of squares observed,
DF: Dilution factor.

2.2 *Electrocoagulation cells*

The plate used as an anode in this study was aluminum (Al), which was first sanded with paper, cleaned with aquades, rinsed using NaCl solution, dried, then cut into pieces of size 20×20 cm and 1.0 mm thick. The electrocoagulation tools were comprised of a DC source, Avometer, process tube electrocoagulation, biomass reservoir and water-storage container. An adapter with a voltage of between 0 and 30 V was used as the DC source. The electrocoagulation tub was a square with a length of 30 cm and a height of 20 cm, and it was equipped with 5 anodes and an aluminum cathode of 6 cm $\times$ 5 cm. The wastewater reservoir measured $30 \times 30 \times 30$ cm and the biomass storage container square measured $30 \times 30 \times 25$ cm.

2.3 *Electrocoagulation chlorella sp*

The chlorella sp solution was introduced into the electrocoagulation bath. By turning on the DC source, the voltage and current strength could be measured. Turn off the DC source within 5 minutes of the electrocoagulation process being completed. The faucet should then be opened so that all of the water and sediment in the electrocoagulation tub will go down and enter the container tube. This should then be left until there is perfect separation between the water and the sediment. The sediment is then taken through the faucet at the bottom of the container tube. This experiment should be conducted using various pH, times and voltage.

3 RESULT AND DISCUSSION

3.1 *Cultivation of chlorella sp*

The density of the chlorella sp cells during cultivation were calculated using a Neubauer-enhanced Hemocytometer with twice as many replications. The calculation of the cell count and salinity was undertaken for 14 days. In the lag phase, the most significant increase was seen in cell size, because physiologically the microalgae become highly active. The metabolism was running but cell division did not occur, so the cell density did not increase because the microalgae was still adapting to a new environment. The growth of the number of cells during the observation period (14 days) is shown in Figure 1 below:

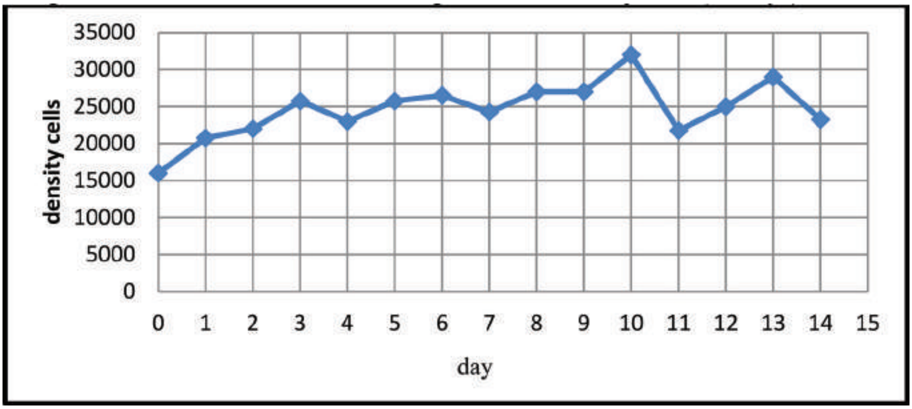

Figure 1. Growth of chlorella during cultivation.

3.2 *Effect of pH*

The pH parameter or the acidity level indicates the alkalinity of a solution. The more OH- ions and hydrogen gas that are produced through the reaction of the reduction of water molecules (H_2O) at the cathode, the greater will be the increase in the pH or alkalinity of the processed chlorella sp. The higher the pH, the more OH^- and the more coagulant $Al(OH)_3$ is formed, therefore more biomass is coagulated, so more chlorella sp biomass is produced. The resulting reactions are as follows:

$$\text{Cathode: } H_2O + 2e \text{ ------------ } H_2 + 2OH^-$$
$$\text{Anode: } Al^{+3} + 3OH^- \text{ ---------------- } Al(OH)_3$$

The $Al(OH)_3$ that is formed acts as a coagulant that will coagulate the biomass of chlorella sp. Figure 2, below, shows the effect of pH on the resulting chlorella sp mass.

From Figure 2, it can be seen that the highest biomass percentage ($88 \pm 0.06\%$) was obtained at pH 7.0. The increase of pH was mainly due to the continuous formation of OH^- ions at the cathode. The formation of hydroxide after the release process of electrocoagulation depends on the pH solution, for example during release aluminum, various formation hydroxide depends on pH solution, in a pH range of 4–9, formation occurs $Al\,(OH)^{2+}$, $Al_2\,(OH)_2^{+4}$, $Al\,(OH)_3$. The hydroxide surface has a large amount of positive charge, which helps with the coagulation of the biomass. At pH > 10, many $Al(OH)^{-4}$ are formed, which shows that the coagulation process is less compared with pH 7. This pH value increase is caused by the increasing number of hydroxide ions (OH^-) formed; with a large number of ions the hydroxide energy needed for hydrogen gas formation or oxygen is lower, which will produce many gas bubbles. The results obtained by Fayad et al. (2017) showed that the chlorella vulgaris that was electrocoagulated at pH 4.0 produced 80%, while pH 8 yielded 10% within 10 minutes.

3.3 *Effect of time on % biomass*

The electrocoagulation process was carried out at pH 7, with a potential of 20 volts and using an aluminum electrode measuring 30 mm × 30 mm × 1 mm. The longer the electrocoagulation time, the greater the amount of chlorella sp biomass that is formed. This is in accordance with Faraday's law, which states that the longer the time and the more electrons that are flowing, the more coagulant and more coagulant biomass will be formed. Up to a certain time, the coagulant gets saturated and its ability to coagulate the chlorella biomass will decrease. If this happens then the chlorella biomass to be coagulated will also decrease. For example, Figure 3 shows that the maximum percentage of chlorella biomass is achieved after 60 min; the percentage yield of the biomass is slightly increased with a further increase in the electrolysis time.

Similarly, Golzary et al. (2015) research result shows an increase in the reaction time from 2.61 min to 14.39 min caused by an increase in algae separation efficiency from 51% to 89.9%. Also, the operating costs increased from 0.042 USD to 0.236 USD.

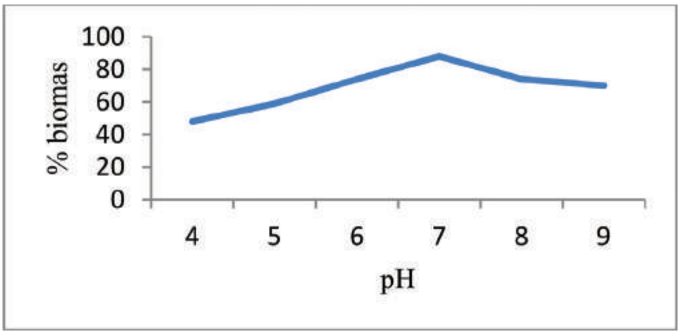

Figure 2. Effect of pH on biomass (%).

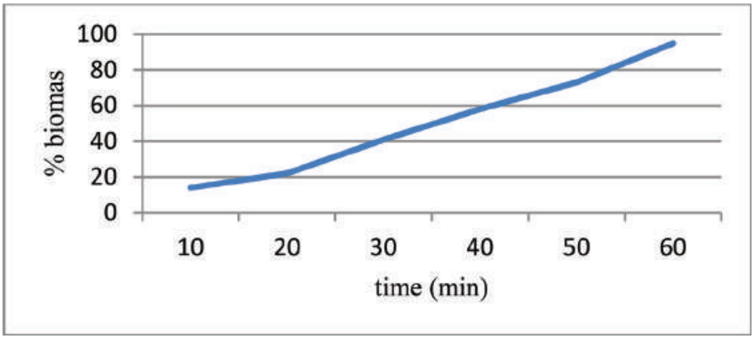

Figure 3. Effect of time on biomass (%).

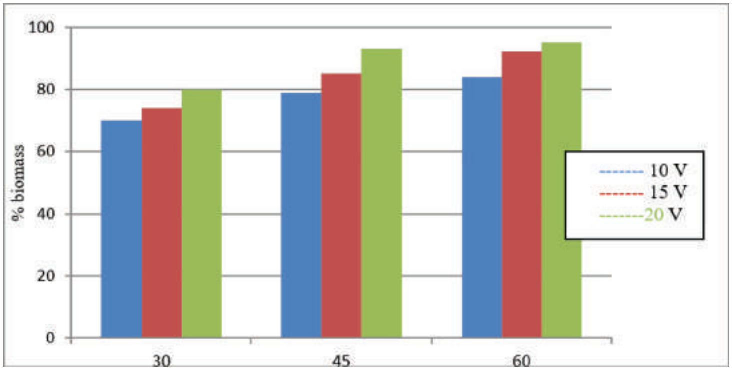

Figure 4. Effect of potential and contact time on% biomass.

3.4 *Effect of time and potential on the biomass yield*

Figure 4 shows the process of electrocoagulation with variations in voltage and contact time. For example, at a voltage of 20 volts and with 60 minutes contact time, the value of the biomass yield reaches 98.04%. While efficiency the lowest yield biomass value is achieved at 10 volt and 30 minutes contact time with value.

The voltage level and amount of contact time in the electrocoagulation process has the effect of reducing the concentration of TSS. The greater the voltage and the longer the contact time, the greater the efficiency of the biomass yield. This is due to the fact that a larger voltage will give a greater potential for the dissolution of the Al electrode to release Al^{3+}, so that the $Al(OH)_3$ flock is also becoming increasingly large and the number of $Al(OH)_3$ formed can bind the biomass more. The formation of the flock caused by the coagulation process will form capable sludge blanket trap and bridge particle colloids that are still in water (Becker, 1994).

The greater the voltage applied, the more biomass is coagulated. The data shows that the voltage increase between the two electrodes will increase the number of ionized atoms. In addition, the electric field between the two electrodes increases. In large electric fields, the ion or electron will move faster. As a result, the formation of biomass at the anode will be faster. This can cause polarization and limit voltage attainment. The limited voltage is indicated by the absence of current flow through the electrolyte solution so that there is no biomass in the cathode area.

3.5 *Effect of current*

The studied effects of the applied current on the microalgal recovery efficiency are summarized in Figure 5. The microalgal recovery efficiency at 60 min for currents of 0.5 A, 1.0 A

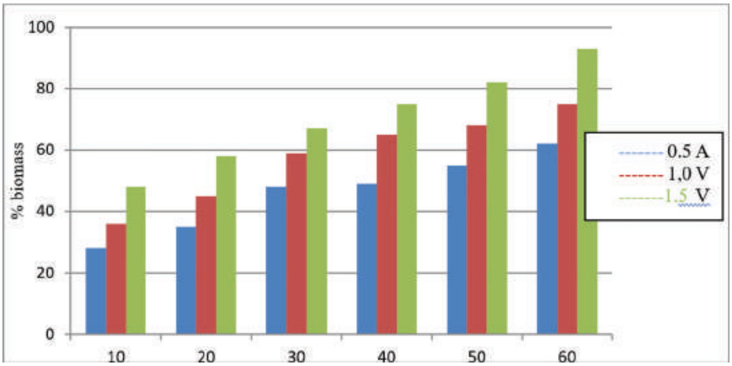

Figure 5. Effect of current on biomass (%).

and 1.5 A were found to be 62.2 ± 0.75%, 75.7 ± 0.45%, and 93.7 ± 0.08% respectively. It was clearly evident that with an increase in applied current, microalgal recovery efficiency also increased significantly ($p < 0.05$). The proportional decrease in optical density of microalgal broth was observed by the progress of the electrocoagulation processes with various experimental designs. The initial microalgal recovery efficiency is faster, as 30.2 ± 1.04%, 43.8 ± 0.36% and 50.4 ± 0.33% recovery efficiency were achieved within 10 min of the beginning of the electrocoagulation process at 0.5 A, 1.0 A and 1.5 A respectively. After 60 min a stationary phase was reached, where no further significant increase in microalgal recovery efficiency was observed. The supply of current to the electrochemical system determines the amount of charge that is released from the respective electrodes. The microalgal recovery efficiency depends on the applied current as well as the conductivity of the microalgal broth. With an increase in the strength of the electric field, the electrical charges on the electrodes, as well as the generation of bubbles, increased accordingly. This increase in the charged particles would result in the effective recovery of microalgae. The difference in the degree of increased recovery with applied current was also dependent on treatment time. When too much current is applied, there is a risk of heating the microalgal broth or the electrocoagulation system, with a subsequent wastage of electrical energy (Vandamme et al., 2011). A current density that is too large would result in high energy input and thus increase the overall process cost. The larger the current density, the more electrons are moved, so the formation of the coagulant also becomes greater. The strong influence of the current on the percentage of biomass produced is shown in Figure 5 below. From Figure 5 it can be seen that the greater the increase in the current, the greater the percentage of biomass produced. More than 50% of the biomass produced at strong currents is more than 3 mA/cm^2. The maximum percentage (97%) of coagulated biomass is achieved at 7 mA/cm^2. A strong increase in current up to 17 mA/cm^2 does not affect the increase in biomass.The increase of recovery efficiency with the increase of current density is consistent with the results of Aragón et al. (1992). The highest recovery efficiency of 99 ± 1% that was reached in this study was higher than the highest recovery efficiencies of 95% and 94.9% reached in the studies of Vandamme et al. (2011) and Matos et al. (2013), respectively, who worked on the same microalgal species (chlorella vulgaris).

3.6 *Analysis of chlorophyll content and carotenoids*

Chlorella is known as a victorious plant with chlorophyll and carotenoids. The results of the chlorophyll and carotenoid content in chlorella sp are shown in Figure 6 below. Based on Figure 6, it can be seen that the chlorophyll content of the chlorella obtained is 1.48%. Some researchers report that the chlorophyll content of the chlorella ranges from 1.4–6.7% (Aljuboori et al., 2016). The results obtained from this research showed the carotenoid content to be 0.89%. This result is similar to that obtained by Jung et al. (2016), who reported that the amount of carotenoid content in chlorella vulgaris was 0.91%.

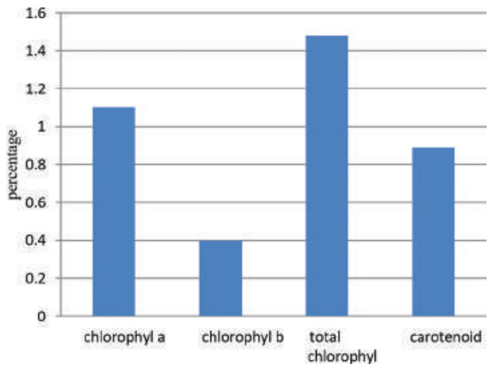

Figure 6. Content of chlorophyll and carotenoids in chlorella.

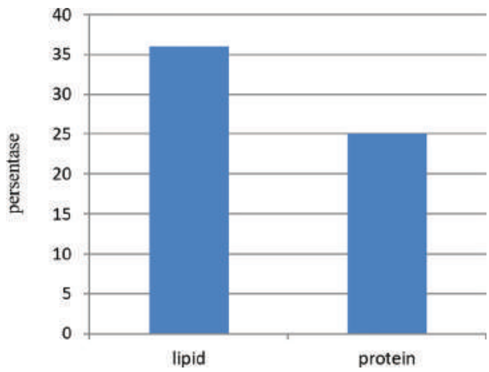

Figure 7. Lipid and protein content in chlorella sp.

In addition to chlorophyll and carotenoids, other compounds that are also present in chlorella sp are proteins and lipids. Because of the amount of lipid content in various types of microalgae, it can be used as a raw material for biodiesel. Figure 7 shows the amount of protein and lipid content obtained in this study.

3.7 *Cost analysis*

The fee in question is the cost of the electricity plus the cost of procuring an anode plate, namely the aluminum plate. The cost of the aluminum plate is calculated based on Faraday's law, namely:

$$m = \frac{I\,t\,Mr}{nF} \tag{2}$$

The required electricity costs are calculated by the equation:

$$W = Vit \tag{3}$$

3.7.1 *Experimental results data*

From the results of the experiment, the following data was obtained:

Potential = 20 volts
Contact time = 1 hour
Current = 1.5 amperes/L.

Electrical energy is needed as follows:

$$
\begin{aligned}
W &= Vit \\
&= 20 \times 1 \times 1.5 = 30 \text{ watts/L} = 0.030 \text{ Kwh/L}
\end{aligned}
\tag{4}
$$

Electricity tariff = Rp 1500/Kwh
Electricity costs required = 1500 × 0.0030 = Rp. 45/L microalgae.

The weight of the dissolved iron plate is calculated by the formula:

$$
\begin{aligned}
m &= \frac{I\ t\ Mr}{nF} \\
m &= \frac{1.5 \quad 3600 \quad 27}{3 \quad 96500}
\end{aligned}
\tag{5}
$$

m = 0,5036 gram/L = 5,036 × 10^{-4} Kg/L.
Price of the aluminum plate/Kg = 5000.
The cost of the aluminum plate for 1 L of microalgae = 5000 × 5,036 × 10^{-4} = Rp 2,5180/L

The total cost needed to harvest 1 L of microalgae

– : = Electricity cost + Cost of iron plate = Rp. 45.00/L + Rp. 2,5180/L = Rp. 47,5180/L.

4 CONCLUSION

In the present study, chlorella sp was harvested using an electrocoagulation system using aluminum plates as electrodes arranged in parallel in order to increase the biomass produced. The experimental results showed that the highest amount of biomass was obtained at 15 volts treatment, pH 9 in 60 minutes with a current strength of 7 mA/cm^2, which produced a biomass amount of 6.05 gr/L. The chlorophyll and lipid content produced from harvesting uses a higher electrocoagulation system compared to the coagulation method.

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Population dynamic of zoobenthos at the mangrove ecosystem on Bira Island

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ABSTRACT: Zoobenthos is part of an animal benthic group that lives at the bottom of the sea, and which can be used as an indicator of aquatic environmental pollution. The ecosystems that are mostly inhabited by benthic organisms are the mangrove ecosystems that are scattered in coastal areas. One of the mangrove ecosystems in Indonesia is on Bira Island, which is located in the Seribu Islands. The research objectives in this study were to determine the population dynamics, abundance, diversity, and dominance of zoobenthos and to discover how the water quality affected the population dynamics of zoobenthos at the mangrove ecosystem on Bira Island during the 6 months of observation. The research method used is descriptive with survey design. The observation station was determined purposively, based on the condition of the mangrove vegetation, and the zoobenthos sampling was undertaken using the transect method. The data were analyzed descriptively by calculating the abundance, diversity and dominance. The results showed that as many as 23 species of zoobenthos were identified, belonging to 4 phylums, with the highest to lowest composition represented by mollusks, arthropods, chordates and Cnidaria, respectively. The zoobenthos population fluctuates during the observation period and tended to show a decline in population every month during the observation period. The most abundant species was represented by Uca sp and the lowest was represented by Chrysaora sp. Meanwhile, based on the observation station, the highest abundance was at station 1, followed by station 2 and 3. The diversity of zoobenthos shows a low criterion and no species dominance exists, while the environmental parameters in general are still in the normal range for zoobenthos life.

1 INTRODUCTION

Bira Island is one of the tourist islands in the North Seribu Islands of Jakarta. It is designated as a nature reserve and a Marine National Park based on Ministerial Decree number 736 in 1982. Compared to other tourist islands, Bira Island is one of the largest tourist islands located in the outermost islands of the Seribu Islands. One of the most important ecosystems in this region is the mangrove ecosystem (Balai Taman Nasional Kepulauan Seribu, 2008). The mangrove ecosystem is an important ecosystem as it is a buffer for this island. One of the biota that lives in this ecosystem is the zoobenthos group, who play an important role. They live on the bottom of the sea, and their life is very dependent on the substrate. Some human activities around Bira Besar Island, such as development and tourist attractions, affect the condition of the mangroves, which are steadily decreasing, thus impacting the biota, one of which is the zoobenthos. As benthic animals, the presence of the zoobenthos is strongly influenced by environmental factors, especially the substrate and the interaction between the biota (Katili, 2011; Aziz, 1995).

Benthos has an important role, both ecologically and economically. Ecologically it acts as a constituent of the benthic communities and economically it has many techniques that can be used for consumption or other economic benefits. Most locations in the Seribu Islands, including Bira Island, have indicated a decline in marine biota production due to overfishing.

Due to the absence of data on benthic organisms from year to year, it is necessary to conduct research to determine the structure of the zoobenthos community as a basis for sustainable conservation and the utilization of natural resources (Panggabean, 1987).

2 METHOD

This research was conducted in the mangrove ecosystem of Bira Island, Thousand Islands, DKI Jakarta Province from December 2017 to May 2018. Observation of the zoobenthos was carried out both in the field and in the laboratory.

The research used was the descriptive method, with a survey design based on direct observation. The research location was a mangrove ecosystem, which was divided into 3 observation stations selected by purposive sampling, and which represented the vegetation conditions of the Bira Island mangrove ecosystem. The coordinates of the stations were determined by using GPS.

At each station, 3 transects are directed toward the sea and parallel to the coastline with a width of 5×50 meters at a depth of 0–5 meters. Each transect has 5 plots of 1×1 meter in size, with a distance of 10 meters between plots, installed at 10th, 20th, 30th, 40th and 50th meters.

The zoobenthos samples were taken using an eckman grab directly on each transect. They were recorded and calculated, and then identified with the help of the zoobenthos identification guides of Setiawan (2010), Dermawan (2015), and Clark and Rowe (1971). The measurement of the physical and chemical environmental parameters was done *in situ*. The temperature was taken using a thermometer and salinity was measured using a salinometer. The depth was measured using a scale pole. The chemical parameters of the pH were taken using a pH indicator or a pH meter. The retrieval of the water environment parameter data was carried out using three repetitions at each station.

3 DATA ANALYSIS

The zoobenthos population data were analyzed descriptively by using several calculations, namely:

3.1 *Abundance*

Abundance was measured using the following formula:

$$D_i = \frac{n_i}{A} \tag{1}$$

Information:

Di = i abundance of individual species,

ni = number of individuals from the i-species,

A = the area of the sampling plots.

3.2 *Diversity index*

To find out the diversity index of the zoobenthos, the Simpson formula was used, namely:

$$C = \sum_{i=1}^{n} \left[\frac{n_i}{N} \right]^2 \tag{2}$$

Information:

ni = value of the importance of each type (number of individual species i),

C = diversity index,

N = total value of interest (total number of all individuals).

Diversity index criteria:

$H \leq 1.0$ hence the diversity is small, productivity is very low, and there is an indication of heavy pressure and an unstable ecosystem.

$1.0 \leq H \leq 3.322$ then the diversity is moderate, productivity is sufficient, the condition of the ecosystem is quite balanced and the ecological pressure is moderate.

$H \geq 3.322$ then there is high diversity, the ecosystem is stable, and there is high productivity and resistance to ecological pressure.

3.3 *Dominance index*

The dominance index was calculated using Simpson's Dominance Index, namely:

$$D = \sum_{i=1}^{S} \frac{(n_i(n_i - 1))}{(N(N-1))} \tag{3}$$

Information:

D = dominance index,
ni = number of individuals from the i-species,
N = total number of individuals,
S = number of types (number of genera).

4 RESULTS AND DISCUSSION

4.1 *Results*

4.1.1 *Abundance and composition of zoobenthos*

Based on the observations, as many as 23 species of zoobenthos were found, belonging to 4 phylums which were arthropods, chordates, Cnidaria and mollusks. Abundance was based on the highest station, which was represented by station 1, and the lowest station, which was station 3. Abundance was also based on the highest phylum, which was represented by Mollusca, and the lowest, which was represented by Cnidaria. Meanwhile, the most abundant species was represented by Uca sp and the lowest was represented by Chrysaora sp (Table 1).

During the study, the zoobenthos population showed a tendency to decline from month to month (Figure 1).

Based on the phylum, the highest to lowest compositions were mollusks, arthropods, chordates and Cnidaria. Whereas based on the species, the largest composition was represented by Uca sp (20.79%) and the lowest was Chrysaora sp (0.86%) (Figure 2).

Table 1. Abundance (Di) and composition (%) of zoobenthos in the mangrove ecosystem.

No	Phylum/species	Di	%	No	Phylum/spesies	D	%
	ARTHROPODS				**MOLLUSK**		
1	*Episesarma sp. 1*	28.33	1.12	11	*Polymesoda sp*	216.66	8.63
2	*Metopograpsus sp.*	41.66	1.66	12	*Anandara sp*	213.33	8.50
3	*Episesarma sp. 2*	70.00	2.79	13	*Cerithidea sp*	286.33	10.69
4	*Thalassina anomalia*	45.00	1.79	14	*Littoraria intermedia*	60	2.39
5	*Uca sp*	525.66	20.79	15	*Littoraria sp*	123.33	4.91
6	*Scylla serata*	215	8.57	16	*Cypraca sp*	100	3.97
7	*Penaeus sp*	126.66	5.04	17	*Perna sp*	61.66	2.46
	CHORDATES			18	*Nerita articulata*	25.00	0.99
8	*Mabouya sp*	25.00	0.99	19	*Dinocardium sp*	53.33	2.13
9	*Periophthalmus sp*	63.33	2.52	20	*Ensis directus*	60.00	2.39
	CNIDARIA			21	*Clypeomorus sp1*	53.33	2.13
10	*Chrysaora sp*	21.66	0.86	22	*Clypeomorus sp2*	38.33	1.52
				23	*Strombus canarium*	85	3.39

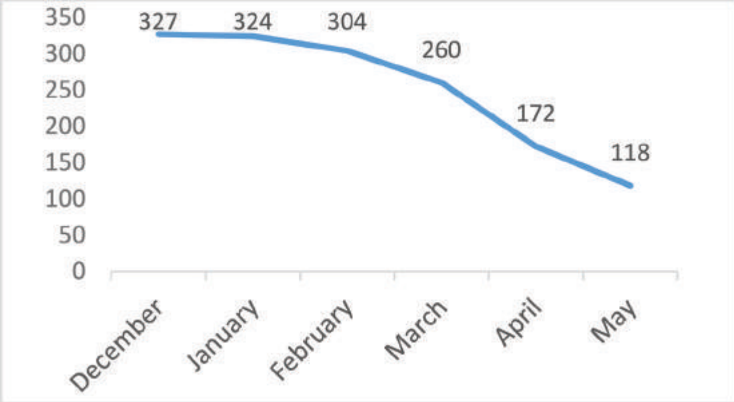

Figure 1. Fluctuation of the zoobenthos population.

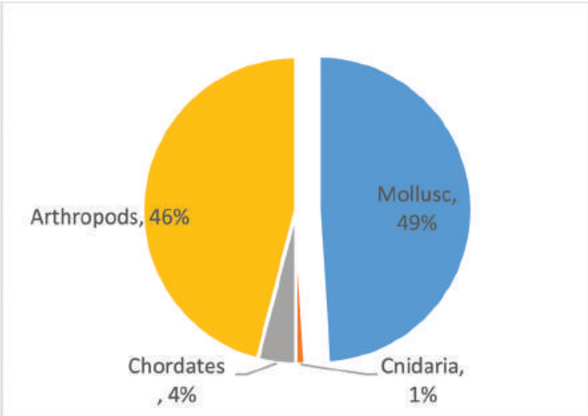

Figure 2. Composition of zoobenthos based on phylum.

Table 2. Diversity index and dominance index of the zoobenthos at each station.

	Month					
Index	Dec	Jan	Feb	March	April	May
Diversity (C')	0.86	0.86	0.81	0.78	0.85	1.02
Dominance (D)	0.49	0.46	0.5	0.49	0.47	0.4

4.1.2 *Diversity and dominance index*

During the study, the diversity index for each month ranged between 0.78 and 1.02, which is generally included in the criteria of low diversity, while the dominance index ranged from 0.40 to 0.50, which shows that no species is dominant, as shown in Table 2.

4.2 *Discussion*

Uca sp is a species of the Phylum Arthropoda, which is the most common species that is found in mangrove ecosystems (20.79%), while the lowest is Chrysaora sp (0.86%). The composition based on phylums showed the highest phylum to be mollusks (54.15%) with an abundance of 815 individuals, followed by arthropods (41.79%) with an abundance of 629, chordates (3.52%) with an abundance of 53 and Cnidaria (0.86%) with an abundance of 13 individuals. The reason for the high abundance of mollusks is due to several of their characteristics, namely that they are adaptive to various environments, they play an important role as a counterweight, they are an indicator species of the polluted marine environment and they can be used for biomonitoring against heavy metal concentrations in the ocean (Bharathi, 1994; Beesley et al., 1998). Due to the effect of rainfall intensity on decreasing temperature and salinity, which affects crab spawning, Uca sp showed the highest abundance, due to crab spawning reaching a peak at the end of the rainy season and toward summer (Kasry, 1996). Uca is included in the order of the crustacean class decapoda of the phylum arthropod group. The most common of the decapoda order are shrimp and crabs (Pearson, 1985).

During the study, the zoobenthos population showed a tendency to decline from month to month. This condition is expected to be influenced by several factors, one of which is habitat conditions and environmental parameters. Therefore this needs to be studied more deeply from other aspects. Finding out the population dynamics in the water can be achieved by studying morphometrics and reproductive aspects (Niswari, 2004).

The value of the zoobenthos diversity index at each station ranged from 0.78 to 1.02, which is included in the criteria of low to moderate, while the Niai dominance index ranged from 0.40 to 0.49, which showed no dominance (Table 2).

Based on the criteria, if $H \leq 1.0$ then diversity is small, productivity is very low and there is an indication of heavy pressure and an unstable ecosystem (Brower & Zar, 1977). The low diversity in Bira Island is because these waters have been used as tourist attractions andfishing boat docks, which affects the existence of the zoobenthos communities in these waters. Low diversity index shows low productivity as an indication of pressure and unstable ecosystem condition (Odum, 1993)

The dominance index values ranged from 0.40 to 0.49, which indicated that at each station there was no dominance of species, although there were abundant species. According to the Simpson criteria, if a population has a low diversity index it can be interpreted that the productivity of the environment is low, which is caused by pressure in the environment. The pressure in this environment can be categorized as a form of pollution.

The results of the water quality measurements obtained showed a temperature range of 27–34°C, pH of 6.5–7.8, salinity of 27.5–31.5 ‰ and depths ranging from 46–60 cm, Dissolved Oxygen (DO) values ranged from 1.13–6.91 mg/l. The ideal temperature for marine organisms to live is 20–30°C, so these results are still ideal to support zoobenthos life (Aziz, 1998), and normal sea waters have an optimum temperature of 28–31°C (Nontji, 2002). The DO values at the study location ranged from 1.13 to 6.91 mg/l and salinity ranged from 30 to 32 ‰. Dissolved oxygen (DO) that supports the life of marine biota is > 5 mg/l. Dissolved oxygen is very important for macrozoobenthos and other aquatic organisms (Odum, 1993). The ideal salinity level for marine life is 30–36 ‰ (Keputusan et al., 2004). The pH of seawater obtained at the study site ranged from 6.5–7.8. The ideal pH value range for marine organism life was 7.5–8.6 (Aziz, 1998; Aziz, 1996). The pH value tends to be slightly acidic to neutral; this is because the pH of seawater usually does not show significant changes and is usually quite stable. The substrate was identified as a type of dusty sand, which could have an influence in the ecosystem composition and distribution. Substrate is a basic factor that influences the composition and distribution of benthic organisms. Besides being a place of life, the basic substrate is also used as a food source for most zoobenthos (Nybakken, 1992).

Based on the value of the water quality measurement, in general it can be said that the water quality of Bira Island is still suitable for zoobenthos life. The decline of the zoobenthos population is allegedly due to the degradation of the mangrove habitat, which is increasingly diminishing.

5 CONCLUSION

As many as 23 species of zoobenthos, belonging to 4 phylums, namely arthropods, chordates, Cnidaria and mollusks, were identified on Bira Island, with the highest phylum represented by mollusks and the lowest by Cnidaria. Uca sp was the species that was most abundant and

Chrysaora sp was the lowest. The diversity of zoobenthos is low criteria and no species dominance exists, while the environmental parameters in general are still in the normal range for zoobenthos life. The decline in the population of the zoobenthos over time is due to a greater extent to habitat degradation.

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Structure of matter—diagnosis of misconceptions and challenges

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ABSTRACT: Chemistry is not easy to teach. For some contents we should know about students' misconceptions which need special consideration: Students should work on a Conceptual Change. There are two kinds of misconceptions: Preconcepts which young boys and girls are bringing from home, from every-day life—their special mental models about burning processes, about gases and properties, about substances and their changes. On the other hand there are "school-made" misconceptions which can be caused by inappropriate teaching methods or by complexity of the topic: equilibrium, acids and bases, redox, energy.

1 INTRODUCTION

Solid salts and salt solutions contain ions as their smallest particles. But mostly students experience by their teachers and textbooks formulae like NaCl and $CaCl_2$—and not ionic written formulae like Na^+Cl^- or $Ca^{2+}(Cl^-)_2$ or model drawings (Barke, Harsch, & Schmid, 2012). So they are thinking often of molecules: "NaCl molecules" in sodium chloride, even of "Cl-Ca-Cl molecules" in solid calcium chloride or in aqueous solutions. The same with acids and bases: Students are thinking of "HCl-molecules" in hydrochloric acid or "NaOH-molecules" in sodium hydroxide solution—they don't have the ions in their mental model, they do not interpret the neutralization by using the involved ions: "$H^+(aq) + OH^-(aq) \rightarrow H_2O$".

Chemical Triangle. Those teachers and students are not used to interpret reactions on the Submicro level of Johnstone's triangle (Figure 1): They are thinking of solutions of acids and bases and indicator colors on the Macro level, or they are writing equations on the Representational level. This causes to think of formation of "salt NaCl" and "water H_2O"—they don't have the reaction of hydronium and hydroxide ions in their mind. In the sense of Broensted's acid-base theory it is a must to interpret acid-base reactions on the Sub-micro level (Barke, Harsch, & Schmid, 2012): acids are particles which give protons, base particles are taking protons, acid particles are proton donors and base particles proton acceptors.

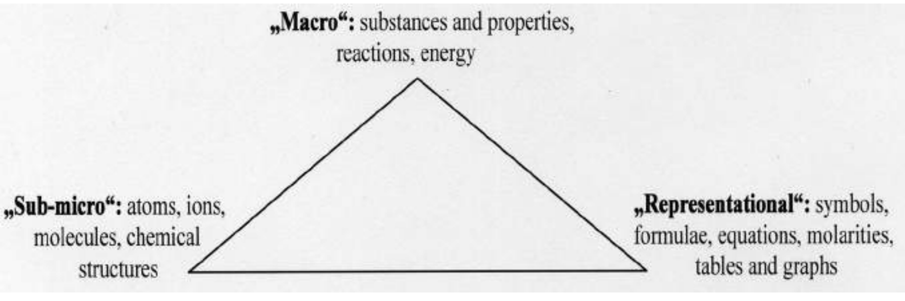

Figure 1. 'Chemical Triangle' for teaching chemistry according to Johnstone (Johnstone, 1997).

2 HISTORICAL CONSIDERATIONS OF BROENSTED'S THEORY

In his essay "On the theory of the acid-base function" (Broensted, 1928) Broensted alluded already in the title to the *function* of acid and base molecules and left out the usual discussion of the properties of acidic and alkaline solutions. In particular, he identified the function through a central mental model:

$$\begin{array}{ccccc} A & \rightleftarrows & B & + & H^+ \\ \text{Acid} & & \text{base} & + & \text{proton} \end{array}$$

By donating a proton, the acid reacts to a base: "The A and B molecules are called corresponding acids and bases. By this definition, the OH^- ion loses the special position of the bases: by losing a proton, any molecule A is transformed to a minus-charged base molecule" (Broensted, 1928). When HCl molecules react with NH_3 molecules, both molecules change into ions: NH_4^+ (corresponding acid) and Cl^- (corresponding base). Broensted also deals with "free H^+ ions" that do not exist in a solution. He therefore states: "An acid molecule A only releases a proton when the proton is simultaneously assimilated by a base molecule" (Broensted, 1928):

$$\begin{array}{ccccccc} A1 & + & B2 & \rightleftarrows & A2 & + & B1 \\ \text{acid1} & & \text{base2} & & \text{acid2} & & \text{base1} \end{array}$$

All of these statements show that Broensted is discussing molecules and ions—not substances. Supposing that a free proton does not exist in the solution he created a hydronium ion H_3O^+:

$$\begin{array}{ccccccc} A & + & H_2O & \rightleftarrows & B & + & H_3O^+ \\ \text{acid1} & & \text{base2} & & \text{base1} & & \text{acid2} \end{array}$$

He furthermore states: "Whenever a proton is transferred from an electrically neutral molecule to another electrically neutral molecule, two ions of opposite charge arise". So, if H_2SO_4 molecules react with H_2O molecules, three types of ions are created: H_3O^+ ions, HSO_4^- ions and SO_4^{2-} ions. Concerning the neutralization reaction, Broensted showed a very modern view: 'When hydrochloric acid ($H_3O^+ + Cl^-$) and sodium hydroxide ($Na^+ + OH^-$) are mixed in aqueous solution, the formation of the salt $Na^+ + Cl^-$ seems only a purely mechanical mixing process ...... the typical process of neutralization of strong acids and bases is thus not the salt formation'. Instead, the actual acid-base reaction is:

$$\begin{array}{cccccccc} H_3O^+ & + & OH^- & \rightarrow & H_2O & + & H_2O \\ \text{acid1} & \text{base2} & \rightarrow & \text{base1} & \text{acid2} & & \end{array}$$

Already in 1928, Broensted emphasized the formation of water molecules while many curricula today still argue with the "salt formation" by neutralization. Broensted also consistently described the molecules and ions as acid and base particles—with more progress than many chemistry teachers or lecturers nearly 100 years later.

3 DIFFICULTIES WITH THE SUB-MICRO LEVEL—EMPIRICAL RESEARCHES

Wisudawati (2018) developed a questionnaire with tasks to find involved atoms, molecules or ions in given acid-base and redox reactions. They have been described on the Macro and on the Symbolic level. One example:

"Macroscopic level: Magnesium reacts with hydrochloric acid, gaseous hydrogen is observed.

Symbolic level: $Mg(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$" (Wisudawati, 2018).

Answers are expected to be provided for the following four questions or tasks (a) – (d):

"a. Which particles (atoms or ions or molecules) are involved?
b. Write down the equation of those atoms, ions or molecules that react.
c. Which atoms, ions or molecules are NOT involved in the reaction?
d. Redox or acid-base reaction? Explain the transfer of electrons or protons" (Wisudawati, 2018).

For introducing the questionnaire to students Wisudawati gave an example:

"Sub-micro level:

a. Which particles (atoms or ions or molecules) are involved?
   Answer: Mg atoms/H^+ ions, Cl^- ions $\rightarrow$ Mg^{2+} ions Cl^- ions (1:2)/H_2 molecules
b. Write down the equation of those atoms, ions or molecules that react.
   Mg atom + 2 H^+ ions $\rightarrow$ Mg^{2+} ion + H_2 molecule
c. Which atoms, ions or molecules are NOT involved in the reaction?
   Cl^- ions are 'spectator ions'
d. Redox or acid-base reaction? Explain the transfer of electrons or protons.
   Mg atoms give two electrons: Mg atom $\rightarrow$ Mg^{2+} ion + 2 e- (oxidation)
   2 H^+ ions take two electrons: 2 H^+ ions + 2 e- $\rightarrow$ H_2 molecule (reduction)"

4 RESULT

Chemistry students in higher semesters of universities in Yogjakarta and Bandung were asked in June and July 2018 to solve the two-pages questionnaire during 45 minutes. There are many good answers in the sense that ions are successfully used in reactions like neutralization, or in metal precipitations out of salt solutions by another metal. Also decisions weather an acid-base or redox reaction exists are right—only the description of particles which give protons or electrons and particles taking those protons and electrons are unclear: students never have interpreted those reactions in this way.

Most misconceptions are stated in the area of solid salt crystals. Formulae like Na_2CO_3, $CaCO_3$ or MgO are shown and students should argue with ions—but they did not: They have seen so often the plain formula and developed metal models of "carbonate molecules" or "MgO molecules". In this correlation many students also don't find complete answers to (c): They have declared i.e. for the reaction of sodium carbonate with hydrochloric acid only the chloride ions as spectator ions—but not the sodium ions of sodium carbonate.

Wisudawati (2018) took two other questions to those eight tasks: "(9) Which of the alternatives (a) – (d) is most difficult to you? (10) Do you like to go with (a) – (d) deep into the Sub-micro level?" The first question is very often answered with (d): "The proton and electron transfer confuses me", "for an answer I need basic concepts of chemistry", "I have to understand first (a) – (c)". Also (c) was discussed: "The name spectator ion confuses me", "for me all ions are involved in those reactions" (Wisudawati, 2018).

The second question has got a lot of positive answers: "Yes—I want to go deep into that level because I can improve my chemistry understanding", "it helps to understand acid-base and redox reactions", "it can support me to be a better chemistry teacher" (Wisudawati, 2018). So it seems that lectures in Inorganic chemistry should teach more about involved atoms, molecules or especially ions of chemical reactions—students would appreciate that!

Avilag (2018) took an equivalent questionnaire in German language for German chemistry students of high semesters at University of Muenster. She found similar difficulties with German students. Barke gave the questionnaire to chemistry teachers in Tanzania and is in the process to compare all those results. So it seems that around the world the Sub-micro level is not enough represented in Chemical instruction!

4.1 *Laboratory jargon and the misconceptions of students*

In chemistry we have in this correlation a special problem. Lecturers mostly use a "laboratory jargon" in their lectures and the question comes up whether teacher students are taking this jargon for their own terminology, or developing "school-made misconceptions", or even transfer them later as teachers to their students. One example: "2 hydrogen react with 1 oxygen to form 2 water" is often stated by experts—instead of pointing out that 2 H_2 molecules and 1 O_2 molecule are forming 2 H_2O molecules. This last statement is totally clear and the learner will develop applicable mental models.

Buechter (2018**).** An empirical pilot study will show first results: About half of the investigated participants could reflect and correct given jargon statements—but even after three years of studying Chemistry the other students are staying with that jargon or other alternative conceptions. Let us discuss one example of the questionnaire:

2. Lab. Jargon: 'Hydrochloric acid gives off a proton'

a. Hydrochloric acid can be deprotonated.
b. Hydrochloric acid can also absorb protons.
c. $H_3O^+(aq)$ ions are present in hydrochloric acid, they can emit protons.
d. HCl molecules are present in hydrochloric acid, they release protons.

The right answer is of course (c): "$H_3O^+(aq)$ ions are present in hydrochloric acid, they can emit protons". We took the famous misconception (d) and were waiting of "HCl molecules". Because of the well-known idea of "deprotonation" we took alternative (a), answer (b) is a fake (Buechter, 2018).

The right answer (c) is chosen by 40% of participants, the real misconception about "HCl molecules in hydrochloric acid" is fortunately taken by only 5%. But answer (a) has reached the majority of 55%: Many students are thinking of scientifically good sound of "deprotonation". Other examples may be studied by Barke and Buechter (2018).

4.2 *Challenging misconceptions*

What shall we do to avoid those mentioned misconceptions with ions as important particles? As soon as atoms and molecules are well known and visualized by ball-stick models and their molecular structural symbols also the third group of smallest particles should be introduced: the ions. Usually, during the introduction of atoms the Periodic Table is shown with all atomic symbols, numbers and masses. If one takes little spheres to visualize that every atom has a specific diameter, it is easy to symbolize also the according ions with their specific diameter (see Figure 2): Charge number are given without comparing any protons in the nucleus and electrons in the shells—the ions can be introduced without the differentiated atomic model! Later during higher classes students may work with the nucleus-shell model of atoms and ions and the number of electrons can be discussed for explaining ion charges.

Analogically to the composition of a water molecule by two H atoms and one O atom, one may state that sodium chloride is composed of Na^+ ions and Cl^- ions in an ionic giant structure (see Figure 3), that the ionic symbol for sodium chloride can be shown as $(Na^+)_1(Cl^-)_1$ or for magnesium chloride as $(Mg^{2+})_1(Cl^-)_2$ (see Figure 3). To shorten those formulae one may write NaCl and $MgCl_2$—but the involved ions should be in the mental model of learners!.

The composition of important salt crystals can be visualized by 2D-drawings of layers of ionic lattices (see Figure 3). If salt solutions will be introduced afterwards, (aq)-symbols should be added: $Na^+(aq)$ ions and $Cl^-(aq)$ ions for sodium chloride solution, $Mg^{2+}(aq)$ and $Cl^-(aq)$ ions in the ratio 1:2 for magnesium chloride solution. Even the neutralization of acids and bases should be visualized by beaker models (see Figure 4). The (aq)-symbol is important because the learner knows that different charged ions are attracting and would go together. The (aq)-symbols show hydrated ions and the 4, 5 or 6 surrounding water molecules are avoiding the strong attraction.

Neutralization. Students know the common equation for neutralization; in the case of hydrochloric acid and sodium hydroxide solution they are writing: $HCl + NaOH \rightarrow NaCl + H_2O$.

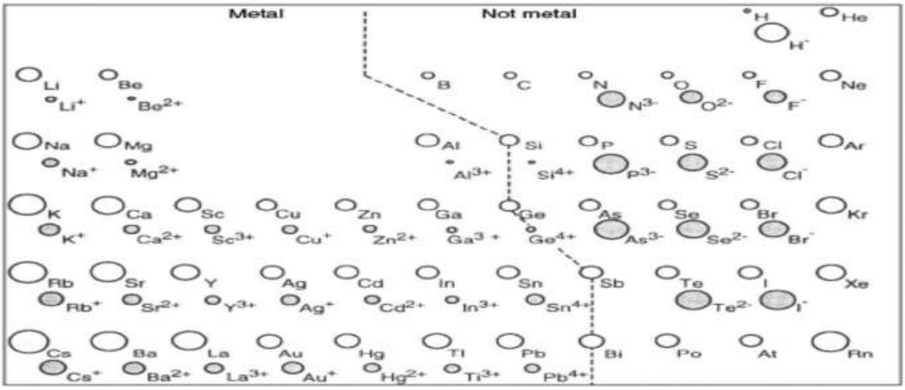

Figure 2. PSE-depiction of a selection of atoms and ions and their spherical models.

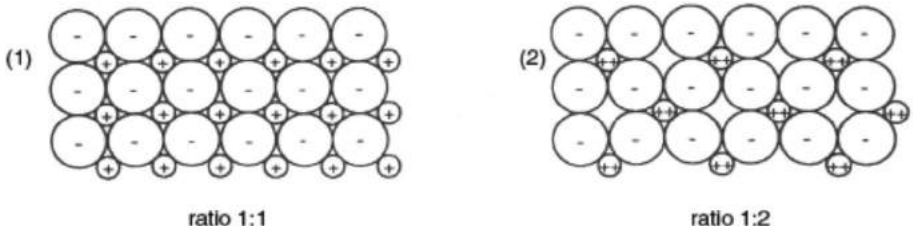

Figure 3. 2-D models of ionic lattices in the ion ratio 1:1 (NaCl) and 1:2 ($MgCl_2$).

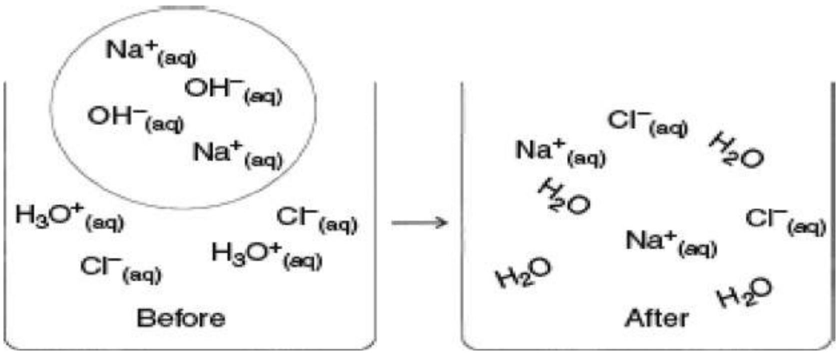

Figure 4. Beaker model for the neutralization of hydrochloric acid by sodium hydroxide solution.

Asking about the particles that are reacting, often HCl and NaOH molecules are mentioned. So it is important to point out that H_3O^+(aq) ions and OH^-(aq) ions are reacting in the sense of Broensted:

$$H_3O^+(aq)\text{ ion} + OH^-(aq)\text{ ion} \rightarrow 2\ H_2O\text{ molecules}$$

With the help of the beaker model (see Figure 4), one can understand that other ions remain: Na^+(aq) ions and Cl^-(aq) ions remain as 'spectator ions', they are not reacting partners. No 'solid salt' or 'NaCl molecules' are produced, but sodium chloride solution remains. It is also advantageous to visualize that the number of ions is the same both before and after neutralization (four ions in the model of Figure 4): H_3O^+(aq) ions are replaced by Na^+(aq) ions.

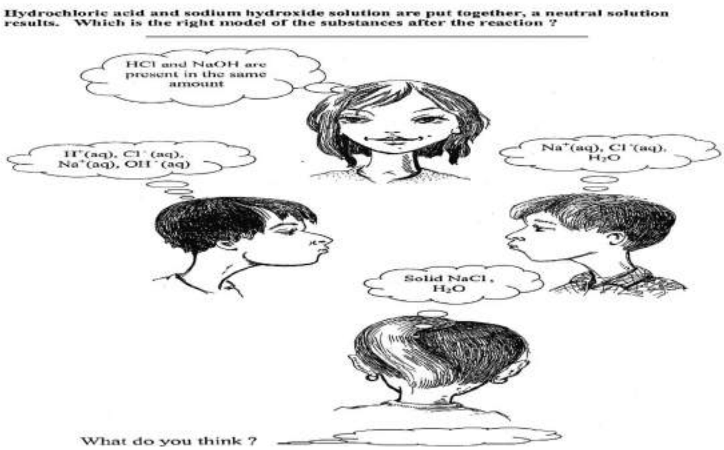

Figure 5. Concept cartoon concerning the neutralization (Barke, Harsch, & Schmid, 2012).

5 CONCLUSION

In older times, teachers liked to perceive students as "blank pages" and thought that they only have "to fill blank pages" with contents of science. Today we know that at a very early stage, boys and girls develop their own preconcepts (Barke, Hazani, & Sileshi, 2009). Empirical studies show that we have more success in teaching and learning when we integrate those alternative models into instruction and after discussing those preconcepts to come up to consolidate the scientific explanation.

Also school-made misconceptions (Barke, Hazani, & Sileshi, 2009) should be mentioned for a special topic to show the right answer between some alternatives. Especially Concept cartoons (Barke, Harsch, & Schmid, 2012) are suitable to analyze misconceptions of students and discuss those conceptions with the goal of scientific explanation (see Figure 5). By this way teachers may challenge those misconceptions and may convict students additionally by experiments, concrete models and problem-solving teaching.

Another challenge concerning working with ions comes up with ionic formulae of salts. With the help of the special Periodic system of atoms and ions (see Figure 2) one should combine the involved ions to models of salt crystals and draw ionic-lattice models (see Figure 3), also beaker models for visualizing salt solutions, or acid and base reactions (see Figure 4). Students should develop accurate mental models—discussed misconceptions may be challenged!

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REMAD COCOPER learning strategy implementation to improve the global competitiveness of biology education students at Universitas Negeri Malang

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ABSTRACT: Facing the 4.0 industrial revolution, Universitas Negeri Malang has chosen Life-Based Learning (LBL) as its education and learning paradigm. Since 2016, in an effort to interpret LBL in practice, the REMAD COCOPER learning strategy has been developed. This strategy includes the activities of reading, creating mind or concept maps, discussing, collaborative learning, cooperative learning, presenting, elaborating, and reflecting. Through this learning strategy, prospective biology educators are given the opportunity to develop their capabilities through a professional learning community that allows them to design a method of learning that best suits the needs of the era and to pay attention to the development of 21st century life skills for their future students. This learning strategy has been piloted in several courses at both undergraduate and graduate level. The test results show that this strategy can be employed to teach students LBL and develop their capabilities. This is because every activity has the potential to develop their basic literacy, 4Cs competencies, and characters. Based on the results of the trial, it was concluded that this strategy could be utilized to improve the global competitiveness of prospective biology educators. It is suggested that efforts can be made to improve the learning processes by emphasizing the authentic assessment more rigorously and consistently.

1 INTRODUCTION

The world has now entered the 4.0 industrial revolution era (Direktorat Jendral Pembelajaran dan Kemahasiswaan, 2018; Kemeristekdikti, 2018; Kemristekdikti, 2018). In order to face this era, Universitas Negeri Malang has chosen Life-Based Learning (LBL) (Staron, 2011; H. Subekti, Susilo, Ibrohim, & Suwono, 2018)as its education and learning paradigm (H. Susilo, Ibrohim, & Suwono, 2017). Accordingly, the concepts of lifelong learning (Biao, 2015; Demirel, Melek, Akkoyunlu, 2017), education for all, continuing education with educational principles in Indonesia *asah-asih-asuh* or teach, love, and care (Saefullah, 2018; Suparno, 2014), as well as *ing ngarsa sung tuladha, ing madya mangun karsa*, and *tut wuri handayani,* which can be interpreted as providing a model, creating a goal, and providing constructive support (N. B. Subekti, 2015; Suparlan, 2016; Suwignyo, 2011), are the insights, spirit inspiration, and identity of Universitas Negeri Malang (Kementrian Riset Teknologi dan Pendidikan Tinggi, 2018).

Since 2016, the researcher has strived to interpret the idea of life-based learning into lectures. This study was initiated from the learning process in the Quantitative Research Methodology course, intentionally and by design, and was developed in order to advance one or more 21st-century life skills and life-based learning in the students. This is supported by several studies that were previously conducted by the researcher, both individually and collaboratively, including studies regarding life-based learning (H. Subekti, Taufiq, Susilo, Ibrohim, & Suwono, 2018; H. Susilo et al., 2017), capacity building (Artayasa, Susilo, Lestari, & Indriwati, 2017; Siswati, Mahanal, Susilo, & Corebima, 2016; H. Subekti, Yuhanna, & Susilo, 2018; Herawati Susilo, 2014), 21st century skill development or critical thinking, communication, collaboration, and creativity (4-C) (Asyari, Al Muhdhar, Susilo, & Ibrohim, 2016; Darmawan, Zubaidah, Susilo, & Suwono, 2016; Kristiani, Susilo, & Aloysius, 2016; Herawati Susilo, 2015; Suwono, Pratiwi, Susanto, & Susilo, 2017), and lesson study (Darmawan et al., 2016; Lukitasari & Susilo, 2014; Lukitasari, Susilo, Ibrohim, & Duran Corebima, 2014; Herawati Susilo, 2013). Various research results generated the REMAD COCOPER learning strategy design, which has been developed and is still in the process of being completed by the researcher.

The REMAD COCOPER strategy is an acronym of the activities of REading, creating mind or concept MAps, Discussing, COllaborative learning, COoperative learning, Presenting, Elaborating, and Reflecting. Through this learning strategy, prospective biology educators are given opportunities to improve their abilities through a professional learning community, which enables them to design the most appropriate learning according to the needs of the era and to address concerns regarding the development of 21st-century life skills for their students.

Among the reasons for the urgent need for this research are training the students to be adaptable to either leading or being led, as the model lecturer, observer, or students in peer teaching; developing a learning community through Lesson Study (LS) activities; capacity building; 4C competencies; and character development. Referring to the aforementioned urgency of the research, the objective of this study is to describe the implementation of the REMAD COCOPER learning strategy in order to improve the global competitiveness of biology education students at Universitas Negeri Malang.

2 METHOD

The research approach is categorized as conceptual research (Attfield, 1976; Blagosklonny, 2003; Chu & Ke, 2017) and action research (32,33,34), which was implemented in order to develop the REMAD COCOPER learning strategy. The semester lecture plan is interpreted as authentic lecture assignments, and this is then followed by action research to implement the semester lecture plan in the lectures. This learning strategy has been tried out in several programs at both undergraduate and graduate level at Universitas Negeri Malang. In addition, a qualitative descriptive method (35) was employed for the data analysis.

3 RESULTS AND DISCUSSION

3.1 *Results*

The development of the REMAD COCOPER life-based learning strategy has strived to improve lectures in order to achieve appropriate conditions for the learners. REMAD COCOPER is an acronym for REading, (mind or concept) MApping, Discussing, COllaborating, COoperative learning, Presenting, Elaborating, and Reflecting. This learning strategy is based on two out of ten LBL characters, which can be interpreted in the form of authentic lecture assignments. These are capacity building and the utilization of numerous learning sources. The visualization of the REMAD COCOPER learning strategy is presented in Figure 1.

The visualization of strategy implementation is an example of the Quantitative Research Methodology course. In brief, the authentic assignment given to the students in the semester lecture plan on the Quantitative Research Methodology course is in the form of a structured or independent task; namely a) filling out the questionnaire in the early; b) peer teaching two materials on the Quantitative Research Methodology course during two lesson study (LS) cycles, with the first cycle emphasizing the selection of the learning model based on the taught materials, while the second cycle, in addition to the selection of the appropriate learning model, the practice of developing one of the 21st-century life skills was also chosen by the group to be practiced on its measurement; c) creating a mind map or concept map relating to the learning material on a day when there is no peer teaching assignment; d) assessing the

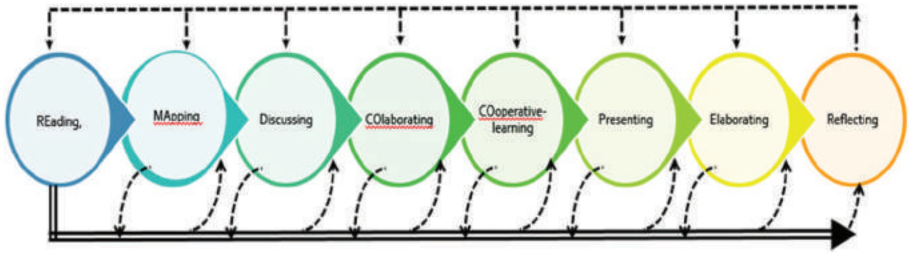

Figure 1. The visualization of the REMAD COCOPER learning strategy.

results of the mind maps or concept maps created by the peers in the group; e) conducting an assessment on the performance of a group who are performing peer teaching; f) writing a learning journal on the day the learning takes place; g) conducting a critical analysis on a reputable journal related to research problems of interest; h) conducting a practice of thesis research proposal writing initiated in sequence by the development of the research problem, the construction of the background of the research problem and the literature review, the research hypothesis, the research design and procedure, the development of the research instrument and data collection design, and data analysis design, and then thoroughly developing the thesis proposal; i) assessment of the critical analysis results and the peer group practicum; j) uploading the files relating to the results of the mind map or concept map, presentation, and learning journal in the determined time. The test results showed that this strategy can be utilized to teach LBL to students and to develop their skills because each activity has the potential to develop their basic literacy, 4C competencies, and characters.

Prior to the presentation, students were to discuss the learning strategy they have chosen with the lecturer (Plan). In the (Do) activity, the two peers who were not the model lecturers observed the learning activities of their peers. Furthermore, the activity in the classroom required the model lecturers to reflect on the learning they had undertaken. Their peers were also asked to make comments regarding the learning they had experienced. Various learning strategies were chosen by different student groups in different classrooms in order to conduct peer teaching of the same material.

The materials taught on the Quantitative Research Methodology course included The Nature of Research; Research Instruments; Research Problems; Research Literature Review; Research Design; Research Proposal; Descriptive Research; Experimental Research; Ex Post Facto Research; Action Research; Utilization of Statistics for Data Analysis; and Research Result Reporting. The students were assigned to groups and allowed to choose the most appropriate learning model for their group's material.

Referring to that material, students were asked to construct a lesson plan for the materials to be taught by their group and then discuss in their small groups (as an LS team) which of their members should be appointed as the model lecturer. They then discussed the lesson plans generated from the group development with the researcher as the team of lecturers of Quantitative Research Methodology course in the scheme of Plan LS to proceed the completed lesson plan based on the results to be implemented in the classroom (Do in LS) and a discussion was conducted after the learning (See in LS).

In practice, not all of the groups of students took the time to discuss the lesson plan with the lecturer team. There were some groups that discussed their lesson plans with one of the members of the lecturer team and there were some groups that discussed their lesson plans with two lecturers, even though the discussions cannot be done simultaneously (independent consultation is needed with each member of the lecturer team).

3.2 *Discussion*

The students' training in capacity building was conducted by giving authentic lecture assignments. The research result that was theoretically expected to rise in the cognitive domain was the conceptual understanding of quantitative research methods; in the affective domain it was the ability to give the best service in peer teaching through the practice of LS by constructing the lesson plan design, discussing the lesson plan with peers and the lecturer (Plan), implementing the lesson plan in the classroom (Do), and reflecting on the classroom learning (See); in the skill domain it was in the form of designing skills, teaching, reflecting on the activities of peer teaching, and the skill of peer observation as an LS observer. The following is the discussion of LS implementation in the research methodology course by implementing the REMAD COCOPER learning strategy.

3.3 *Reading*

Competence in reading is very important for people in managing daily life (Dağ, 2013). Reading is one of the most important skills for all students (Eng & Nordin, 2017). Reading is a complex interaction between mental and physical activity. which involves more than merely language code analysis or the process of interpreting texts (Dağ, 2013). An interest in reading is closely related to critical thinking skills (Zubaidah, Corebima, Mahanal, & Mistianah, 2018). In this era of information and knowledge, each individual strives to develop their expertise by obtaining abundant amounts of information and knowledge as quickly as possible. One of the ways to obtain information and knowledge is through reading (Zubaidah et al., 2018). Most of the learning activities in schools are conducted by reading (Basar & Gürbüz, 2017). A good level of reading skill is the key to success at school, and this is one of the reasons why the researcher tried to explore the significant variables of education and psychology, which can explain reading skills and academic achievement (Swalander & Taube, 2007).

3.4 *Mapping*

Mind maps help readers to identify the problems that need to be solved and the solution proposed by the author (Guerrero J. M., & Ramos, 2015). Students are encouraged to be both creative and flexible when producing a mind map (Darmawan, Zubaidah, Susilo, & Suwono, 2015). In the Quantitative Research Methodology course, those students who did not undertake peer teaching were assigned to develop a mind map or concept map. The objective of the assignment was to make the Quantitative Research Methodology course run more smoothly because the students that were taught by their peers had prepared themselves by learning the material that was to be taught that day. The mind maps and concept maps were assessed by their peer group using the agreed rubric. The mind map was also used as a tool to construct a Chapter Design (CD) in order to prepare the Lesson Design (LD) and the lecture lesson plan.

3.5 *Discussing*

This discussion activity had an effect on the students' behavior (Tsai, 2013). The distribution of assignments through a group discussion activity was conducted in order to design the strategy of peer teaching. A discussion activity was also conducted during the lecture in which the students were taught by peer teaching.

3.6 *Collaborating*

Collaboration is also an important instructional strategy (Lee, Huh, & Reigeluth, 2015). Collaboration allows the construction of knowledge to occur due to the students sharing information and ideas through dialog (Hsieh, 2017). This skill was trained as an effort to develop the skill of acting in the sense of using Information Technology (IT). The students were trained to upload the learning materials that would be taught using presentation media, such as the video and PowerPoint slides that were used in the classroom for peer teaching, the learning journal, the mind map/concept map files, and the critical analysis results, to their class group's Edmodo. The students were also taught to download the files that had been uploaded by their peers/lecturer onto Edmodo when needed.

3.7 *Cooperative learning*

Learning in groups enables the students to transfer knowledge peer-to-peer, enhances critical and creative thinking, clarifies knowledge, and develops interpersonal skills (Leung, Hashemi Pour, Reynolds, & Jerzak, 2017).

3.8 *Presenting*

As a follow-up to the classroom discussion activity, students were then assigned to present their group discussion results. This was in an effort to develop the students' communication skills. The ability to communicate is a competence that needs to be mastered by students so that they can take their place as global citizens. Communication skills are also one of the learning and innovative skills that are expected to be developed in curriculum 2013 as one of the areas of Communication, Collaboration, Critical Thinking, and Problem Solving, and Creativity and Innovation (4-C), as formulated by Partnership for the 21st Century. The area of communication skills reflects both spoken and writing skills.

The activities now taking place in our world are supported by data-based website applications, which make extensive use of databases and services (Costa & Santos, 2017). The use of visual representations (such as figures, diagrams, and models) have previously been employed in science, and their utilization enables the researchers to interact with and represent complex phenomena that are unobservable using any other method. Even though numerous studies in science education have explored visual representation, the emphasis of this research is mainly on conceptual understanding when using visual representation and less on visual representation as an epistemic object (Evagorou, Erduran, & Mäntylä, 2015).

3.9 *Elaborating*

Training in the ability to elaborate was conducted through practicum activity and peer assessment of the practicum results in order to develop the quantitative research proposal. It was meant to train critical thinking, which is defined as a special skill that includes analyzing arguments, claims, or proof, drawing a conclusion using inductive or deductive reasoning, identifying and analyzing problems, finding and evaluating relevant information to make a decision or solve a problem, and reaching an appropriate conclusion. Another example of elaborating is that the students were assigned to write an elaboration that supported the received theory (Namdar, Lai, Linn, Donnelly, & Vitale, 2016).

3.10 *Reflecting*

The capacity to think reflectively and critically is an important domain development object (Darmawan et al., 2015). Reflecting makes the students think about and evaluate the information received from the readers and to find the correlation between the received knowledge (Swalander & Taube, 2007). Reflection and cognition provide opportunities for students to explore a new condition (Darmawan et al., 2015). One of the reflecting activities was conducted through the practice of observation and then the discussion of the observation results in the LS groups who had conducted peer teaching. The peers being taught could also state the results of their experience of the peer teaching conducted by the LS group. This was implemented in order to train them in the skills needed to live their lives, as well as the activities needed to prepare them to be lecturers.

4 CONCLUSION

Based on the results, it can be concluded that this strategy could be beneficial for improving the global competitiveness of prospective biology educators. It is recommended that efforts should be made to improve the learning process by emphasizing authentic assessments more rigorously and consistently.

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Ethical dilemma story pedagogy—a constructivist approach to values learning and ethical understanding

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ABSTRACT: Ethical Dilemma Story Pedagogy (EDSP) is a constructivist approach to values education. Lily's work on EDSP has focused on its use in science education where our research has demonstrated enhanced critical scientific literacy and critical self-awareness amongst students. EDSP is different from other approaches to values education such as socio-scientific argumentation and character education. In EDSP, a story containing ethical dilemmas evokes critical thinking and critical reflection. The focus is on the reflection process rather than on argumentation skills or moral reasoning. Used in the context of socially responsible science education, EDSP has been trialled in science classes at secondary level and at elementary level. As a pedagogical strategy, EDSP originates from values education and is suitable for teaching contentious issues that require students to draw on their values and content knowledge to engage in informed, evidence-based decision-making, critical thinking and critical reflection and collaborative problem solving.

1 INTRODUCTION

With the rapid advance of science and technology in an increasingly globalised and postmodern world, new ethical questions keep arising: should we allow geneticists to create life from scratch in a Petri dish? Should we nurture the economy at the risk of the natural environment? Should we allow the market to regulate everything? Should we plant genetically modified crops to feed our increasing population? Should we endorse genetic research to further the chance of preventing rather than curing numerous serious diseases? Many teachers around the world—and science teachers in particular—find themselves confronted by these questions, and they may feel under-equipped and under-prepared to engage in the teaching of socio-scientific issues where science and society meet. In the teaching of socio-scientific issues (SSI), "…SSI are equated with the consideration of ethical issues and construction of moral judgments about scientific topics via social interaction and discourse" (Zeidler, 2003, p. 8). The main focus here is on moral and scientific reasoning. At the same time, they may feel challenged by professional questions, such as; what pedagogical methodologies should I use when teaching about contentious socio-scientific issues? Should values be taught in my science classrooms at all or should they be left to the Religious Education Department? This last question has given rise to debate in science education in Australia.

2 VALUES AND SCIENCE EDUCATION

The Department of Education, Science and Training (DEST, 2005b) stated that the role of teachers in values education is 'critical' and "…all teachers are values educators". This statement set the scene for science teachers finding themselves responsible for values education in school settings. Many science teachers have since expressed, "…concern that they were insufficiently equipped" to accommodate debate that may arise during ethical discussions initiated through values education (Levinson, Douglas, Evan, Kirton, Koulouris, Turner & Finegold, 2000, p. 113). Additionally, many of these teachers expressed concern about their personal opinions emerging to displace the equilibrium between a "balanced viewpoint and acknowledging one's own person belief system" (Levinson et al., 2000, p. 118). These concerns were supported by a case study in which a teacher faced the dilemma of whether to question a student's racist remarks or leave the comments alone and risk her silence being "…interpreted as tacit approval" (Wallace, Louden, Dawson, Lock, Brickhouse, & Crosthwaite, 2002, pp. 176–179). However, this does not appear to be the only reason some science teachers refrain from explicitly teaching values in the classroom.

Australian science teachers cite curriculum overload as the main reason for not teaching values, stating that there is simply no room in an already crowded curriculum. The science curriculum, as with many other learning area curricula, is densely-packed and overcrowded. Since science specialists tend to look at the world through scientific glasses, some science teachers may find it difficult to justify teaching values and ethics in an already crowded curriculum (Fensham, 2004). Levinson et al. (2000, p. 118) learned from interviews of science teachers that even though there was widespread recognition of the importance of the social and ethical dimensions of science, the combination of an overcrowded curriculum and high status content left teachers unwilling to tackle the values implicit within science. To be fair, we cannot just blame the teachers for marginalising the ethical dimension of science. As Levinson et al. (2000, pp. 111–112) identified, students too tend to "draw a strong distinction between subject discourses and 'talk' that they see as not related to subjects." In the science education context, this may also lead students to consider a discussion with a strong emphasis on social and ethical issues (i.e. socio-scientific issues) as "non-science and of low status." In a case study of a Year 10 science teacher who implemented ethical dilemma teaching, the teacher noted that, "…most of the students relish the opportunity to engage in rich discussion about ethical issues although some have reacted angrily to the changes from their regular science classes" (Wallace et al., 2002, p. 176).

An issue playing on many people's minds when thinking about teaching values in science classrooms is that science is perceived by many as an objective, content driven, values-neutral discipline (Levinson et al., 2000; Stevens, 2007). Traditionally, science education has been driven by a 'positivist program' with a strong emphasis on 'technical rationality' and an unquestioning acceptance of the knowledge to be learned (Driver, Asoko, Leach, Mortimer & Scott, 1994, p. 11). Many science teachers are heavily invested in this epistemological view of science which necessitates a clear distinction between values and facts. Even though many controversies surrounding science-based developments, such as In-Vitro-Fertilisation (IVF) or human cloning are saturated with moral and ethical dilemmas, the discussion of social and ethical issues in the science classroom is viewed by some as subverting fact-based teaching and diluting "the strong conceptual basis associated with school science" (Levinson et al., 2000, p. 118). In their research, Levinson et al. (2000) found that many science teachers view their primary role as correcting student misconceptions and saw it as the role of teachers of other subject areas to tackle general social issues. Fensham (2004), on the other hand, emphasised that science and values were inextricably linked, since most socio-scientific issues are scientifically highly complex, meaning that, scientists have to be selective about what aspects exactly they choose to research. They make this decision based on their own values. As such, science itself can be viewed as being infused with values and serving the purpose of certain groups. "Any field of human discourse in which the general value-terms 'good' and 'ought' figure, falls within the range of axiology, even that of scientific method with its principles about the degree of belief one 'ought' to give to a hypothesis in the light of a given body of evidence" (Bullock & Trombley, 1999, p. 60). Consequently, science itself as a way of knowing is value-laden. This perspective directly undermines the often quoted fact-value dichotomy. By contrast, Stevens (2007) rejected the value-laden perspective of science, arguing that a scientific fact is a distinct and different domain to values and, therefore, the two domains should not be conflated. However, he too acknowledged that political and moral dilemmas arise from the developments of science.

The suggestion that science is a collection of facts only has indeed been the topic of a longstanding debate. As Driver et al. (1994, p. 6) pointed out, science is a social construct that is socially negotiated by the scientific community as a series of constructs that have been, "…invented and imposed on phenomena in attempts to interpret and explain them." Scientific constructs are then communicated to the public through cultural and social institutions such as schools, religion, and media (Driver et al., 1994, p. 6). This social-constructivist notion of science does not preclude the empirical basis of science but rather places an emphasis on the "…social construction and validation" of scientific knowledge which connotes a strong interdependent relationship with values (Driver et al., 1994, p. 6).

Ultimately, we can argue, scientific knowledge can be used for both beneficial and detrimental purposes. Whereas in the past "science was mainly concerned with explaining phenomena," modern science is a "crucial part of man's efforts to change the world" (Frazer & Kornhauser, 1986, p. v). As such, this raises questions of ethics, social responsibility and value judgements. "Scientific knowledge is not only used but it is also misused to serve the purposes of specific groups and, as such, scientific knowledge must always be ethically assessed. This assessment should not only consider scientific evidence, but also the values that underpin its application" (Paul, 1988, p. 15). It is this discrepancy between the moral dimensions of science in the real world and the lack of it in science classrooms that causes concern (Fensham, 2000, p. 75).

Hence, rather than avoiding addressing values in science altogether, there are at least two good reasons for including social and ethical aspects of science in the classroom, as Paul (1988, pp. 15–16) explained: addressing contentious, value-laden issues is of greater interest to most students and of greater practical use to them than the more traditional 'pure-science' emphasis. Furthermore, working through such issues helps students develop a more unified perspective on their values and personal beliefs and on the moral issues that science inevitably generates when applied to the real world.

In my (Lily's) own work as a science teacher-educator, I emphasise the importance of values education with my pre-service teacher education students when I remind them that, as teachers of science, we contribute actively to preparing our students for life. We wish to enable them to participate in the environmental debate and in the discourse on science as informed members of society and future decision-makers. For this purpose, it is crucial that learners develop critical scientific literacy by developing an understanding of ethical issues in addition to content and inquiry skills. Given the tensions between those who are in favour of teaching about values in the science classroom and those who are against, we briefly provide an overview of how the debate about the teaching of ethical understanding has unfolded in the Australian context over the past two decades.

3 VALUES EDUCATION IN AUSTRALIA

'Values' – a word that is bandied around and used in regular everyday conversations. But what exactly are values? The *Australian Oxford Dictionary* defines values as, "the regard that something is held to deserve" or as "…the principles or standards of behavior" or as, "…one's judgement of what is important in life" (Oxford University Press, 2018). Values have been an ongoing topic for debate in the Australian education arena and, depending on the political flavor of the day, governments wish to see more- or less-values education in Australian classrooms. The Australian Curriculum, that is, the national curriculum that is currently mandated as the basis for all education in Australian schools has been rolled out from 2010 and is overseen by the Australian Curriculum, Assessment and Reporting Authority (ACARA). It not only outlines the content and skills curriculum mandated for learning areas such as Mathematics, English and Science but it also highlights a set of Cross-Curriculum Priorities (Aboriginal and Torres Strait Islander Histories and Cultures, Asia and Australia's Engagement with Asia and Sustainability) and—most relevant to values education—the General Capabilities (i.e. Literacy, Numeracy, ICT Capability, Personal and Social Capability, Critical and Creative Thinking, Intercultural Understanding and Ethical Understanding). Ethical Understanding is the most relevant capability for values education: Ethical Understanding involves developing an understanding of ethical concepts and becoming able to explain what constitutes an ethically better or worse outcome and how it might be accomplished (Australian Curriculum, Assessment and Reporting Authority, ACARA, n.d.). The General Capabilities are to be addressed by teachers of all the learning areas and all year levels. The General Capabilities encompass the knowledge, skills, behaviours and dispositions needed by young Australians to live and work successfully in the twenty-first century (ACARA, n.d.). Hence, it can be argued that the curriculum now clearly states that all Australian schools, all learning areas, and all teachers have been charged with the responsibility to teach ethical decision-making however, it has not been a straightforward process to introduce values education into Australian schools. When a previous government mandated the explicit teaching of a set of core Australian values the question arose as to what we actually mean by 'Australian Values'. The Government's nine core values, which, at the time, were regarded as promoting "Australia's democratic way of life" (DEST, 2005a, p. 5), included: Care and Compassion; Doing Your Best; Fair Go; Freedom; Honesty and Trustworthiness; Integrity; Respect; Responsibility; and Understanding, Tolerance and Inclusion (DEST, 2005a, p. 4). Whilst there is nothing inherently wrong with any of these values, Australians baulked at the idea that the Government would define values to be taught explicitly to all children. It was the Government's definition of how values education should be conducted that proved to be problematic and led to debate and resistance. Teaching values explicitly is the hallmark of values education that is conducted in a behaviourist manner which is often the case in character education. To many in Australia at the time, the direct teaching of values chosen by the Government seemed akin to 'indoctrination' of minors, reminiscent of religious schools of the past. Many Australians resent this type of values education and do not want to see it in public, government-funded schooling. When the Australian Curriculum was developed, it seems that ACARA avoided this conflict by referring to (what is effectively) values education as teaching the General Capability of Ethical Understanding—something that can hardly be argued against.

Given the resistance to behavourist approaches in the Australian education arena, the question arises as to what alternatives we can choose instead. It helps to look at the other side of the epistemological and axiological spectrum, where we can find approaches to values education that are constructivist in nature and that, rather than indoctrinating students and promoting a certain set of pre-approved values, encourage students to think for themselves and challenge their own taken-for-granted assumptions through critical thinking and critical reflection: enter EDSP.

4 ETHICAL DILEMMA STORY PEDAGOGY (EDSP)

In this type of transformative learning, the values learning process is initiated by confronting students with an ethical dilemma, that is, a situation in which a decision has to be made which can potentially lead to harmful outcomes, and where there is no simple right or wrong answer. In typical constructivist fashion, students are guided through the story and the embedded ethical dilemmas by the teacher who acts as facilitator of student thinking and interaction, rather than as an instructor of explicit values in the classical sense. Students learn to listen carefully to other students' ideas and discuss with their peers potential solutions. According to Jack Mezirow (1991), it is in the moment when students are experiencing a disorienting ethical dilemma and are 'forced' to engage in critical reflection on their taken-for-granted assumptions in order to find a suitable solution that transformative learning occurs. Through the reflective process and interactions with peers, students are given opportunities to change their values if they feel it is appropriate or needed. They do this by constructing new values or adapting existing ones. The underlying constructivist assumption about how values learning occurs is based on Lawrence Kohlberg's work (1984) which, drawing on Piaget's constructivist throught, cautioned that values cannot be taught explicitly as is the assumption in behaviourist approaches to values education—rather it is the student herself/himself who actively constructs values.

The teacher's role as facilitator requires that she/he not impose opinions or share her/his own values. This is a core difference to behaviourist approaches to values learning. Rather, the teacher as 'storyteller' tells a story that contains one or more ethical dilemma situations which is interrupted at appropriate times, that is, when an ethical dilemma arises in the story. At this point, students are asked to make a decision on behalf of the characters in the story, "Put yourself into the shoes of… – how would you decide if you were…? Give reasons for your decision. Please reflect by yourself first and then discuss with a partner." Note that students are always asked to reflect by themselves first before engaging with others. This is to ensure that they draw on their own values rather than just copy what their friends are saying. Usually, student collaboration is scaffolded by starting with Think-Pair-Share early in the story, followed by groups of three, then groups of four students, before engaging the whole class in a plenary discussion. It is the role of the teacher to facilitate students' collaborative decision-making, ensure student engagement by playing devil's advocate, and manage the classroom in terms of individual and group work options. This constructivist pedagogical approach to values learning is referred to as ethical dilemma story pedagogy.

Ethical dilemma stories, also referred to as moral dilemma stories, can be used at any grade level and in a variety of forms. "They present a realistic situation in which some dilemma is thrust upon the actors in the story" (Benjamin, 1986, p. 160). 'Provocation' to start the story can be a range of stimuli such as "a poster/picture, a single slide, an oral or printed story without an ending, or even simple puppets acting out a story" (Benjamin, 1986, p. 160). The story should be such that there is not an obvious 'right' or 'wrong' response, but a narrative in which options must be weighed and a decision made. When students share their responses they also share the reason for their choice and this allows students to practice moral decisions-making (Benjamin, 1986, p. 160). Ethical dilemma stories are a genre inasmuch as they are stories containing ethical dilemmas, and there are a number of ways in which they can be implemented in the classroom. In my doctoral research on moral dilemma stories in science classrooms (Settelmaier, 2009), the participating teachers narrated the dilemma story to the students and the ethical dilemma story lesson was concluded with poster presentations and a plenary discussion.

Rather than using pre-fabricated dilemma stories that others had written, we trialled a different approach during the project 'Socially Responsible Science'. As part of this project, a group of science teachers received intensive professional development in ethical dilemma story pedagogy. Furthermore, they were taught how to write their own ethical dilemma stories, since appropriateness of the story to the context and the students is vitally important for its success. Ideas for the dilemma story topics were provided by guest speakers who spoke about the 'ethical dilemmas inherent in their professions'. This included a speaker from the Perth Zoo, an agricultural scientist, and a geneticist interested in genetically-modified foods (GMO). The teachers chose and researched an ethical dilemma which they consequently developed into an ethical dilemma story and trialled with their own students. The stories were mapped onto the curriculum and linked to the local context. Moreover, the teachers provided their own reflections on the implementation of the stories in their classrooms. The ethical dilemma stories resulting from this project were compiled on the website titled 'Socially Responsible Science—a Living Resource' (www://sociallyresponsiblescience.com.au) that is hosted by the Science Teacher Association of Western Australia (STAWA). The stories, curriculum links, and teacher reflections are available to teacher across the globe. We call the website a 'living resource' because we encourage teachers to write their own stories and share them with other teachers via the website. We provide support with editing and ensuring that the stories fit the guidelines for ethical dilemma stories. Since its inception, the website has grown and is now hosting stories from Australia, Austria, Japan and Pakistan. Details about how to write and share an ethical dilemma story with us are provided on the website.

5 EDSP—A CONSTRUCTIVIST VALUES EDUCATION STRATEGY

The demands on teaching professionals in Australia –and the rest of the world—have expanded beyond the concrete boundaries of traditional key learning area concepts. To address the breadth of the curriculum for the 21st Century, the Australian Curriculum Assessment and Reporting Authority (ACARA) introduced the Cross-Curriculum Priorities and the General Capabilities in the Australian Curriculum. For values education, this means that the role of the teacher has clearly moved past the public setting of academia and entered the "private domain of personal morality, belief and practical conduct" (Lovat, n.d., p. 2). All teachers in all learning areas are now responsible for teaching of the General Capability of Ethical Understanding. Some Australian science educators may still experience this situation as a challenging imposition due to the fact-values dichotomy still prevailing in many science classrooms. On the other side of the spectrum, we find those who argue that science is already value-laden, as demonstrated by the many ethical dilemmas that arise from scientific advancements. Since behaviouristic approaches to values education promoting direct teaching of specific values were not well received in Australia, a constructivist strategy such as Ethical Dilemma Story Pedagogy lends itself as a viable alternative. By implementing a cognitive approach to values education that uses ethical dilemma stories to initiate active values construction by learners, this strategy has the potential to help science teachers fulfil their responsibility of teaching values, content and science inquiry skills whilst at the same time enhancing students' critical scientific literacy.

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Transformative STEAM education for sustainable development

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ABSTRACT: Humanity has created *The Anthropocene,* a new geological era characterized by the impact of our destructive footprint on the planet's natural systems. However, the push to create curriculum synergies between Science, Technology, Engineering and Mathematics (i.e., STEM) is largely ignoring this global crisis in favour of preparing students for employment in the *fourth industrial (digital) revolution*. This narrow focus is doing little to prevent students from turning a blind eye to the ethical dilemma of how global production, consumption and disposal of STEM products is implicated in destroying the natural environment. To save our ecosystems we need a transformative curriculum perspective that gives rise to a socially responsible STEM education. Integrating STEM with the Arts enables us to create interdisciplinary STEAM curriculum spaces for designing transformative pedagogies that develop students' disciplinary knowledge/skills and awaken their creative self-consciousness, elevate their moral/ethical and spiritual awareness, and empower them to practice environmental justice.

1 INTRODUCTION

200 years after the European industrial revolution the Earth's natural systems are under severe duress due to our modern technological footprint. We have not only developed the means for vastly improving the material quality of our lives, but also the means for our collective destruction. This new geological era – *The Anthropocene* – manifests in numerous ways, two of the most visible being catastrophic climate change and dire plastic pollution of the world's marine ecosystems. These are hugely deleterious side effects of a fossil fuel-based market economy premised on uncritical production, consumption and waste disposal.

For over 10 years the United Nations has advocated the urgency of education for sustainable development that reconciles the competing interests of our globalising economies, biocultural diversity, and the natural environment. However, despite inter-governmental agreements, most recently the Paris Agreement on climate change (UN 2015a), progress is disappointingly slow. The most recent report on global warming issued by the Intergovernmental Panel on Climate Change (IPCC 2018) warns that we have only 12 more years left to reduce carbon emissions in order to limit the global temperature increase to +1.5C. Going beyond this modest target is predicted to result in an unmanageable climatic 'tipping point'. The Bulletin of the Atomic Scientists' (2018) *Doomsday Clock* is now set at 2 minutes to midnight. And the World Economic Forum (WEF, 2016) estimates that, at current rates of plastic leakage into the natural environment, by 2050 there will be more (toxic) plastics than fish (by weight) in the oceans. Clearly, we are facing environmental crises on a global scale.

The recent UN Emissions Gap Report (2018) calls on all sectors, including education, to develop emissions mitigation strategies. From an eco-justice perspective, it is clear that professional educators, especially in the STEM field, have a moral imperative to engage students (from early childhood to graduate school, including teacher education) in education for sustainable development. Although the worldwide endeavor to create synergies between the disciplines of Science, Technology, Engineering and Mathematics is promising, we are falling short of preparing young people with *transdisciplinary abilities* necessary for engaging in sustainable development practices. Many government-sponsored innovative STEM curricula and pedagogies are driven by the economic imperative of the *Fourth Industrial (Digital) Revolution* (WEF 2016). Although critical thinking, creativity, digital literacy, teamwork and communication skills are essential for employment in a globalizing digital economy, they are not sufficient for transforming unsustainable practices in the home, community and workplace.

Education for sustainable development needs to be guided by a philosophy of education based on a broader notion of the public good (Hazelkorn & Gibson 2017) that envisions young people as active citizens of democratic societies that value equally the competing interests of globalizing economies, diverse cultures, and the natural environment. Educating young people with transdisciplinary abilities for reconciling these global conflicts involves immersing them in *transformative learning* experiences in which they learn how to reflect critically on their valued beliefs and habits of mind, engage empathically in real-world ethical decision-making scenarios, contemplate their spiritual connection with the natural world, and develop their moral agency for making the world a healthier and happier place in which to thrive.

In this paper we explain how a *transformative philosophy of learning* can help to save our planetary ecosystems (and our own species). By integrating the Arts with STEM we can create powerful and inspiring interdisciplinary curriculum development spaces for designing transformative learning experiences that enable our students to develop not only STEM disciplinary knowledge and skills but also transdisciplinary abilities for ensuring their active engagement in sustainable development decision-making. We conclude by outlining an example of a successful transformative STEAM strategy – *ethical dilemma story pedagogy* – that is being embraced by teachers and researchers in Australian, Indonesian and Thai schools and universities.

2 EDUCATION FOR SUSTAINABLE DEVELOPMENT

We are now experiencing an unparalleled period in the geological history of the Earth, an epoch in which we have wrested control over Nature: *The Anthropocene* (Crutzen & Stoermer 2000). This era has its genesis in the European industrial revolution and is characterised by our use of fossil fuels and development of powerful technologies. Alarmingly, our use of these technologies is dangerously altering the natural systems of the planet, including the atmosphere, oceans and soils, resulting in fundamental changes to biological and geological systems. The impact of the modern human footprint has become so profound that, for the first time in history, natural ecosystems are at the mercy of human systems.

In the public mind the clearest evidence of our detrimental impact on the planet is climate change (National Research Council 2011). Another major impact, one that is not so well embedded in public consciousness, is loss of linguistic, cultural and biological diversity, which together are framed as *biocultural diversity*. The importance of the intimate interrelationship between language, culture and the environment has been documented by United Nations Educational, Scientific and Cultural Organisation (UNESCO), The World Wide Fund for Nature (WWFN) and Terralingua (Skutnabb et al. 2003, p. 10):

> In the language of ecology, the strongest ecosystems are those that are the most diverse. That is, diversity is directly related to stability; variety is important for long-term survival. Our success on this planet has been due to an ability to adapt to different kinds of environment over thousands of years (atmospheric as well as cultural). Such ability is born out of diversity. Thus language and cultural diversity maximises chances of human success and adaptability.

Because we have failed to resolve human-induced global crises the United Nations established the 2030 Agenda for Sustainable Development (UN 2015b). Goal 4 is Education, which states that our education systems need to promote the well-being of self, family, community, nation, and humanity at large, as well as the planet's living systems and other life forms. In setting out the following principles of education for sustainable development, UNESCO (2006) recognises that sustainable development is an ethical challenge as well as a scientific concept. Education for sustainable development:

- uses a variety of pedagogical techniques that promote participatory learning and higher-order thinking skills,
- promotes lifelong learning,
- is locally relevant and culturally appropriate,
- is based on local needs, perceptions and conditions, but acknowledges that fulfilling local needs often has international effects and consequences,
- addresses content, taking into account context, global issues and local priorities,
- builds civil capacity for community-based decision-making, social tolerance, environmental stewardship, an adaptable workforce, and a good quality of life, and
- is interdisciplinary.

By embracing these principles, a socially responsible STEM education would incorporate values education and citizenship education, and address global issues. It is clear that, in addition to developing students' disciplinary knowledge and skills, a socially responsible STEM education needs to contribute to preparing students as future citizens by developing their transdisciplinary abilities, as mandated by the Australian Curriculum.

3 SOCIALLY RESPONSIBLE STEM EDUCATION

The Australian Science Curriculum provides a futures perspective on preparing young people with not just disciplinary knowledge and skills but also essential transdisciplinary abilities for working and living in a rapidly globalising world in which we are experiencing unprecedented development and disruption, especially in regard to the natural environment.

The Australian Science Curriculum is impressively multi-dimensional, comprising three distinct strands. The *Science Understandings* strand directs teachers to engage students in understanding the evolutionary dynamics of scientific knowledge, concepts, principles, theories, models, etc. The *Science Inquiry Skills* strand focuses on developing skills of inquiry and evaluation of scientific explanations. The innovative third strand of *Science as a Human Endeavour* opens the door to understanding the nature and limitations of science and to considering the cost to the planet and humanity of its unintended side-effects. This strand "acknowledges that in making decisions about science and its practices, moral, ethical and social implications must be taken into account." (Australian Curriculum Assessment and Reporting Authority 2010).

Although the third strand is a significant advance towards building a socially responsible science education, two overarching dimensions of the broader Australian Curriculum fully open the door to a radically expanded scope for science education to address pressing global issues. The *general capabilities* and *cross-curriculum priorities* invite teachers to develop their students as global citizens capable of not only adapting to a rapidly changing world but also participating actively in shaping it for the better. Importantly, this includes consideration of the many competing (values laden) perspectives on what 'better' might mean.

The general capabilities focus on developing a suite of transdisciplinary abilities – *critical and creative thinking, personal and social capabilities, ethical understanding and intercultural understanding* – aimed at preparing future citizens "to contribute to the creation of a more productive, sustainable and just society" (Australian Curriculum Assessment and Reporting Authority 2016). The cross-curriculum priorities – *sustainability, Aboriginal and Torres Strait Islander histories and cultures, Asia and Australia's engagement in Asia* – provide compelling learning contexts for students to understand the worldviews of culturally different others and develop a moral conscience about the impact of their planetary footprint. It is intended that teachers of all learning areas, including Science, Technology, Engineering and Mathematics (STEM), will build these new curriculum dimensions into their teaching programs.

However, the prospect of designing teaching and learning activities to develop students' transdisciplinary abilities can be daunting for STEM teachers whose experience has been restricted to teaching disciplinary knowledge and skills. A solution to this issue lies in making the walls of traditional disciplinary silos permeable, thereby fostering interdisciplinary collaboration between STEM and the Arts.

4 ARTS + STEM = STEAM

The Arts focus uniquely on developing our creative abilities (ingenuity, imagination), our aesthetic appreciation (beauty, sentiment), our ethical values (virtues, human rights, social justice), and our rhetorical ability (expression, representation, persuasion). As Eliot Eisner (2008), a leading arts educator, explains: the Arts are concerned with expressiveness, evoking emotion, generating empathic understanding, stimulating imagination that disrupts habits of mind and creates open-mindedness, and eliciting emotional awareness.

In sum, the Arts enable us to perceive the heights of our humanity, of what it means to be fully human. And Arts education can enable us to ascend these heights, to enrich our lives with transdisciplinary abilities that we can apply in different ways for different purposes. These abilities are especially empowering for concerned citizens endeavoring not only to make sense of a complex, chaotic and contested (post-truth, fake news) world, but also to exercise their democratic agency by intervening constructively in private, public and professional discourses aimed at deciding the (ethical/morally) right way to resolve global crises such as climate change and the scourge of feral plastics destroying our marine environments.

Such debates are hotly contested by competing interests arising from different (perhaps invisible) value systems that underpin strongly held convictions that often are immune to the objective facts and rhetoric of scientists. For example, the starkly contrasting responses of world leaders to the IPCC (2014, 2018) scientific reports on the urgent need to mitigate climate change evidences a split between climate change deniers and acceptors, with the former refusing to accept that climate change is due in large part to (irresponsible) human actions, as concluded to an overwhelming degree (98% probability) by climate scientists.

This political stalemate makes it abundantly clear that a socially responsible STEM education must focus on developing not only young people's disciplinary knowledge and skills but also their transdisciplinary abilities – *critical and creative thinking, personal and social capabilities, ethical understanding and intercultural understanding* – for engaging constructively in sustainable development debates, decision-making and practices.

The good news is that there is a wellspring of opinion worldwide that combining STEM education and Arts education is a curriculum imperative for a creative, scientifically literate, and ethically astute citizenry and workforce for the 21st Century (Boy 2013, Piro 2010, Root-Bernstein 2008). Recognising the urgency of developing students' transdisciplinary abilities, visionary STEM educators are teaming up with colleagues in Language Arts (drama, poetry, prose), Performing Arts (dance, music, theatre) and Visual Arts (drawing, painting, sculpture, architecture, film making) to design interdisciplinary STEAM curricula and teaching approaches (Sousa & Pilecki 2013). In the Asia-Pacific region (Australia, Korea, Indonesia, Thailand), STEAM curricula are being developed, trialled and evaluated, and international conferences are bringing STEAM educators together around the theme of conservation of the natural environment (e.g., Ocean Park 2019).

5 TRANSFORMATIVE LEARNING

However, missing from this 'Arts+STEM = STEAM' equation is a compelling philosophy of learning that guides the design of STEAM teaching and learning approaches aimed at developing students' transdisciplinary abilities for engaging as future citizens in sustainable development debates, decision-making and practices. To address this need we turn to a philosophy of *transformative learning* that has been articulated in various ways for much of the

20th Century by leading educational philosophers and psychologists, including Jack Mezirow, John Dewey, Parker Palmer, Carol Gilligan and Abraham Maslow, who call for our subjectivities and lived experiences to be addressed in the curriculum of formal education. This inner education perspective resonates with the Ancient Greek maxim of *know thyself*.

Transformative learning involves engaging students in reflecting critically on the presuppositions underpinning their (largely invisible) values and beliefs. Using cognitive, emotional, social and spiritual development methods students learn to reconceptualise and reshape the relationship between their outer and inner worlds. It is useful to articulate transformative learning as five interconnected ways of coming to know (Taylor 2015).

a. *Cultural-self knowing* (self-realisation) involves coming to understand our culturally situated selves, in particular how the (mostly invisible) premises underpinning our worldview—our shared values, beliefs, ideals, emotionality, spirituality—give rise to our cultural identities and govern our habituated ways of being in, making sense of, and relating to our social and natural worlds.
b. *Relational knowing* (opening to difference) involves learning to connect empathically and compassionately with our true (nonegoic) selves, our local community, the culturally different other, and the natural world.
c. *Critical knowing* (political astuteness) involves coming to understand how and why (political, institutional, economic) power has structured historically our social realities by creating seemingly natural categories of class, race, gender, vocation, intelligence, etc., and how this mostly invisible power governs (especially distorts) our lifeworlds, our relationships with others, and our relationship with the natural world.
d. *Visionary and ethical knowing* (over the horizon thinking) involves creative, inspirational and discursive processes of idealising, imagining, poeticising, romanticising, meditating on and negotiating a collective vision of what a better world *could be* like and, importantly, what a better world *should be* like.
e. *Knowing in action* (making a difference) involves consciously developing our capacity to help make the world a better place, committing to making a difference, and taking action locally while thinking globally.

These five dimensions comprise a 21st Century philosophy of learning that supports the moral imperative for STEM educators to draw on Arts education methods to develop students' transdisciplinary abilities for participating as key stakeholders in sustainable development debates, decision-making and practices. We conclude by outlining a successful STEAM teaching and learning strategy—ethical dilemma story pedagogy—currently being implemented in schools and universities in Australia, Indonesia and Thailand.

6 ETHICAL DILEMMA STORY PEDAGOGY

To summarise, we have argued that STEM educators have a moral imperative to develop curricula that prepare students with transdisciplinary abilities to participate as socially responsible citizens in helping to resolve global crises such as climate change and plastic waste pollution. We have argued that the Arts can provide STEM educators with much-needed methods for achieving this pressing goal. And we have outlined a transformative philosophy of learning to help drive transformative development of STEAM approaches to teaching and learning.

Our experience shows, however, that many STEM teachers feel unprepared to develop their students' transdisciplinary abilities. At the heart of the issue is an epistemological conflict: STEM education has traditionally focused on imparting objective knowledge, whereas transdisciplinary abilities are inherently intersubjective in nature. By and large, STEM specialist teachers (especially in secondary education) lack the professional skills and experience to embrace arts education methods.

However, there are ways of overcoming this stalemate, one of which is for a STEM teacher to team up with a colleague in an Arts learning area and co-design transformative STEAM lesson plans, perhaps around project based learning. However, this might be a curriculum bridge too far for STEM teachers who wish to confine their socially responsible teaching innovation to a small-scale strategy within the curriculum borders of their own classrooms. The good news is that this goal is being well served by ethical dilemma story pedagogy, a transformative STEAM approach that we introduced into Australian schools over a decade ago (Settelmaier 2009).

In brief, we have guided numerous STEM teachers to embrace Arts-based methods of dramatic storytelling, narrative reflective writing, and dialectical reasoning. We have helped them to write short stories in which the central character (a young person) experiences ethical decision-making scenarios in resolving real-life sustainable development dilemmas. The stories focus on ethical dilemmas such as: land clearance for housing development versus conservation of native bushland, genetically modified food versus organic farming, traditional organic fertilisers versus modern inorganic fertilisers to improve crop yield, intervening to save stranded whales versus not interfering with natural processes, using convenient plastic shopping bags versus environmentally harmful waste disposal methods. These ethical dilemma stories have been incorporated into lesson plans aimed at developing students' disciplinary knowledge/skills and transdisciplinary abilities. Details of ethical dilemma story pedagogy and research that has explored its efficacy in developing students' transdisciplinary abilities can be found in our other paper in these conference proceedings (Taylor, Taylor, & Hill 2019), and ethical dilemma stories and lesson plans can be found on our website: http://sociallyresponsiblescience.com.au.

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A makerspace; a space to play and a space to learn

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ABSTRACT: This paper examines the creation of STEM makerspaces in Indonesia and India and the perceived benefits of using makerspaces as learning and playing 'spaces'. It was determined that in makerspaces, students were encouraged to be playful and engage deeply in hands-on activities, to demonstrate 21st-century skills such as creativity, collaboration and problem-solving and to learn science, technology engineering, and mathematics. A purpose developed questionnaire was used to capture students' engagement and enjoyment of the activities in the Makerspace and their understanding was measured through the use and analysis of drawing. It was determined that the majority of students enjoyed learning in the makerspace and took pride in the production of an artefact and were able to articulate their learning through text and drawings.

1 INTRODUCTION

Makerspace started as Hackerspace where people came together to 'hack' and then to make and create in online spaces (Smith, Hielscher, Dickel, Söderberg, & van Oost, 2013). These spaces quickly developed from virtual spaces and physical sites were developed including Stanford University which launched the FabLab@School project in 2008. From there Makerspaces took off and often became incorporated into libraries and civic centers where technological and craft ideas became part of the Makerspace creations. Although there was a view that this was a 'grassroots' approach which meant it was organic in nature and could be created and developed to fit its purpose which was at the whim of its creator.

It seems that whilst some of this ideology was true there was, in fact, a strong underpinning purpose that was developed during the 1990s that imagined makerspaces to be places of 'play'. Rather than the simplistic notion of play that has become a negative idea in the 21st century. Papert & Harel (1991) defined play as involving experimentation, taking risks, testing the boundaries, and iteratively adapting when things go wrong. He sometimes referred to this process as "hard fun." Papert was in many ways ahead of his time envisioning learning as encompassing projects, passion, peers, and play (Papert, 1999, in Bergner & Chen, 2018). This approach is very much where makerspaces developed where students work on projects rather than problems, which drew out their interests and passions, where they could work collaboratively and where they could 'play'. Papert and colleagues warned of the dangers of technology for the sake of new ideas and gadgets enshrining the term 'epistemological dilution' refers to the way in which technologies for learning are drawn into the existing curriculum in an engaging but mindless way" (Papert, 1999, in Bergner & Chen, 2018. p. 552).

These Makerspaces described in this paper mirrored the work of Papert focusing on the creation of an artefact and the establishment of collaborations (working with peers) and displaying all the characteristics of 'play' as defined by research (Papert, 1999, in Bergner & Chen, 2018). The researchers developed an approach they called 'the Makerspace Approach'

Table 1. *Makerspace approach* and a comparison between a traditional *Makerspace* and the *Makerspace approach* (adapted from Blackley, Rahmawati, Fitriani, Sheffield, & Koul, 2018).

Traditional makerspace—a recreational activity	Makerspace approach—targeted learning activity	Makerspace approach example
Makers create their own communities	Makers are organized into pre-determined communities	Student makers arranged groups of 4 with a support educator.
Makers choose materials at their own discretion	Makers are provided with a base-level kit of materials	Student makers provided with the model, for example, *Wiggle bot activity materials one per child. Group assigned pipeline materials
Makers envisage and produce individual, often unique, artefacts	Makers are shown a completed base-level & operational (as appropriate) artefact and are challenged to construct a similar artefact	Student makers examine the working model and where necessary deconstruct it and then create their own versions with the Wigglebot this included feathers and eyes
Makers are not mentored	Makers are mentored (not instructed)	Student makers are encouraged to practice perseverance when attempting their model, supporting educators are encouraged to use questions to guide the students
Makers might evaluate their artefact	Makers are scaffolded to evaluate their artefact	Using questions students makers refine the artefact to ensure it functions effectively
Makers might be cognizant of the underlying science, technology, engineering, mathematics or other concepts	Makers are made aware of related underlying science, technology, engineering, mathematics or other concepts in line with curriculum documents	Student makers are encouraged to explore their understanding of key aspects of STEM content through writing or drawing and skills demonstrated can also be examined.

*Wigglebot is one activity used in the Makerspace.

which was not supporting a totally free and open space but uses a scaffolded approach with an identified group of learners.

The focus of these Makerspaces has been in STEM as it has been perceived internationally that there is a need to increase the number of STEM practitioners created and develop their content knowledge. Creating students with strong STEM content knowledge and skills set who will go on to become leaders in the space has been identified worldwide. The United Nations Educational Scientific and Cultural Organization (2017) reported.

> *Advances in STEM have already brought about improvements in many aspects of life, such as health, agriculture, infrastructure, and renewable energy. A STEM education is also key for preparing students for the world of work, enabling entry into in-demand STEM careers of tomorrow*. (p. 14).

Beyond content knowledge, there has also been an increased focus on the development of 'STEM skills' which when examined closely resemble 21st-century skills or transversal competencies. These skills are not easy to facilitate or measure in the more traditional didactic classes found in Indonesian and Indian schools where students are expected to listen rather than to do (Manna, 2017). Schools in these countries currently focus on classes of discrete subjects such as science, mathematics, and technology and therefore the move into a more integrated space raises curriculum as well as pedagogical challenges.

Therefore it was proposed that makerspaces are 'sandpits' where teachers and students can be encouraged to 'play' and for teachers to develop and trial new pedagogical approaches without fear of failure and seek to integrate and assess more than a single subject. In some

Table 2. UNESCO transversal competencies including sub-domains (United Nations Educational Scientific and Cultural Organization, 2015).

Domains	Sub-domains
Critical and innovative thinking	creativity, entrepreneurship, resourcefulness, application skills, reflective thinking, reasoned decision-making
Inter-personal skills	presentation and communication skills, leadership, organizational skills, collaboration, initiative, sociability, collegiality
Intra-personal skills	self-discipline, engagement, perseverance, self-motivation, compassion, integrity, commitment
Global citizenship	awareness, tolerance, openness, respect for diversity, intercultural understanding, ability to resolve conflicts, civic/political participation, conflict resolution, respect for the environment

technology areas such as at the International Conferences of Technology Education (ISTE), there are playgrounds where participants are encouraged to wander for the table to table 'playing' with pedagogical tools and technologies that appeal to them (International Society for Technology in Education, 2016).

In this paper researchers examined how primary students engaged in the Makerspace in Indian and Indonesian schools, how they undertook the creation of an artefact and the learning that they demonstrated using language and drawings. The research project involved pre-service teachers who were trained in the 'play' or makerspace approach of makerspaces at their Universities and then subsequently created makerspaces at designated schools. The focus here is on the learning and engagement of the students in the schools whilst working with the pre-service teachers in the makerspaces.

1.1 *Research questions*

Specifically, the focus here examines

How engaged and motivated do students report being whilst doing the Wigglebot activity in the makerspace?

How can drawing be used as a tool to examine learning in science?

What level of understanding did students demonstrate through their use of drawing in the Wigglebot activity?

1.2 *Indonesian context*

Indonesia rates as 65 of 130 on the Global Human Capital Index, thus a developing Country (World Economic Forum, 2017). Indonesia's focus on continued improvement in education is standards-based with five principles of *Pancasila* (the official, foundational philosophical theory of the Indonesian state) that impact on the societal values and practices. In the education system, these five principles constitute the basic concept in civics education and are integrated throughout the education system. Standards-based education system consists of eight national education standards of graduate competencies, content, process, assessment, educators and supporting staff, financial, and management and guide government, formal and informal educational settings (Government Law, 2003).

1.3 *Schools*

The study was carried out in four co-educational government schools managed by the Education Commission in the Jakarta District. 285 students from Year 5 and 6 participated in the study. The four schools co-share a campus space, located in four different wings surrounded a parade ground.

1.4 *Indian context*

In 2017 India ranked at 103 the top of the bottom quartile of the Global Human Capital Index (World Economic Forum, 2017). Although the report concluded India's educational attainment rate has seen improvement over past generations, its youth literacy rate is still 89%, which is well behind the rates of other leading emerging markets. India also ranks poorly on labour force participation, with one of the world's largest employment gender gaps.

More positively, India's increased ranking in education quality suggests that the science and technology actions plans announced by the Indian Prime Minister will continue to increase India's position. There is a 3-year action plan, a 7-year strategy and a 15-year vision for achieving scientific 'self-sufficiency' in India and improving India's position in world rankings (Science Academies to the Honourable Prime Minister of India, 2017 p. 2).

1.5 *School*

The Demonstration Multipurpose School on the campus is a laboratory school for Grades I to XII the students in Grades V and VI included sixty-one males and fifty-six females who listed their gender on the surveys the remainder did not identify.

2 METHOD

The methodology for this project was interpretive qualitative research considering how the event unfolds and what is it about (Elliot, & Timulak, 2005), based on an exploratory case study to examine school students' engagement with and reflections on a Makerspace approach to create STEM artefacts. Paper-based surveys were deployed in English (India) and Bahasa Indonesia (Indonesia) to examine school students' engagement and participation. Using Likert scale questions survey asked students about their engagement and their participation, numerical values and pictures were used (5 = strongly agree to 1 = strongly disagree) and symbols (☺☺ to ☹☹).

For Item 5, the participants' diagrams of the Wiggle Bots and labeling were categorized based on the work of Bowker (2007) by identifying features that were privileged by the participants. Four categories were developed after two of the researchers and the research assistant trialed the scoring on the same sample as for Items 3 and 4. The categories were:

0. NL – Not Labeled
1. Breadth (B): the labeled diagram shows component parts of the Wiggle Bot; however, they are not evident as a system (i.e. do not indicate how the individual components work together). In this case, advanced and basic were combined.
2. Depth (D): the labeled diagram shows component parts of the Wiggle Bot, and they are evident as a system.
3. Extent (E): a working artefact could be constructed using the diagram and labeling.
4. Mastery (M): a drawing of a completed Wiggle Bot plus a diagram that shows depth plus a caption.

3 RESULT AND DISCUSSION

Indonesian engagement and participation. *It can be seen here that 83% of strongly enjoyed working on making the Wigglebot artefact in the makerspace.*

Results also determined that 99% of students found collaborating with their group members and mentor was helpful to their success and 99% also agreed or strongly agreed that they could see science in the Wigglebot. Students were not asked to identify the mathematics or other STEM areas in this artefact in this survey. Some of the open-ended comments

Table 3. Indonesian students' survey responses (Items 1, 2 and 3 – engagement) (n = 285).

	Strongly agree			Strongly disagree	
Statement	5	4	3	2	1
I enjoyed the Makerspace activity	83.2%	14.8%	–	–	–
Working in a small group with a mentor helped me to complete the activity successfully.	85.3%	14.0%	–	0.7%	–
I can see that this activity uses science knowledge.	83.5%	15.4%	1.1%	–	–

Table 4. Indian students' survey responses (Items 1, 2 and 3 – engagement) (n = 126).

	Strongly agree			Strongly disagree	
Statement	5	4	3	2	1
I enjoyed the Makerspace activity	96.1%	3.9%	–	–	–
Working in a small group with a mentor helped me to complete the activity successfully.	88.9%	9.5%	0.8%		0.8%
I can see that this activity uses science knowledge.	82.%	18%	–	–	–

demonstrated students' capacity to persevere when they found the task difficult and they identified that collaboration was helpful to them.

> *The most interesting thing for me was making the eyes and fixing the legs—although rather difficult but it was doable.* (204Y, Student's open-ended questions from surveys, October 14, 2016).

3.1 *Students also reported on the science*

> *There is chemical energy that changes in electrical energy that will then change into kinetic energy* (4Y, Student's open-ended questions from surveys, October 14, 2016).

Indian engagement and participation. *It can be seen here that 96% of students strongly enjoyed working on making the Wigglebot artefact in the makerspace. Not every student enjoyed working in a group in this group with several students responding that they strongly disagreed it was helpful.*

Students were asked to write what the science knowledge was and this was examined separating the responses on the basis of the students' use of scientific language and their demonstration of processes. One students reporting the use of battery, motor, wires working of wigglebot, moving of motor (110, Student's open-ended questions from surveys, November 20, 2017) and some students also discussed the balance *the triangle shape that balances the bot and how to fix the motor so that the bot rotates* (113, Student's open-ended questions from surveys, November 20, 2017).

Whilst the drawings showed different levels of scientific understanding, the student responses to Item 3 of the survey "I can see that this activity uses science knowledge. If so, what is the science?" provided more evidence of authentic science learning but has not been able to be included in depth in this article.

Table 5. Categorization of the students' diagram and labeling. (Indonesia n = 285 India n = 126).

Categorization	Indonesian percentage (%)	Indian percentage (%)
Did not Draw	9	2
DNL Did not label	17	22
Breadth	25	8
Depth	37	50
Extent	9	17
Mastery	2	1

4 CONCLUSION

This paper examined the makerspace phenomena as it was enacted in two culturally different contexts in India and Indonesia. It determined that students enjoyed the hands-on aspects of the makerspace concept and by their ability to create and then discuss their creation using science terminology the pedagogy of the makerspace supports learning and highly engages the learner. A more comprehensive review of the makerspaces is being completed by the authors.

The authors posit that makerspace can be a place whereby STEM teachers can feel safe to try an integrated curriculum approach and a strong 'play' based or inquiry-based pedagogy that can build artefacts or solve a real-world problem. Into the future, the next step will be to create makerspaces around the play based makerspace approach to provide 'sandpits' for practicing teachers.

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Learning environment measurement for teaching and learning improvement

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ABSTRACT: Students spend up to 20,000 hours in classrooms, by the time they graduate from university, leaving a significant impact on student's experiences and perceptions of the learning environments they encounter. Research and evaluation in science education focus heavily on conceptual change, which cannot give a complete picture of the educational process. One such area which needs more focus is the student's understanding of an interaction with the place when engaging in place-based learning. Place-based pedagogies were developed in a reaction to concerns that, due to globalization, students were becoming disconnected from the local communities, cultures and the ecological environments surrounding them in the places that they lived. The goal of place-based learning is to actively engage students in interacting with their local communities through hands-on, real-world problem-solving, which leads to greater appreciation of the natural environment within which they live and a greater connectedness to local community. In this workshop, we will briefly review the research into conceptualizing, assessing and investigating the determinants and effects of the learning environments of science classrooms. Following which participants will be familiarised with the structure and practical applicability of the place-based learning environment instruments.

1 INTRODUCTION

The study of learning environments have grown out of 40 years describing the context in which students learn and the relationships between variables found in that environment, teaching practice and learning outcomes (Fraser, 2012). A student's social experience within the class-room is a fundamental influence on that student's perception of an engagement with learning (Fraser, 2001). Based on Lewin's (1936) influential field theory, which recognised the interaction between personal characteristics and the environment to determine behaviour, Murray (1938) developed a 'needs-press' model of behaviour. This model describes the interaction between the external pressure from the environment which supports or frustrates a student in attaining their goals based on their personal motivational needs. Learning environment's research began with the premise that students know the environment within which they learn far more intimately than an external observer, since they experience that environment over many hours and in a variety of different contexts (Fraser, 2012). Murray (1938) refers to these two view-points as alpha and beta press to differentiate between observations of external researchers and classroom participants respectively. Building on Murray's definitions, Stern, Stein & Bloom (1958) identified two further categories of beta press. Private beta press indicates the personal view of the classroom as it effects the individual participant and consensual beta press, which describe the view of the classroom environment as it effects the group.

A number of inventories probing students' perceptions of their learning environment have been developed, validated and refined from both the private and consensual beta press perspectives. Two foundational questionnaires about the classroom environment were developed in the USA by Walberg (Walberg & Anderson, 1968), the Learning Environment Inventory (LEI), and Moos and Trickett (1974), the Classroom Environmental Scale (CES). Wubbels and colleagues (Wubbels & Brekelmans, 2012) in The Netherlands deepened understanding of the classroom environment by investigating the interactions between teachers and students using the Questionnaire on Teacher Interaction (QTI). In Australia, Fraser and colleagues (Fraser, 2012) probed understanding of the student-centred classroom through questionnaires such as the Individualised Classroom Environment Questionnaire (ICEQ), the Science

Table 1. Summary of learning environment questionnaires.

Questionnaire	Authors	Scales measured
Learning Environment Inventory (LEI)	(Walberg & Anderson, 1968)	Cohesiveness, Friction, Favouritism, Cliqueness, Satisfaction, Apathy, Speed, Difficulty, Competitiveness, Diversity, Formality, Material environment, Goal direction, Disorganisation, Democracy
Classroom Environment Scale (CES)	(Moos & Trickett, 1974)	Involvement, Affiliation, Teacher support, Task Orientation, Competition, Order and organisation, Rule clarity, Teacher control, Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	(Fraser, 1990; Fraser & Butts, 1982)	Personalisation, Participation, Independence, Investigation, Differentiation
College and University Classroom Environment Inventory (CUCEI)	(Fraser & Treagust, 1986)	Personalisation, Involvement, Student cohesiveness, Satisfaction, Task orientation, Innovation, Individualisation
My Class Inventory (MCI)	(Fraser, Anderson, & Walberg, 1982)	Cohesiveness, Friction, Satisfaction, Difficulty, Competitiveness,
Questionnaire on Teacher Interaction (QTI)	(Wubbels & Levy, 1993)	Leadership, Helpful/Friendly, Understanding, Student responsibility and freedom, Uncertain, Dissatisfied, Admonishing, Strict
Science Laboratory Environment Inventory (SLEI)	(Fraser, McRobbie, & Giddings, 1993)	Student cohesiveness, Open-endedness, Integration, Rule clarity, Material environment
Constructivist Learning Environment Survey (CLES)	(Taylor, Fraser, & Fisher, 1997)	Personal relevance, Uncertainty, Critical voice, Shared control, Student negotiation
What Is Happening In this Classroom? (WIHIC)	(Fraser, Fischer, & McRobbie, 1996)	Student cohesiveness, Teacher support, Involvement, Investigation, Task orientation, cooperation, Equity
Technology-Rich-Outcomes-Focused Learning Environment Inventory (TROFLEI)	(Aldridge & Fraser, 2008)	Student cohesiveness, Teacher support, Involvement, Young adult ethos, Task orientation, Cooperation, Differentiation, Computer usage
Constructivist-Oriented Learning Environment Survey (COLES)	(Aldridge, Fraser, Bell, & Dorman, 2012)	Student cohesiveness, Teacher support, Involvement, Young adult ethos, Personal relevance, Task orientation, Cooperation, Equity, Differentiation, Formative assessment, Assessment criteria

Laboratory Environment Inventory (SLEI), the Constructivist Learning Environment Survey (CLES) and What Is Happening In this Classroom (WIHIC).

A summary of the most prominent learning environment questionnaires, the level for which it was designed and the scales that are measured are presented in Table 1. These questionnaires have been a powerful tool to investigate the relationships between factors within the classroom environment and student outcomes (Fraser, 1994, 2012). They have also been effectively used as criteria to determine the efficacy of educational interventions (eg. Pickett & Fraser, 2009). Finally, they are often used by teachers to understand and improve their pedagogy in order to provide a more positive classroom environment (eg. Fraser & Fischer, 1986).

2 PLACE-BASED LEARNING

Many studies of learning environments have been of a quantitative nature. However, more recently both quantitative and qualitative methods have been combined to extend understanding of students' learning environments from both an alpha and beta press perspective (eg. Aldridge, Fraser, & Haung, 1999). Many of these studies have shown that students' perceptions of the learning environment are predictors for the educational outcomes that they achieve within that learning environment (Fraser, 2012).

One area which still needs more focus is the student's understanding of an interaction with the place when engaging in place-based learning. In the 1980s, place-based pedagogies were developed in a reaction to concerns that, due to globalization, students were becoming disconnected from the local communities, cultures and the ecological environments surrounding them in the places that they lived (Sobel, 1990). The goal of place-based learning is to actively engage students in interacting with their local communities through hands-on, real-world problem-solving, which leads to greater appreciation of the natural environment within which they live and a greater connectedness to local community (Sobel, 2004).

Many benefits have been observed when students engage with their communities and the local environment in their learning such as: the development of a greater appreciation for the ecosystems surrounding them (eg. Basile, 2000; Kenny, Price-Militana, & Horrocks-Donohue, 2003); greater engagement in learning of students of all abilities (Basile, 2000; Kenny et al., 2003); and more positive behaviour from students who were otherwise disaffected within the classroom (NEETF, 2005). Other benefits of place-based learning programs have been improved social and collaborative skills (Johnson & Johnson, 2003) and a more positive attitude towards the environment and greater understanding of our role in caring for that environment (Kenny et al., 2003).

Zandvliet (2012) recognised that a new learning environment's questionnaire was needed, which could be used to better understand those aspects of the place-based learning environment that supported these reported gains and that not only probed students' perceptions of the social aspects of their learning, but also determined their perceptions of the physical place in which they were learning. To this end, he combined scales from two well validated learning environment's inventories, the SLEI and WIHIC. To understand aspects of place-based learning related to the environment and outdoor learning, he also included scales from the Environment Science Learning Inventory (ESLEI) (Henderson & Reid, 2000) and the Science Outdoor Learning Environment Instrument (SOLEI) (Orion, Hofstein, Pinchas, & Giddings, 1997). After consultation with a series of focus groups consisting of various stakeholders, scales from other questionnaires such as the MCI and CLES were included resulting in the aptly named Place-based and Constructivist Environment Survey (PLACES).

PLACES consist of 40 questions measuring eight scales: relevance/integration, critical voice, student negotiation, group cohesiveness, student involvement, shared control, open-ended ness and environmental interaction (Zandvliet, 2012). Students indicate their perceptions of these questions on a five-point Likert scale ranging from Almost Always (5) to Almost Never (1). The survey was tested on 514 students Grade 9 and 10 students (20 classes) and was found to be reliable with Cronbach's alpha reliability scores ranging from 0.61 to 0.82 indicating internal consistency within individual scales (Zandvliet, 2012). Descriptions and examples of items form each scale taken from Zandvliet's seminal paper (2012) are presented in Table 2.

Table 2. Description and examples from scales of the PLACES instrument (Zandvliet, 2012).

Scale	Description	Example question
Relevance/Integration	The degree to which lessons are relevant to students and/or integrated with environmental and community-based activities	Lessons are supported with field experiences and other field-based activities
Critical voice	The degree to which students have a voice in classroom procedures and protocols	It's all right for me to openly express my opinion
Student negotiation	The degree to which students can be involved in influencing activities	Other students ask me to explain my ideas.
Group cohesiveness	The degree to which students know, help and support each other	Members of this class help one another during classroom activities
Student involvement	The degree to which students participate in class by being attentive, joining discussions, completing additional work and enjoying classes	I pay attention
Shared control	The degree to which the teacher allows students to choose activities and curriculum	I help the teacher to decide which activities I do
Open-endedness	The degree to which the teacher gives freedom to students to think about and plan how to address tasks	I am encouraged to think for myself
Environmental interaction	The degree to which students become involved with community-based or field work activities	Learning is very important for me during our field trips

An important study by Fraser and Rentoul (1980) has shown that students' learning outcomes are most positive when they are learning in an environment that is most closely aligned to their preferred learning environment. Thus two forms of the PLACES instrument were prepared, Actual PLACES and a Preferred PLACES inventory (Zandvliet, 2012). The preferred version investigates the student's ideal learning environment and is usually administered before learning begins while the actual instrument asks students to respond on the basis of their experience of that environment over a period of time (Ormond & Zandvliet, 2016). An example of an item from the Preferred PLACES instrument is: 'I want my lessons to be supported with field experiences and other field-based activities' (Ormond & Zandvliet, 2016).

Results from administering the Actual PLACES instrument showed that students generally had quite positive perceptions of their experiences during environmental place-based learning (Zandvliet, 2012). However, these perceptions were not as positive as students' ideal experiences as measured using the Preferred PLACES instrument which is consistent with other studies (Fraser, 2012). PLACES was also shown to be satisfactorily discriminate between perceptions of students in different classes and thus can be used as a powerful tool to interrogate the possible causes of these differences (Zandvliet, 2012).

An adapted form of PLACES was also developed for use in elementary schools to focus attention and improve place-based education programs, code named SMILES (Zandvliet, 2013). SMILES was effectively used by teachers in Canada to improve classroom practice after determining students' preferred learning environment using a preferred version of SMILES. For instance, after finding that the greatest gap between Preferred and Actual student perceptions from the SMILES instrument was in the scale of Shared Control, a teacher from this primary school focused on providing students with opportunities to determine classroom routines and activities. The Actual SMILES instrument was then administered again to determine if there was any change in students' perceptions of Shared Control (Zandvliet, 2013).

PLACES have not only been used effectively in the secondary setting but have also been studied in the higher-education setting. In this setting, it was used to understand the role of place-based learning environments in environmental education in teacher education and has been used to evaluate environmental education programs for teacher education (Ormond & Zandvliet, 2016). This study utilized Actual and Preferred versions of PLACES and also included student interview data after students engaged in an outdoor-based environmental studies program. Surprisingly, they found that students' actual and ideal perceptions of experiences were closely aligned and in fact, their actual experiences sometimes surpassed their preferred experiences (Ormond & Zandvliet, 2016).

In order to further understand students' experience of place and to compliment the PLACES instrument, Zandvliet (2014) developed a second instrument, the Structural, Physical and Campus Environment Survey (SPACES), to evaluate students' perceptions of built environment as sustainable learning environments to support place-based learning within the higher-education setting. Sustainable learning environments are classified as those that meet the needs of students, teachers and administrators and inform understanding of the culture and identity of the institution (Zandvliet, 2014). SPACES evaluate learners' perceptions of the special environment, scale and aesthetics, ambient factors, architectural elements and visual environment. Administration of both the PLACES and SPACES instruments revealed that students perceived having a Critical Voice in their learning as being the most important factor of their learning environment and valued feeling comfortable within their physical environment very highly (Zandvliet, 2014).

Despite the promise that place-based learning environment inventories such as PLACES and SMILES offer, there have only been a limited number of studies using these instruments.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

New directions in STEM education

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ABSTRACT: There is increasing global concern about the engagement of students with the STEM subjects, and the need for students to acquire the STEM skills necessary for participation in 21st century living and work futures. Calls for new directions in STEM Education amount to a re-thinking of the STEM subject disciplines. Drawing on an analysis of the discourse around STEM advocacy, this paper investigates the nature of drivers of a strong STEM interdisciplinary agenda, and the implications for school systems and for the STEM disciplinary subjects. An analysis of integrated STEM innovations in Australian schools raises questions about the relationship between authentic interdisciplinary STEM tasks and the nature of STEM subject epistemes. It is argued that the STEM subject disciplines in schools need to remain the basis of STEM learning, but need to be significantly re-thought if they are to answer the call for critical and creative thinking that underpins STEM advocacy.

1 INTRODUCTION: THE NATURE AND REACH OF STEM

The acronym "STEM" (Science, Mathematics, Engineering and Mathematics) has achieved wide currency in the English-speaking world as representative of a broad grouping of disciplines that are held to be related by common or interlinking practices. For instance, engineering design is informed by scientific evidence evidence (Honey, Pearson, & Schweingruber, 2014), and mathematics is central to science and engineering practices. The term was coined in 2001 and has since achieved global importance in policy advocacy related to school curricula, participation in higher education, and industry and research (Freeman, Marginson & Tytler, 2015). Yet the term is imprecise at a number of levels. In reporting on higher education participation, or on industry and research figures, 'STEM' sometimes includes agriculture, sometimes health and medicine, and sometimes not. In schools, STEM mainly refers to the core subjects of science and mathematics, and engineering is only recently becoming a feature of school STEM curricula, overlapping with design technology which has tended to be a longer-term curriculum presence but of lower status. In curriculum policy and schooling practice the term has taken on a variety of meanings:

- An emphasis on attracting more students into mathematics and science, as these subjects are seen as important for national workforce futures;
- Increasing emphasis on 'STEM skills' important in the fast changing world of work of the 21st century;
- An emphasis on creativity and critical thinking and problem solving, leading in a number of countries to advocacy of 'STEAM' curricula incorporating the creative arts and design;
- Promotion of digital technologies as a stand-alone subject or promoted across the curriculum;
- Inclusion of engineering activities including problem solving, project-based design activities, such as in the cross cutting concepts in the US Science Standards;
- Increasing emphasis on the world of STEM professional work, often including advocacy of school-industry-research partnerships;
- Interdisciplinary project work combining two or more of the STEM subjects, focused on problem solving in meaningful, 'authentic' contexts;

Thus, while 'STEM' has been adopted as a unifying construct focusing attention on this particular curriculum grouping, there are a number of dimensions to STEM advocacy that offer challenges to capturing its core meaning.

2 DRIVERS FOR THE FOCUS ON STEM

The arguments for a global focus on STEM in education, research and development are well rehearsed and widely recognised (Freeman, Marginson & Tytler, 2015). The key argument is that STEM knowledge and skills, and innovation in STEM, are central to national wealth creation. This position has been argued in high level reports in a number of western countries (COSEPUP, 2006; Office of the Chief Scientist, 2014), and is linked to concerns about a drop in numbers in the 'STEM pipeline' and an impending shortfall in the professional STEM workforce. The concern to increase numbers of students going into post compulsory STEM and to lift countries' ranking on global comparative assessments such as PISA and TIMSS reflects a belief in links between educational attainment, success in scientific R&D, and economic dynamism:

> "*In governments around the world it is believed there is a relationship between, on the one hand, national investment in STEM-related skills, and the quality and quantity of the national skill base, and, on the other hand, the economic productivity of the workforce … and research-based innovations in industry. There is no contemporary nation with an economy both vigorous and well-integrated that is not also strong in STEM (Freeman, Marginson & Tytler, 2015, p. 1).*"

In developing countries such as Indonesia, or Brazil, and also in the emerging Asian powerhouse economies such as Singapore, Korea and China, STEM Education is seen as an important plank in the pathway to national wealth (Freeman, Marginson & Tytler, 2015).

Flowing from this, 'STEM' has come to represent more than simply a grouping of subjects, but is now part of a distinctive discourse around a globalising economic modernisation agenda driven by the New Knowledge Economy. It has shifted the argument for school curricula towards a much tighter linking with national wealth creation agendas.

There are two aspects of STEM and economic modernisation that drive arguments for a an emphasis on STEM Education. The first is the growing importance of the STEM workforce for national prosperity. Second, is the changing nature of work.

2.1 *The STEM workforce needs*

The increasingly strong links between advocacy of STEM Education and national economic wellbeing are driven by perceptions of the increasing importance of STEM disciplines in developing the wealth creating workforce. The Australian Chief Scientist's Office (2014) claims that 75% of the fastest growing occupations require STEM skills (Office of the Chief Scientist, March 2014). "*The (STEM) fields and those who work in them are critical engines of innovation and growth: according to one recent estimate, while only about five percent of the U.S. workforce is employed in STEM fields, the STEM workforce accounts for more than fifty percent of the nation's sustained economic growth (Australia's Chief Scientist, 2012, p. 2).*"

In the US, most of the fastest growing occupations are predicted to involve STEM, particularly in computing, and health (Lacey & Wright, 2009). There is longstanding concern in the US with the future supply of STEM professionals and particularly engineers (COSEPUP, 2006). However, questions have been raised about claims of impending shortfalls of STEM professionals, and for some, the argument has shifted from a focus on STEM jobs, to a greater emphasis on the development of STEM competencies that are argued to be widely useful beyond the particular STEM professions. Further, questions have been raised about some of the predictions of shortfalls in STEM professionals, on the basis of widely different findings depending on definitions of STEM jobs (Oleson, Hora and Benbow, 2014). Recently, the US National Science Board (2015) questioned the simplicity of links made between a linear STEM pipeline and STEM professions, and argued a need instead to 'foster a strong, STEM-capable workforce' (p. 2).

2.2 *Work futures and STEM capabilities*

The world of work is changing rapidly, causing significant disruptions to patterns of jobs and changing the projected work futures for young people in schools today. They can no longer expect settled careers, but must focus on building skills that are marketable across a range of future jobs. "*A 15-year-old today will experience a portfolio career, potentially having 17 different jobs over five careers in their lifetime (FYA, 2017b, p. 3)*."

The drivers for these changes are largely understood, including trends of "globalization, technological progress and demographic change" (OECD 2017, p. 2). Key sites for technological progress are in "Big Data, artificial intelligence, the Internet of Things and ever-increasing computing power (p. 4)." Further to technological change are substantial natural world and social disruptions: climate change, urbanization, globalization, demographic changes, and population pressures.

Increasingly, this fourth industrial revolution (Schwab, 2016) has seen the shift from manufacturing and the loss of many repetitive jobs to machines. Over the next decades machines will change the nature of professional work such as accounting, office work, and even medical diagnosis. In a major future work study in Australia, Hajkowicz and colleagues (2016) emphasize the importance of education, of digital literacy, literacy and numeracy, and increased importance of new knowledge and skills. They argue for a change in focus for school education: "*The current education system teaches people to be effective in a highly structured system, but Australia's future workforce is likely to encounter much ambiguity and openness. For this reason, commentators argue that our future educational system will need to do more to encourage innovative, entrepreneurial and flexible mindsets (Hajkowicz et al, 2016, p. 87)*."

Consideration of these new work futures are thus driving a shift towards competency-based curriculum framing, and a focus on STEM skills. The US National Science Board (2015) talked about STEM capabilities in terms of disciplinary knowledge, and: "*STEM skills, such as complex problem solving, technology design, and programming; and STEM abilities, including deductive and inductive reasoning, mathematical reasoning, and facility with numbers (p. 8)*."

3 INTERDISCIPLINARY STEM

In the last few years, STEM advocacy has increasingly shifted towards advocacy of interdisciplinary curriculum practices built around authentic problems. The argument has a number of aspects: that interdisciplinarity reflects STEM innovative practice in the real world (although we need to acknowledge that interdisciplinary teams are to a large extent made up of disciplinary experts); that authentic problems will engage students in more meaningful learning; and that interdisciplinary projects can foster the develop the STEM capabilities of innovation and creative problem-solving, critical thinking, and collaborative team work, in ways that current pedagogical traditions do not.

Studies of interdisciplinary STEM in schools have uncovered a confusing picture of the curriculum and timetable arrangements characterised this work (Bybee, 2013). Vasquez (2015) and others distinguish between multi-disciplinarity, interdisciplinarity and transdisciplinarity in terms of the extent to which disciplines interact to create distinctive forms of 'meta-knowledge'. A major review of integrated STEM curricula in the US (Honey, Pearson & Schweingruber, 2014) found that while here was a gain in student attitudinal outcomes, there was little evidence of improved learning, especially for mathematics. They nevertheless argued for integrated approaches as having potential, alongside the individual subjects. Clarke (2014) argues that given the very different epistemic practices of the four STEM disciplines, in terms of the relations between truth claims and evidence, the discursive practices, and the material and conceptual tools used, interdisciplinary STEM may constitute a 'monumental category error'. Lehrer (2017) argues that while many integrated STEM activities may be engaging for students, they fail to attend to the progression in knowledge that characterises disciplinary subject arrangements. Nevertheless, meta-analyses of interdisciplinary mathematics education (Williams et al., 2016) have shown learning gains, "mainly for learning outcomes of affect, of problem-solving processes, and of metadisciplinarity (p. 17)."

Thus, there is evidence that interdisciplinary STEM can engage students and lead to meaningful learning, but are best considered alongside the subject disciplines if progression in knowledge is to be attended to. Progression seems particularly a problem for mathematics in interdisciplinary settings, but learning gains are in areas that are not generally valued in mathematics assessment processes. The contemporary focus on STEM capabilities have thrown up challenges for traditional approaches to content and pedagogy in school science and mathematics, so that advocacy of interdisciplinary STEM can be seen as a critique of 'practice as usual' in these subjects. In the final sections of this chapter I will draw on studies of two major Australian interdisciplinary professional learning programs to explore the challenges and possibilities of interdisciplinary STEM for mathematics in particular.

3.1 *Findings from Australian case studies*

This section draws on reports of research into two major Australian STEM professional learning programs, the 'STEM Enrichment Academy' run by the University of Sydney, and the 'Successful Students: STEM' program run by Deakin University. Both involved teachers of science, mathematics and technology from the one school attending workshops over at least a year, and being supported to introduce interdisciplinary curricula in their schools. They were supported in this by mentors, and the workshops included sharing across schools, and joint planning. Case studies were constructed of these programs through field notes, interviews with teachers and students and school leaders, and collection of student work samples [].

For both programs there was a variety of arrangements for interdisciplinary STEM work. These included: 1) inter-disciplinary project work involving two or three STEM subjects with teachers planning together, round topics such as space exploration (science of rocketry, mathematics of mars calendar or inter-planetary communication), often involving major design work such as an inner urban sustainable house, go-cart construction (science of motion, engineering design, mathematics of wheel size) or a school garden; 2) cross disciplinary project work within a single subject, for instance the design of a wheelchair ramp involving investigating motion and slope, structural design within a mathematics unit focused on measurement, geometry and trigonometry; 3) special STEM project activities such as competitions, industry visits; 4) a separate integrated STEM unit with teachers from different subjects consulted; and 5) a focus on incorporating progression in digital technology work across the curriculum.

The data showed (Tytler et al., in press) there were challenges in this curriculum innovation work arising from timetable restrictions, resistance from staff committed to disciplinary subject teaching and lack of planning time. Leadership both within the team and from school leaders was important to maintain the innovation. Teachers talked about the pleasure of working with colleagues from other disciplines, and the importance of sharing ideas across the network of schools. From a teaching and learning perspective, teachers talked about growing confidence with student centred, group-based pedagogies involving open questioning and exploratory tasks. Mathematics teachers experienced difficulty, but growing confidence, in designing inter-disciplinary tasks that involved mathematical problem solving and development of mathematical concepts. Initial problems, well represented in the literature, were with design tasks that involved mathematics only trivially, utilising well known mathematics such as counting, or tabular and graph work.

In terms of student outcomes, teachers perceived that students were more motivated and engaged more with learning, through these interdisciplinary projects, and claimed there was deeper learning as students were involved in solving fresh problems. There was, however, variation in the extent to which mathematics, for instance, broke new ground. In the ramp activity, teachers talked about the learning advantage of having students deal with their own data, the way in which new concepts arose such as recognition of a need for trigonometric relations, and also about how students gained insight into what it was like for people with disability, and how STEM contributes to generating solutions for them. Students, in interview, expressed enthusiasm for the fact that they could see the purpose of the mathematics and science they learnt, applied to real world problems. There was some indication of improved attitudes and aspirations with respect to STEM, although it is hard to say how this might translate in the longer term. Teachers described the advantage of introducing mathematics and science knowledge as it was needed for the interdisciplinary task, compared to introducing the necessary concepts weeks or months before, when again students could not see the relevance. Time is thus a key factor in establishing an advantage for disciplinary learning within interdisciplinary settings.

4 RESULT AND DISCUSSION

The acronym STEM has come to represent a globalising discourse centred on national economic agendas, that raises questions particularly about the nature of the curricula and pedagogies currently practiced in the high-status school STEM subjects of mathematics and science. Growing recognition of the importance of STEM capabilities in the workforce, beyond simply STEM professional pathways, and predictions of the rapidly changing nature of work, imply a need to reconfigure the school STEM curriculum to shift the focus towards STEM capabilities involving critical and creative thinking, problem solving and STEM-specific reasoning.

Advocacy of interdisciplinary STEM is built around a recognition of the need to focus learning on authentic, meaningful problems, and I argue that while this can involve the interaction of subjects, it can also apply to the nature of teaching and learning within mathematics, and science. Integrated approaches are often discussed in terms of a spatial metaphor of disciplinary overlap, but in the study described above, the 'meta-knowledge' associated with interdisciplinary activity had more to do with having students realise the nature of how the STEM subjects interact, such as the role of mathematics in framing thinking about measure, and patterns in science and engineering, or the way science knowledge is shaped and brought to bear on societal applications and engineering design.

As a curriculum principle this implies the need for clarity around the core epistemic practices of the STEM disciplines, and around how progression in these knowledges can be organised. We are currently engaged in research exploring pedagogies and conceptual progression in interdisciplinary mathematics and science. Underpinning the approach is recognition of representation construction and model-based reasoning as foundational to mathematics and science epistemic practices, and student reasoning and learning. In this we are extending our own work (Tytler, Prain, Hubber & Waldrip, 2013) and that of Lehrer and Schauble (**) to frame how these disciplines interact.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Novel written task as a formative assessment strategy in physics

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ABSTRACT: This study investigated the incorporation of a formative assessment strategy called the Novel Written Task (NWT) in Physics instructions and its impact on the cognitive learning achievement of seventy-eight Grade 10 students. The researcher-designed 5E lessons integrated the assessment activities in the three physics modules (Electricity and Magnetism, Electromagnetic Spectrum, and Optics). Achievement tests and short quizzes measured the effect of the intervention throughout the course. NWT results revealed low consistency in students' factual knowledge and reasoning, their misconceptions, common errors, and overgeneralizations. The students exhibited significant learning gains during formative and summative evaluations with small to large effect sizes. Findings also revealed meaningful improvement in the higher-order cognitive process skills of the students.

1 INTRODUCTION

Assessment is an integral part of teaching and learning (Shavelson, Young, Ayala, Brandon, Furtak, Ruiz-Primo, Tomita, & Yin, 2008), of curriculum implementation, and is vital to the education process (Centri for Educational Research and Innovation [CERI], 2008). Advanced view of assessment emphasizes the learning process and the holistic development of students' cognitive, affective, and conative abilities which, in contrary, the traditional concept of it lacks the qualities that can provide necessary information for teachers to take decisions about student needs and progress (Letina, 2014). In science, Fulmer, Chu Treagust, and Neumann (2015) identified an "ongoing tension" between one's ability to construct conventional test items (e.g. multiple choice questions) that can be highly reliable but perceived to be incapable of providing richer insights into students' conceptions and ways of thinking. The rise of alternative assessment, as a consequence of the paradigm shift on theories of learning from conservative to the constructivist perspective, does not really mean omitting the traditional assessment but rewording the questions in such a way as to address higher levels of learning. Correspondingly, assessment tasks maybe formatted in various ways that would require the students to apply skills and competence in the interpretation of scientific data and presentation of gathered data.

Two-tier assessment has been designed as a tool to evaluate scientific knowledge and skills as well as promote student learning. Examples of such include the two-tier multiple-choice (TTMC), open-ended two-tier items, items under Tasks Inspired by Physics Education Research (TIPER) namely Ranking Tasks, Working Backwards Tasks, and several others, and a variety of formative assessment probes. Various studies indicated that two-tier assessment generated better learning performance and achievement (Bulunuz et al., 2016; Yang et al., 2016).

Additionally, Hawkins, Frank, Thompson, Wittman, and Wemyss (2011) endeavored to vary the ways of questioning in physics tasks using alternative questioning strategies. They investigated student knowledge of electricity concept by employing four different questions known as the *correct traditional*, *incorrect traditional*, *given response*, and *given correct*. Their study showed that the questions provided information that can possibly impact physic instruction. Literature, however, indicates insufficient insights as regards the effect of this

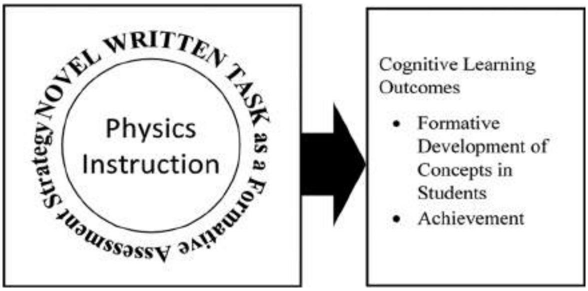

Figure 1. Framework of the study.

alternative format of assessment on student achievement. Particularly, there has been no evidence showing that the assessment format is used as a strategy to promote student learning. Thus, the present study hopes to range over the stated intentions.

The study delves on effective science learning that emerges from constructivist perspective integrating a 'formative use of assessment' perspective. The principle of formative use of assessment originated from Benjamin S. Bloom's *Learning for Mastery* (Guskey, 2005). Bloom, Hastings, and Madaus (1981) stated that the learning model helps students identify what they have learned well at a certain point and what they need to learn better (Guskey, 2005). With the information obtained from the formative activities, feedback, corrective, and enrichment process; and instructional alignment are performed. Constructivist in nature, inquiry-based learning cycle called 5E (engage, explore, explain, elaborate, and evaluate) instructional model can effectively facilitate learning in science. This model of learning embraces personal and social constructivist learning emphases (Yore, Anderson, & Shymansky, 2005) as well as embeds scientific investigation emphasizing science inquiry skills, diagnostic, formative, and summative assessment practices (Skamp & Peers, 2012).

As shown in Figure 1, the study utilizes the alternative questioning techniques by Hakwins et al. (2011) to create two-tier physics tasks called the Novel Written Tasks (NWT). The assessment strategy is deemed to provide students with information about the extent of their conceptual understanding and thinking through its two-tier format, checking system, and feed-backing. The varied questioning styles can disclose the depth and breadth of the students' ideas about physics concepts (Hawkins et al., 2011). The NWT instruction is expected to dispense opportunity for the students to compare their existing conceptions with the scientifically accepted reasoning, while the feed-backing is supposed to facilitate conceptual development which, in turn, enhance their achievement. Bell and Cowie (2001) supported this proposition as when a teacher takes into account, responds, and interacts both with their existing knowledge and thinking processes, the teacher is undertaking formative assessment while teaching for conceptual development. Consequently, it is expected to reinforce student-teacher and student-student interactions wherein the intention is to support learning and to further their understanding.

Thus, this study intends to find out how the Novel Written Tasks embedded as a formative assessment strategy in teaching Physics impact student achievement. Specifically, the study sought answers to the following objectives: 1) describe the formative development of concepts; and 2) determine the effects of the NWT on cognitive learning outcomes in terms of student achievement.

2 METHOD

The study utilized design and development research. Seventy-eight conveniently-selected Grade 10 students of a government-owned high school in Hagonoy, Bulacan, Philippines participated in the 16-week NWT assessment program. Preliminary profiling of the students who were pre-grouped into two classes showed similar entry level in terms of their knowledge about the physics topics. Between-groups comparison was not performed since both

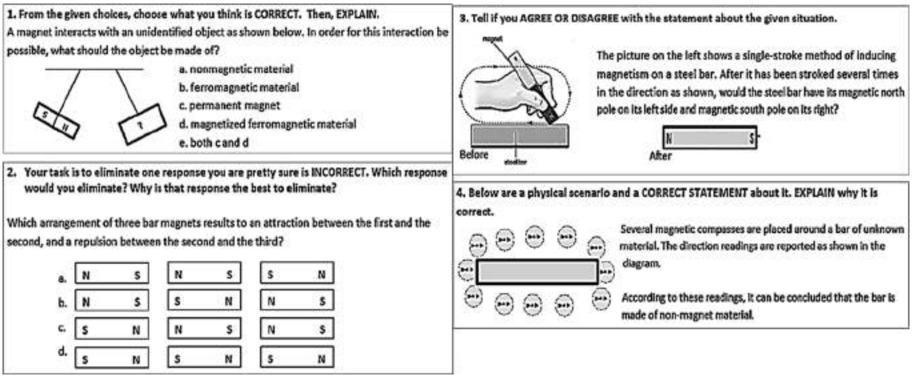

Figure 2. Sample NWT items.

groups received the NWT program; however data were collected and interpreted separately to check for the consistency of the effect of the program for each class. The research materials included the physics lesson plans, the assessment tasks, quick quizzes, and achievement tests. A pool of three physics experts determined the content validity of the research materials. In addition, thirty science teachers provided further evaluation of the NWT lessons.

During the development phase, a total of 13 lesson plans (five lessons in Electricity and Magnetism, two lessons in Electromagnetic Spectrum, and six lessons in Optics) served as another instrument for NWT implementation with the developed assessment tasks. The first NWT question called the *correct traditional* (CT) is the conventional multiple-choice item which focuses on the selection of correct answer. Students select the answer to a given question and provide justification for their answer. The second type is called the *incorrect traditional* (IT) wherein students eliminate one of the choices which they think is incorrect and justify their answer. The third item called the *given response* (GR) gives a specific response to a question which the students should agree or disagree with and explain their reasoning. The last task called the *given correct* (GC) explicitly states the correct answer and the students are asked to explain why it is correct. Figure 2 presents sample questions of the Novel Written Task. Through the adopted and modified rubric (Clarke & Clarke, 2002), the assessment tasks were evaluated against four levels where Level 1 signifies little progress or understanding evident; Level 2 shows students' attempt to make progress; Level 3 displays substantial progress or understanding; and Level 4 means full accomplishment of the task.

Prior to the program, the student knowledge of the selected physics concepts was determined. The sessions were delivered following the 5E instruction flow with inquiry-based learning activities. Then, students were asked to answer the NWT to assess their formative learning. The teacher evaluated the outputs and facilitated the feed-backing and corrective instruction based on the assessment outcomes. Quick quizzes given before and after the intervention provided data sets for the students' formative achievement. At the end of each lesson, students wrote a reflection journal about how their learning and understanding change and compare with and without the NWT. Finally, the students were post-tested to measure their summative achievement. Table 1 presents the summarized data analysis framework. Descriptive statistics were obtained to determine the extent, significance, and effect size of score variations. In addition, reflection papers were decoded and analyzed to determine overall theme and trends.

3 RESULT AND DISCUSSION

3.1 *Formative development of concepts in students*

Initially, we describe the performance of the students across the NWTs in the three modules. Table 2 reports that more than 50% of the two groups correctly selected the answers across

Table 1. Data analysis framework.

Phase	Data collection	Instrument		Data analysis
Implementation	Achievement	Quizzes, Tests	Summative	Score Increase Percentage t-test for repeated measures
	Students' Perceptions of their Understanding after the Formative Instructions	Reflection Write-ups		Overall Theme Thematic Analysis

Table 2. Level of progress across the NWT.

	Response (%)		Level of progress (%)				
CLASS A	Correct	Incorrect	4	3	2	1	0
Electricity and Magnetism	55.9	44.1	1.0	2.8	19.6	56.4	20.2
Electromagnetic Spectrum	71.8	28.2	3.6	12.3	20.9	40.0	23.2
Optics	50.1	49.9	3.5	5.8	14.2	57.1	19.4
Overall	56.8	43.2	2.6	5.9	17.2	54.0	20.3
CLASS B							
Electricity and Magnetism	50.5	49.5	2.0	3.3	14.5	54.7	25.5
Electromagnetic Spectrum	60.4	39.6	8.7	10.9	13.7	44.2	22.6
Optics	54.7	45.3	7.5	6.6	11.2	56.1	18.6
Overall	55.6	44.4	5.8	6.2	12.7	53.6	21.6

Legends: 1 = little progress; 2 = some progress; 3 = substantial progress; 4 = full understanding.

the tasks whether asked to select the correct choice, eliminate the incorrect choice, or agree or disagree with a given response. However, only about 25% of the responses were justified mostly within Level 2 and fewer within 3 and 4. These results clearly showed the low consistency between students' factual knowledge in tier 1 and the quality of their reasoning in tier 2. The students inconsistently select the correct answer and supply justifications to their answers with sound reasoning. Thus, most of the students were unsuccessful in demonstrating scientific physics concepts even after the activity-oriented, formative phases of the instructions.

During the class feed-backing, the teacher and the students engaged in more personal interactions which focused on their current understanding and thinking as revealed by their NWT performance and how they can better develop sound and scientific reasoning. Having the NWT results reported to the class, the students got the opportunity to resolve issues with their conceptions as well as to realize the support of the teacher and the other students in their learning. This part of instruction made the teaching more responsive to the needs of the individual students and of the whole class, actualizing assessment for learning. Also, it was observed that the students readily volunteered to share insights orally especially during the discussion of their narratives. Students who excelled in the tasks were also encouraged to share their ideas. The feed-backing and corrective instruction became student-driven, argumentative, and responsive. The observed classroom interactions were helpful to support conceptual development and learning of the students (Harlen, 2003 & Tytler, 2003).

The students' conceptions were evaluated from different perspectives with the NWT questions. The two-tier tasks, namely the correct traditional (CT), incorrect traditional (IT) and given response (GR) questions, revealed to the students that the class as a whole may have agreed in similar ideas in most cases but the quality of reasoning regarding these ideas greatly differed. They had identified contrasting beliefs about a given situation which triggered argumentative discussions between the believers of an answer and those who did not. Through the whole class deliberation, the acceptability of each other's reasoning was determined and existing difference and similarity between their reasoning and the scientific explanation was recognized. For CT, the students figured out the concepts that satisfy the criteria for choosing the correct answer and those false contents of the incorrect choices. For IT, misinformation in given choices were pointed out which eventually led them to the one that best answered a question. For GR, they were limited to express their reasons for a given response which either they believed or not and understood the reasons for the ideas which they initially disbelieved. The last task, which is the given correct (GC), established their strength or weakness in explaining an explicitly stated correct answer. Along the process, they realized that they needed to correct or modify the ideas they previously believed in.

Two-tier assessment methods do not only provide information about students' thinking but can actually facilitate students to develop deep thinking and deeper understanding (Bulunuz et al., 2014; Bulunuz et al., 2016; Yang et al., 2016). The written reflections of the students were suggestive to show that they had understood the concepts better after undergoing the NWT program. For instance, most students believed that the unknown object in the leftmost picture in Figure 3 was a nonmagnetic material because it did not attract the magnet. Students later realized that the objects repelled each other, and so there present was a repulsive force. A student wrote: "*Now I know that not only magnets but also magnetized ferromagnetic objects can repel each other.*" Likewise, another student stated: "*I understand now that if a force of repulsion acts between an object and a magnet, then the object may be a permanent magnet or a magnetized ferromagnetic material.*" Another fundamental concept is the pathway a light ray takes from the object to the eye. NWT showed that eight out of 10 students believed the flawed illustration. Obviously, the students thought that light rays were reflected off to the eyes directly from an object's image. At the end of the lesson, a student stated his realization: "*A line of sight with an object or image makes it possible to view it. But, the eye views the image by capturing the light ray reflected by the object off the mirror along the line where it seemed to come from the location of the image.*" Overall, the students' reflection journals implied what we perceive as indications of the effect of the NWT in developing conceptual understanding.

3.2 *Cognitive learning impact of the NWT in terms of achievement*

The students' realization on developing clearer understanding of the concepts is cross-checked with their performance in the given quizzes. Primarily, about 50 percent of the students were tracked with higher scores after the NWT instruction, 23 percent lower, and 27 percent neutral performance for section A and B across the 13 lessons. Both groups showed more improvement toward the middle and the last modules, more remarkably for section B. Also, we found that majority of the noted increase was demonstrated by underperforming students or those students tracked with performance below the 50% mark of the quiz prior to the NWT instruction. We found, on average, that 70% of the noted score gains were obtained by these students (7 of 10 gains in Module 1 and 3, and 4 in Module 2 for group A; and about 8 of 10 in Module 1, 5 in Module 2, and 7 in Module 3 for group B). The report generally suggests that several

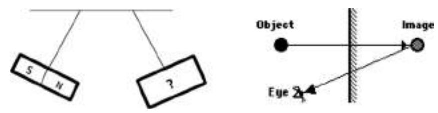

Figure 3. Magnetic interaction (left) and reflection (right).

students who generated gains initially started with lower achievement than the rest of the class. This may mean that we perceive a positive impact of formative assessment on student achievement especially to those low achievers (Black et al., 2004; Herman et al., 2006).

Further statistical analysis (Table 3) shows that post-evaluation means obtained by both groups are generally higher across the 13 physics lessons with eight significant mean differences for group A and five evaluations for group B at $\alpha = 0.05$. Of five lessons, Lesson 1.1 and Lesson 1.4 showed large effect sizes (0.78 and 0.66). Additionally, the two sections obtained meaningful score differences in Module 2. In the last module, group A exhibited significantly higher scores in all the lessons with small to large effect sizes. Group B showed meaningful gains in three lessons with reported substantial impact. The overall computed effect sizes of 0.39 for group A and 0.42 for group B estimated a moderate influence of the assessment strategy on learning. This size amounts higher than the small effect size of 0.25 determined from reviewed studies aligned with K to 12 (Kingston & Nash, 2009).

At the summative level, both groups demonstrated a significant change in achievement at the end of the three modules. Furthermore, computed overall effect sizes, 1.6 and 1.41 respectively, describes the very large effect of the NWT program on achievement. Meaning, that an ES of 2.07 (highest of section A) indicates that the group's pretest did not overlap with their posttest scores by 81.1% while that of B's 1.61, indicates that the pre- and post—scores do not overlap by 73.1%.

In account of the students' cognitive process skills as specified in the formative and summative evaluations, the groups demonstrated better thinking skills across the modules as reported in Table 5. The groups exceeded their ability to answer more challenging, higher-order questions. These overall gains and the NWT activities had shown some parallelism with each other as to what cognitive areas are improved by the students. We consider the attributes of the

Table 3. Formative evaluations before and after the NWT lessons.

	A				B			
Lesson	N	Mean diff	T	Effect size	N	Mean diff	T	Effect size
1.1	26	0.73	3.88*	0.78	31	0.29	1.12	0.20
1.2	34	0.03	0.10	0.02	33	0.36	1.58	0.28
1.3	33	0.33	1.38	0.25	35	0.40	1.67	0.28
1.4	34	0.12	0.38	0.27	24	0.92	3.18*	0.66
1.5	25	0.32	1.36	0.14	28	–0.21	–0.77	–0.14
2.1	22	0.18	0.68	0.14	28	0.21	0.92	0.17
2.2	30	1.13	3.29*	0.62	27	1.33	3.43*	0.66
3.1	31	0.58	2.30*	0.41	29	1.59	5.36*	1.00
3.2	29	0.66	3.62*	0.62	31	0.90	4.97*	0.91
3.3	31	0.97	3.46*	0.62	23	0.09	0.27	0.05
3.4	30	1.07	3.12*	0.57	31	0.52	1.81	0.32
3.5	37	0.16	0.78*	0.13	35	0.86	4.01*	0.68
3.6	31	0.74	2.53*	0.46	31	0.45	1.85	0.33

*Significant at $\alpha = 0.05$.

Table 4. Pretest and posttest achievement.

	A					B				
Module	N	Diff	SD	t	Effect	N	Diff	SD	T	Effect
Electricity and Magnetism	38	7.12	4.09	10.78*	2.07	36	7.31	4.79	9.16*	1.61
Electromagnetic Spectrum	37	4.05	3.24	7.61*	1.35	34	4.00	3.14	7.42*	1.38
Light: Mirrors and Lenses	38	6.45	4.42	8.99*	1.49	27	5.67	5.08	5.79*	1.24

*Significant at $\alpha = 0.05$.

Table 5. Comparison of students' cognitive process skills.

	Module 1			Module 2			Module 3		
Dimensions	Items	A	B	Items	A	B	Items	A	B
Formative									
Remembering	2	0.13	0.27	2	0.30	0.42*	9	0.67	1.50*
Understanding	17	1.19*	0.40	5	0.33	0.46*	9	0.73	0.83*
Applying	4	0.00	0.00				12	2.13*	1.42*
Analyzing	3	0.06	0.13	6	0.52	0.29	5	0.87*	0.20
Evaluating	3	0.19	–0.13	3	0.33*	0.25	1	0.00	0.42*
Summative									
Remembering	4	2.16*	1.78*	2	0.43*	0.38*	6	1.53*	1.44*
Understanding	12	2.97*	3.11*	5	1.49*	1.38*	5	1.26*	1.19*
Applying	3	1.05*	1.28*				10	2.71*	1.89*
Analyzing	3	0.26	0.42*	5	1.30*	1.53*	3	0.53*	1.00*
Evaluating	3	0.68*	0.72*	3	0.84*	0.71*	1	0.42*	0.19

*Significant at $\alpha = 0.05$.

NWT, having been characterized by experts as a rich assessment tool and learning-enriching task, to have played a vital part in developing the students' higher-order and critical thinking skills since the NWT covered a wide range of cognitive abilities instead of mere reproduction of facts (Swan & Burkhardt, 2014). Furthermore, the NWT had shifted the focus of the students to develop their reasoning and thinking skills rather than on answer getting.

4 CONCLUSION

The study aimed to determine how the Novel Written Tasks embedded as a formative assessment strategy in teaching Physics impact student achievement. Findings revealed that the NWT lessons adhered to the principles of inquiry-based learning with embedded assessment tasks perceived to potentially impact cognitive learning outcomes. The assessment outputs indicated inconsistency and low progress in students' conceptions and understanding of physics concepts. As to the results, students acknowledged changes in their conceptions and demonstrated better achievement at the formative and summative evaluations. At the forefront, the study has showed that the NWT program had a meaningful impact on student achievement. It provided further evidence on the learning benefits of formative assessment as an effective approach to promote learning. Taken together, the research findings conclude that embedding the NWT in physics instructions meaningfully increases achievement and reduces achievement gaps among students with emphasis on the benefits of the program among underperforming students. The two-tier assessment provides multitude of information about students' ideas and ways of thinking which makes it an effective tool for aligning actual learning with the standards. Thus, the NWT is a fair tool for assessing learning and assessing for learning. NWT-based feed-backing creates student-teacher, classroom interactions that help them clarify thinking and adjust their learning. In addition, the NWTs are facilitative in developing conceptual understanding as well as in honing higher-order thinking skills such as reasoning and critical thinking. Since the 'formative use of assessment' perspective in science teaching paves the way for conceptual development and learning success, feedbacks should focus on specific learning correctives to address the problem and align students' learning with the set standards. By involving the whole class into this assessment experience they become active and responsible participants of the learning process and develop deeper approach to learning.

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Profile of the spatial thinking of junior high school students using the concept of earth science

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ABSTRACT: Studies have already been done regarding the spatial thinking profiles in science learning. This study aims to discover the spatial thinking profiles of students. The participants are 8th graders (N = 63) at a junior high school in Cianjur, Indonesia. The instruments used are multiple choice questions. Data were analyzed by calculating the mean score. The results show that students' level of spatial thinking is low. Students' spatial thinking at the input level showed a medium criteria (52.38%), the process level of the spatial thinking showed low results (42.86%), while the spatial thinking at the output level showed a very low criteria (20.63%). This shows that there needs to be an improvement in the spatial thinking abilities of students. Applying spatial technology and developing teaching materials that engage spatial thinking are recommended.

1 INTRODUCTION

Science education in a junior high school combines the concepts of Biology, Physics, Chemistry and Earth Sciences. Among all of this content, the achievement of earth science concepts of Indonesian students is the lowest, based on TIMSS 2015 (Puspendik, 2016). Brusi et al. (2016) said that the main goal of the study of earth science is to promote a knowledge of earth science, which would enable students to understand the world around them and allow them to make responsible decisions, and also to provide information that enables them to act responsibly.

Rivet (2017) poses two challenges in earth science teaching. First, the size of the earth is very large compared to the size of the classroom. Second, earth-related processes work on time and spatial scales that are too large and long to be experienced during classroom learning. This means that certain spatial aspects need to be mastered by the students. Kastens et al. (2014) said that spatial thinking can help students to think more deeply about earth processes and understand the concept of earth science.

Spatial thinking in the context of earth science can be defined as the introduction, consideration, and knowledge of the processes and characteristics of the interconnections between the atmosphere, the lithosphere, the hydrosphere, the geosphere, the anthrosphere (human impact), and the biosphere on the scale and timeframe corresponding to the phenomenon studied (Kerski, 2008). Spatial thinking can be developed based on three aspects: (1) the concept of space; (2) the tools of representation; and (3) the process of reasoning (NRC, 2006; Jo & Bednarz, 2009).

Research shows that spatial thinking is important in science, especially in earth science. Nevertheless, the development of the spatial thinking ability of students is still rare. Students often find spatial questions difficult to answer. This is because teachers rarely offer learning strategies that would enable them to master spatial thinking. Students with a high level of spatial ability lack guidance and tend to get low grades. Also, textbooks that include spatial thinking rarely get much attention (Kastens et al., 2014).

Based on these findings, research needs to be done in order to reveal students' spatial thinking profiles. The purpose of this study is to get a picture of students' spatial thinking. The results of this study can be used to choose strategies that will help to improve spatial thinking.

Table 1. List of instruments' spatial thinking aspects.

No	Spatial thinking aspect		
	Reasoning processes	Concept of space	Representation
1	Input	Location	Block diagram
2	Process	Location	Map
3	Output	Location	Map

2 METHOD

This research uses a descriptive method. This study aims to determine the spatial thinking profiles of junior high school students in science. The participants in this study were 8th grade junior high school students (N = 63) in Cianjur, Indonesia. The participants were chosen because they had studied earth science concepts in 7th grade.

The instruments used in this study are questions presented in the form of a spatial thinking test, interviews and direct observation. The spatial thinking test was arranged by reconciling aspects of the reasoning process, the concept of space, and representations. The spatial thinking aspects of each question can be seen in Table 1.

Data were analyzed both quantitatively and qualitatively. The quantitative data was obtained by calculating the average or percentage of the students' spatial thinking results. The spatial thinking criteria used were ≤ 34 (very low); 35–50 (low); 51–65 (medium); 66–80 (high); ≥ 81 (very high) (Ermayanti et al., 2017).

3 RESULT AND DISCUSSION

The results show that students' level of spatial thinking is still very low. The results shown in Table 2 indicate that the students' spatial thinking at the input level showed a medium criteria (52.38%), the process level of the thinking process showed low results (42.86%), while the spatial thinking at the output level showed a very low criteria (20.63%). This shows that there is a need to improve spatial thinking at all levels of the reasoning process, but especially at the output level, which had the lowest results.

Spatial thinking with regards to the concept of earth science is very important. One of the reasons is that geotechnology development is growing very rapidly, such as GPS, navigation systems, and virtual globe software. Without spatial thinking, people will not be able to work proficiently with that technology (Kerski, 2008). Ermayanti., et al (2017) says that increased levels of spatial thinking can help to develop reasoning in related concepts. Students with low spatial abilities make more errors (Hegarty & Waller, 2005).

The results of the interviews and direct observations in the classroom show that learning activity does not support the development of spatial thinking. Teachers are often not stimulating enough to encourage spatial thinking and are also not familiar with spatial technology. They prefer to use books for teaching and do not provide the type of instruction that would allow spatial thinking to develop. Moreover, students are used to working on problems where they only need to rely on their memory rather than their thinking skills.

The level of students' spatial thinking needs to be developed. Current research supports the ideas that spatial thinking activities conducted on a regular basis can improve students' spatial thinking, that spatial thinking-oriented science activities have special attitudinal benefits for students, and that spatial thinking science activities can be developed in all of the science concept areas (life, earth, space, physical, technological) using various activity formats, such as hands-on activities, paper and pencil challenges, games, simulations, storylines, and imagineering (Mccormack, 2017). Unfortunately, research on spatial thinking is still very rare.

Research on spatial thinking in the context of earth science is dominated by the use of media, tools, and technology, for example, the use of the Geospatial Information System

Table 2. Students' spatial thinking results.

No	Result	Criteria
1	52.38%	Medium
2	42.86%	Low
3	20.63%	Very Low

Note: Very high (75–100); High (61–74); Medium (51–60); Low (35–50); Very Low (≤34).

(GIS) (Bodzin et al., 2013; Bodzin et al., 2014; Bodzin et al., 2015; Blank et al., 2016; Kulo & Bodzin, 2013), and 3D animation (Ermayanti et al., 2017).

Related research textbooks that support spatial thinking are still very rare. Scholtz et al. (2014) argue that textbooks that support spatial thinking are still very new. However, the study of textbooks that support spatial thinking by Subhani et al. (2017) proves that spatial thinking can be taught through instructional materials that are designed in a way that pays attention to spatial concepts.

Spatial thinking can be developed based on three aspects: (1) the concept of space; (2) the tools of representation; and (3) the process of reasoning (NRC, 2006; Jo & Bednarz, 2009). Integrating the three aspects of spatial thinking into teaching activities, such as using spatial technology, 3D animation, hands-on activities, paper and pencil challenges, games, simulations, storylines, and imagineering, and also developing spatial thinking teaching materials, will help to improve students' levels of spatial thinking.

4 CONCLUSION

The level of spatial thinking ability in students is low and there needs to be an improvement. The test results indicated that students' spatial thinking at the input level showed a medium criteria, at the process level of the thinking process it showed a low criteria, while spatial thinking at the output level showed a very low criteria. Some types of education research on the concept of earth science use spatial technology to improve spatial thinking. Others believe that the preparation of textbooks that are oriented on spatial thinking is worth trying. Integrating the three aspects of spatial thinking into teaching activities, such as using spatial technology, 3D animation, hands-on activities, paper and pencil challenges, games, simulations, storylines, and imagineering, and also developing spatial thinking teaching materials, will help to improve students' levels of spatial thinking.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Chemistry laboratory skills video: Design and development

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ABSTRACT: Laboratory work is the core of learning chemistry. Research has shown that students who are well prepared for laboratory classes and possess a high level of competency in laboratory skills are more likely to gain the maximum possible benefit. This development uses quantitative analysis by adapting the Kemp Model as an instructional design model. The video skills developed are how to use a thermometer, how to smell gas, how to make a standard solution from the stock solution, and how to make a standard solution from a solid. The results of the feasibility percentage, based on material and language expert tests, media expert tests and students' evaluations, are 92.27%, 91.45%, and mean 3.79 (SD = 0.463) respectively. The research is conducted in a chemistry education program, which is aimed at the freshmen who take the chemistry practicum I course. It is hoped that using a facilitated video in the pre-laboratory phase can be an aid to delivering prior knowledge, reducing the number of potential mistakes in laboratory skills and undertaking the practical lab work effectively.

1 INTRODUCTION

Laboratory work is a crucial component in learning chemistry; it helps students to understand the concept, proves the theories that are studied and is used to perform simple research. Moreover, the chemistry laboratory is used to provide students with chemical techniques, as well as to help students to understand the concepts (Tawfik, 2012). Laboratory experiments have been described as a 'necessary and important' part of science coursework, and they are purported to support many aspects of learning chemistry (Reid & Shah, 2007). Laboratory work has become a core component of any chemistry curriculum (Seery et al., 2017). Working in a laboratory is not the same as studying chemistry in a classroom; practicing in the lab demands a greater degree of activity and skill from the students. A student who knows and understands proper laboratory techniques will have an easier time when undertaking an experiment, be less stressed, work more safely, obtain results that match expectations and re-enforce the lessons learned in the lecture (Canal et al., 2016).

Working in the laboratory provides a unique learning environment, in that students physically manipulate the equipment with their hands—they are not sitting at a desk taking notes (Galloway & Bretz, 2015). When doing experiments, students need to have good basic laboratory skills so that the experiment is carried out in the most effective and meaningful way. Reid and Shah (2007) identify that one of the aims of laboratory work is to acquire good practical skills, which include handling equipment and chemicals, learning safe scientific practices, mastering specific techniques, measuring accurately, and observing carefully (Bruck & Towns, 2013). In order for students to acquire practical skills, they need to have clear and well-structured advice and guidance about how to undertake experimental tasks (Gasowska, 2015). Therefore, students need pre-laboratory activities to facilitate them in reasserting their prior knowledge regarding basic practical laboratory skills. Students who are well prepared for laboratory classes are more likely to successfully acquire laboratory skills and gain the maximum possible benefit from the laboratory learning environment (Gregory & Trapani, 2012).

Over the years, students have been, and still are, mentally prepared by the traditional short lectures that are presented at the start of the laboratory period, and also by demonstrations, reading assignments, graded quizzes, and other pre-laboratory assignments (Tawfik, 2008. Pre-laboratory preparations in universities were mostly carried out verbally by lecturers or laboratory assistants before conducting the practicum, but there were still students who used the wrong skills for their work. Consequently, the practicum did not work effectively. Based on the observations of first-year undergraduate students majoring in chemistry, most of the students appeared to be incapable of performing basic laboratory skills and did not understand the use of tools and the handling of hazardous chemicals.

1.1 *Observation of laboratory experience for undergraduate students*

Pre-laboratory activities cannot significantly change a student's perceptions of laboratory work (Spagnoli et al., 2017). In addition, approximately 37 percent of first-year university students majoring in chemistry have never undertaken a hands-on chemistry experiment during high school. According to the results of direct observations and interviews conducted with basic chemistry practicum assistants at universities, there was not sufficient time to demonstrate all of the basic laboratory skills during the pre-laboratory activity, and it was challenging to control the practicum skills of the students who were doing a basic chemistry practicum. The desire to earn a good grade and finish the work in as little time as possible led students to identify the avoidance of mistakes as an important goal in their lab work (DeKorver & Towns, 2015).

The results of a study involving high-level students show that there is a level of incompatibility between the faculty goals and the practical work objectives of the students. It also emphasizes that students must complete practical work as quickly as possible when they are working in a laboratory (DeKorver & Towns, 2016). Hence, there is no significant impact on increasing their knowledge and skills when doing experiments.

1.2 *Development of a chemistry laboratory skills video*

Based on the explanation above, this study aims to develop a demonstration video of practicum skills for use as a pre-laboratory stage in basic chemistry practicum I. This laboratory skills video will be developed for first-year chemistry students who have taken chemistry in their high school. This laboratory skills video will help students to visualize experiments that they have never done before, but not to completely understand the basic laboratory skills needed for the chemistry experiment. The simulation video is used at the pre-laboratory stage in order to prepare students for laboratory work by reducing the cognitive burden when working in the laboratory (Winberg & Berg, 2007; Jolley et al., 2016).

This laboratory skills video is presented with the concept of *don't* and *do*. It aims to induce a cognitive conflict that will challenge students to alter their misconceptions. A student who experiences a cognitive conflict will experience a change in concept (changes in cognitive structure). This leads to an improvement in the occurrence of misconceptions by using the right strategy (Arief & Suyono, 2012). The development of a basic laboratory video emphasizes how to perform basic skills in basic chemistry practicum. It can therefore be an alternative solution for improving students' psychomotor knowledge in the laboratory. It is hoped that using a facilitated video in the pre-laboratory phase can be an aid to reducing the potential mistakes in laboratory skills and undertaking the practical lab work more effectively.

2 METHOD

2.1 *Respondents*

Four experts from the area of chemistry laboratory content and three experts of instructional design were selected as validators for the connoisseur-based study. They evaluated the chemistry laboratory skills video with regards to the pedagogical content of the basic laboratory skills for first-year undergraduate students, instructional design, validity, and the reliability of the video.

Sixty-five students majoring in chemistry and chemistry education were selected as the respondents for the objectives-based study, in order to investigate the effect of watching a

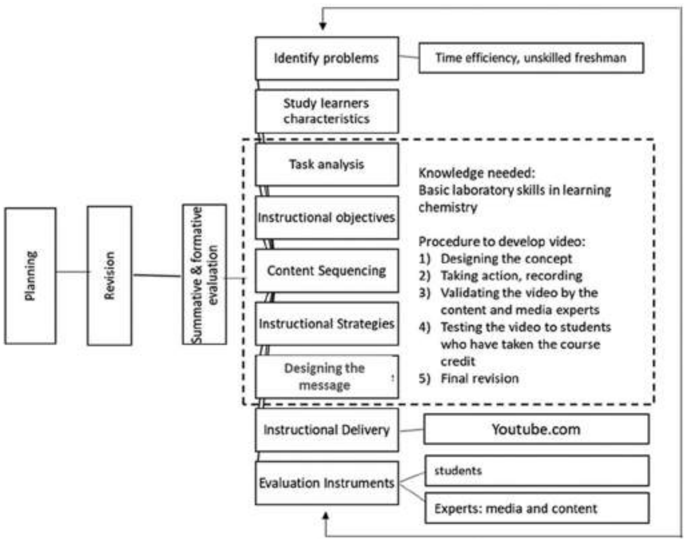

Figure 1. Design and development process (Kemp Model, 1994).

laboratory skills video on the reduction in the potential mistakes in laboratory skills and the effectiveness in undertaking practical lab work. There were ten respondents for small-group trial and 55 respondents for field-group trial All of the respondents were students in their third semester who had taken a basic chemistry laboratory course in their first semester.

2.2 *Design research and procedure*

In this study, we develop a basic laboratory skills video for use as an additional or supplemental tool in pre-laboratory activities by applying the Kemp Model (1994) as the instructional design model. The Kemp Model describes elements, rather than steps, stages, levels or any following items in instructional design (Kemp, J.E., Morrison, G.R. & Ross, S.V., 2004). This non-linear model with no start or end point defines nine different components that indicate the independence of the elements in the model. All the processes of designing, developing, implementing and evaluating can be done concurrently and continuously (Tien Lee & Osman, 2012). The Kemp Model is particularly useful for developing an instructional program that mixes technology, pedagogy, and content in order to deliver effective, reliable and efficient learning (Ibrahim, 2015).

In order to develop a basic laboratory skills video, we needed to identify instructional problems in a subject chosen from the basic chemistry laboratory course (Lee T.T. & Osman K., 2010; Lee T. & Osman, 2012) and also recognize learners' characteristics (Lee T.T. & Osman K., 2012; Tien Lee & Osman, 2012). Then, we could analyse the related goals and purpose of the basic laboratory content. The three following steps are about developing the video content. Next, we designed the evaluation instruments in order to assess the students' understanding in each section. When everything was done, a formative evaluation questionnaire was carried out to evaluate the basic laboratory skills video that had been developed.

2.3 *Materials*

The materials used in this study are the basic laboratory skills video, students' questionnaire, and video validation by experts.

2.4 *Chemistry laboratory skills video*

The basic laboratory skills video was developed based on analyzing the subject content in the basic chemistry practicum course I. It was also based on the student's needs, which were

Table 1. The subtopics of the basic chemistry practicum course.

Experiment	Experiment activity	Video	Laboratory skills involved
Basic skills at the laboratory	Introduce some types of chemistry equipment and how to use them	How to use thermometer	Reading the thermometer scale; Utilizing the thermometer for hot solutions
	Making and introducing a gas	How to smell gas	Heating the test tube; Smelling the gas properly
	Dilution with a measuring flask	How to make a standard solution from the stock solution How to make a standard solution from a solid	Dissolving solids; Determining the fluid meniscus in volumetric gas; Swirling the solution in a measuring flask
	Diluting H_2SO_4		
	Filtering		
	Acid-base titration		

discovered from the survey undertaken while conducting the observation. Each video contains an introduction, by delivering the aims of the video to be presented, the content, which is modified with a 'don't and do' strategy, and the summary, which is the final part of the video. Four basic laboratory skills videos have been developed, as summarized in Table 1.

2.5 *Validity questionnaire*

A video validity questionnaire was developed with the use of instructional media in Universitas Negeri Jakarta. There are two types of validity questionnaire: basic chemistry laboratory content and technical qualification.

2.6 *Evaluation questionnaire*

A video evaluation questionnaire was utilized to evaluate the quality of the module, based on some of the components in the video. This questionnaire included assessment of the content and the appearance of the video. The questionnaire was given to students so that the quality of the video could be considered from their perspective.

3 RESULT AND DISCUSSION

3.1 *Chemistry laboratory skills video*

The chemistry laboratory skills video consisted of an opening section, the main content, which applied cognitive conflict to enhance the students' potential in chemistry experiments, and a closing section. Cognitive conflict activity was added by applying 'do' and 'don't' strategies in the video. First, the video presented the common mistakes made when undertaking laboratory skills, which paid special attention to inducing cognitive conflict to students' prior knowledge. Then, in the following section, the appropriate laboratory skills were displayed. It is hoped that using a facilitated video in the pre-laboratory phase can be an aid to reducing the potential mistakes made in laboratory skills and allowing the practical lab work to be undertaken effectively.

3.2 *Video validation*

A video validity questionnaire was administered to experts in order to evaluate the module with regards to the content and technical validity. All of the items in the questionnaire were

Figure 2. Opening video (introducing the tools utilized).

Figure 3. Closing video (reviewing the material).

Figure 4. Presenting the proper laboratory skills.

Figure 5. Presenting incorrect laboratory skills.

Table 2. Feasibility test by four media experts.

Aspects	Indicator	% per item	% per sub aspect	Criteria
Audio quality	Sound	91.67%	86.46%	Very good
	Music	81.25%		
Visual quality	Presenter appearance	85.42%	90.28%	Very good
	Writing	93.75%		
	Pictures/animations	91.67%		
Program attractiveness	Program presentation format	94.79%	94.79%	Very good
Total			91.45%	Very good

constructed by using instructional media at the university. The data collected was processed by summing it up and then comparing the number and percentage obtained to the expected amount (Arikunto, 2006). Afterwards, the qualification of the video was determined by using the Likert scale. Both the content and technical areas showed an excellent criteria, which shows that this video is valid and is qualified to enhance student learning during pre-laboratory activity. The value of each characteristic of the videos validity is summarized in Table 2 and Table 3.

3.3 *Quality of the chemistry laboratory skills video*

The video questionnaire used for evaluating the quality of the video was assigned to students who took the basic chemistry practicum I course in their first year. The questionnaire was shown to have an acceptable validity and reliability (Cronbach's alpha = 0.828) and can be used to examine the quality of any learning tools, such as video. The students rated the chemistry laboratory skills video as high quality, with a mean of 3.79 (SD = 0.463). Means for all of the components in the basic chemistry laboratory video are shown in Table 4.

Table 3. Feasibility test by three experts of content laboratory skills.

Quality type	Aspects	% per item	% per sub aspect	Criteria
Quality of content and aim	The accuracy of the material	92%		
	Balance	87.50%	89.58%	Very good
	Interest/attention	91.67%		
	According to student needs	87.50%		
Instructional quality	Provide learning opportunities and assistance	100%	98.33%	Very good
	Impact on learning	97%		
Technical quality	Ease of use	91.67%	88.89%	Very good
	Program management	87.50%		
Total			92.27%	Very good

Table 4. Mean scores in the video evaluation from the students' questionnaire.

Type quality	Aspects	Category	Mean	SD	Quality
Technical quality	Quality of views/ impressions	Overall clarity of the displayed image	3.75	0.440	High
		Narrator's voice clarity	3.64	0.522	High
		Sound volume quality	3.69	0.466	High
		Suitability between size, color, and typewriting	3.76	0.429	High
	Quality of management program	The accuracy of the length of the video duration	3.76	0.429	High
	Easy used	Easiness of video flow to be understood (rational)	3.80	0.404	High
		Easiness to access	3.51	0.505	High
		Easiness of understanding video material	3.65	0.480	High
Instructional quality	Provide learning assistance	Video capabilities to help students in the pre-laboratory stage	3.51	0.505	High
	Impact induced on students and their learning	Video capabilities in giving prior knowledge regarding basic laboratory skills for first-year students	3.64	0.485	High
		Video capability to prevent errors in practicum	3.73	0.449	High
Content quality and aims	Interest and attention	Student interest in video	3.53	0.504	High
	The accuracy of the material content	The clarity of information in the introduction	3.64	0.485	High
		Clarity of the material displayed on the video	3.78	0.417	High
	Suitability to student situations	The suitability of information on videos with the cognitive domain	3.75	0.440	High
		The suitability of the language used in the video for first-year students	3.73	0.449	High
Total			3.679	0.463	High

3.4 *Discussion*

The most important thing in multimedia is how the multimedia elements are used to express the content in a meaningful way and, hence, to deliver it effectively to users (Tien Lee & Osman, 2012). The technical elements used in the chemistry laboratory skills video were text, graphics, simple animation, contrast, audio, and narrator appearance. All of these elements were verified as having very good media output in the validation questionnaire. The media experts gave the highest percentage rating to the overall format of the video presentation.

Regarding the video's substance, the four content experts confidently stated that the video of basic chemistry skills could provide learning opportunities and assistance before the practicum is conducted. One of the essential keys in laboratory teaching is to prepare students' minds for learning new concepts, as well as learning new skills (Tawfik, 2008). Videos of basic chemistry skills are useful and helpful in order to visualize unknown experiments, so that students are more familiar with the skills needed in the laboratory when they are learning new concepts. Students also prefer to see videos that are true to what they will experience in the laboratory (Canal et al., 2016). Through videos, students can identify the critical part of the content and this will help them to prepare notes during the learning process.

The evaluation questionnaire showed that this chemistry laboratory skills video had the capability to give prior knowledge regarding basic laboratory skills to first-year students. Over the years, students have been, and still are, mentally prepared by the traditional short lectures that are presented at the start of the laboratory period, and also by demonstrations, reading assignments, graded quizzes, and other pre-laboratory assignments. The laboratory videos that were developed have been shown to be a useful tool in improving the students' laboratory learning experience, because the students are able to watch and repeat it as many times as they need to in order to enhance their understanding. Most students felt that they had a deeper understanding of the experiment/theory due to the videos, indicating that they felt more confident about the experiment having watched the instructional videos before attending the laboratory (Canal et al., 2016).

Moreover, the 'don't and do' concept that was applied in each video was shown to prevent errors during the practicum. It is argued that, in order to change the students' incorrect concepts, we need to generate a sense of student dissatisfaction with the concept. This can be caused by showing them an anomaly or event that is contrary to what is in the student's mind. Displaying conflict activities (don't) causes dissatisfaction with a concept. This means that students can remember the correct skills (do) for longer.

We considered the corrections, suggestions, and recommendations made by the students and the experts. For instance, some of the text was too small, which made it difficult to read it on a smartphone, and some of the sound, especially of the presenter, was unclear and should be fixed.

4 CONCLUSION

The basic laboratory skills video has been made, and the formative evaluation has been carried out through objectives-based study and connoisseur-based study, involving 65undergraduate students, four media experts, and three content chemistry laboratory experts. The connoisseur-based study has proven that the basic laboratory skills video is valid, that it has an excellent technical appearance and very good substance, which has been verified by the content experts. The objectives-based study has proven that the laboratory videos developed have been shown to be an effective tool in improving students' laboratory learning experience during the pre-laboratory phase because they are able to watch and repeat it as many times as they need to in order to enhance their understanding. Most students felt that they had a deeper understanding of the experiment/theory due to the videos. Besides that, the 'don't and do' concept contained in the videos helped to prevent the students' from making skill errors when experimenting. Consequently, the practicum runs more smoothly and effectively, and becomes more meaningful.

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Students' cognitive structure with regard to chemistry concepts through the Learning Cycle 8E approach

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ABSTRACT: This study aims to analyze the students' cognitive structure regarding acid-base material in grade 11 through using the Learning Cycle 8E approach. The Learning Cycle 8E consists of engagement, exploration, e-search, elaboration, exchange, extension, evaluation, and explanation. The research employed a qualitative approach with a free word association test during the stages of exploration, elaboration, extension, and explanation, while concept mapping was used at the end of the lesson. Then, interviews and observations took place at the end of each meeting. The data analysis of reduction, presentation, and verification was conducted in order to portray the students' cognitive structure. The findings indicated that the students developed their conceptual understanding in each stage of the Learning Cycle 8E. Learning Cycle 8E had an impact on the improvement of the students' cognitive structure and on the decrease in the students' misconceptions. Therefore, chemistry teachers can employ the Learning Cycle 8E in order to improve their students understanding and help them to overcome misconceptions.

1 INTRODUCTION

Since Curriculum 2013 was applied in Indonesia, the government has provided cross-interest subjects for those majoring in science and social science. These cross-interest subjects are based on school policy and not on the students' interests. Therefore, each school has different cross-interest subjects. In this research, the school decided on Biology and Chemistry as cross-interest subjects for social science students. The characteristics of social science students are very different, in terms of affective, cognitive, and psychomotor skills, than those of science students. It was these differences that made the researchers want to examine how the cognitive structure of social science students developed when studying chemistry. The preliminary observation of the data regarding the characteristics of social science students in grade 11 showed that they were less active and less motivated when studying chemistry, because some students considered chemistry to be an unimportant subject and unrelated to their goals in life. These challenging reasons attracted the researcher to analyze their cognitive structure by applying the Learning Cycle 8E, which has a complex cycle that can be used to develop their understanding and cognitive structure. The results of this research can be useful for teachers in planning their learning activities for social students.

1.1 *Learning Cycle 8E*

The Learning Cycle 8E approach comes from the development of learning cycles 3E, 5E and 7E (Ridwan & Rahmawati, 2016). The Learning Cycle itself is a learning model that uses the constructivist theory that has been implemented since 1960 by Karbles and colleagues in the first level of the science curriculum (Qarareh, 2012). The Learning Cycle initially consisted of 3 stages: exploration, reaching a concept, and application. But as the process of teaching and learning science developed, the Learning Cycle evolved into 4 stages: exploration, explanation, elaboration, and evaluation. The Biological Science Curriculum Study (BSCS) in 1993 developed a constructivist research method called Learning Cycle 5E, consisting of (1) engagement, (2) exploration, (3) explanation, (4) elaboration, and (5) evaluation (David, 2003; Khataybeh, 2005). This learning model places the teacher as a facilitator so that students can explore their abilities and be more active in learning and expressing their opinions. The Learning Cycle 8E approach consists of (1) engage, (2) explore, (3) e-search, (4) elaborate, (5) exchange, (6) extend, (7) evaluate, and (8) explain. During the engage stage, the teacher gives a case study to the students at the beginning of the lesson. In the explore stage, the teacher undertakes an exploration of the students' pre-knowledge using self-reflection, relating the learning material to daily life, and the students' understanding. The e-search stage is the stage where students search various learning sources for information about the material. In the elaborate stage, students reflect on their pre-knowledge using existing learning resources. In the exchange stage, teachers form groups and the students conduct discussions on given case studies. Students undertake this group work to convey their ideas and negotiate with other students so that they can develop their knowledge. In the extend stage, students are able to apply their new knowledge in different situations. Students associate, compare, and prove their pre-knowledge using the new knowledge they obtained in the previous stage. In the evaluate stage, the teacher and students conduct an interactive discussion that contains questions and answers about the given case study and the material that is studied. Then the teacher provides feedback related to the learning materials used on that day. In the explain stage, the teachers randomly select students who will describe their understanding (Ridwan & Rahmawati, 2016). This research uses the Learning Cycle 8E approach, rather than 3E, 5E, or 7E, because Learning Cycle 8E contains e-search and exchange, which helps to develop students' understanding by using both self and group study.

1.2 *Cognitive structure*

This research will analyze social science students' cognitive structure in characteristics of acid-base. Cognitive structure can explain students' understanding of alternative concepts. Cognitive structures can also explain what concepts in a chapter are generally understood by students. The cognitive structure provides a stable and organized framework for building new knowledge. Students' cognitive structures can reveal 'what students learn' and 'how students learn' (Atabek, 2015). The cognitive structure of the students can be analyzed using several techniques: multiple choice two-tier tests, drawing, interviews, word association tests, structured grids, diagnostic trees, concept mapping, conceptual change texts, analogy, prediction-observation-explanation, and other techniques (Kurt et al., 2013). The technique of using word association tests is a trusted method of determining the cognitive structure of the student because it is able to explore aspects of the content and structure of the student's knowledge of specific material, reveal the types and several concepts in the student's cognitive structure, and the relationship between the concepts (Drechsler & Schmidt, 2005). The other technique that is used in the research is concept mapping, which is based on the validation of experts and has the aim of helping to develop teaching aids (Sisovic & Bojovic, 2000), helping students to understand how concepts relate to each other, discovering how to develop one concept along with other concepts, and helping students to deepen their overall knowledge of chemistry (Kurt et al., 2013). Concept maps can be used as a technique for either qualitative or quantitative analysis. The structural framework of this research relied on the qualitative analysis of concept maps (Kinchin et al., 2000). Students and teachers benefit from using concept maps, since they can develop new meanings and relationships in different types of interpretation such as circular, hub or spoke, and tree (Kinchin et al., 2000; Vanides et al., 2005).

1.3 *Acid-base*

This research chose acid-base material because this is one of the materials that is contextual, as it is related to our daily life. Some studies suggest that upper secondary students have an incomplete understanding of acid-base material. Drechsler and Schmidt (2005) found that students lack an understanding of chemistry because, in their minds, chemistry is seen as an abstract and unstructured subject. The study explains that students have not been able to link the concept of chemistry with their daily life. In fact, it is important to learn and understand the concept of chemistry because it is very useful and can be related to our daily life. If students do not have a complete understanding then this will have an impact on the emergence of misconceptions. Sheppard's (2006) study explains that students lack an understanding of acid-base characteristics, both in theoretical and pH descriptions, while Nyachwaya's (2016) study suggests that students' still lack an understanding of the concept of acid-base reactions, especially on the right species that involved, symbol, and submicroscopic representation. The concept of acid-base in chemistry is known to be a difficult concept to understand at secondary school level (Demircioglu et al., 2005). Students need to have an extensive pre-knowledge and understanding of the concept of acid-base because these materials involve an understanding of the concepts of different areas of chemistry, chemical equilibrium, chemical reactions, stoichiometry, material characteristics, and chemical solutions (Sheppard, 2006).

2 METHODOLOGY

This study aims to analyze the cognitive structure of students with regard to acid-base material by using the Learning Cycle 8E. The research method used in this study is qualitative descriptive. This method is based on image and text data, which has unique analysis stages as well as diverse image designs (Creswell, 2014). In this research method, an interpretive paradigm was used by looking at reality as subjective, created, and found. This paradigm was used for the purpose of interpreting and understanding a phenomenon, which is done by interpreting a fact as something unique and contextual (Thanh & Thanh, 2015). This research was conducted on social science students in grade 11, and the total number of students was 36. Data that was taken during the study using free word association tests and concept mapping techniques was used to examine the students' cognitive structure (Drechsler & Schmidt, 2005) and this was reviewed by interview. Free word association tests were undertaken in the explore, elaborate, extend, and explain stages of the Learning Cycle 8E, while concept mapping was done at the end of the learning material. The study analyzed the cognitive structure of social science students with regard to acid-base material, and this consisted of a preliminary stage, preliminary research, conducting research, data analysis, and a conclusion of the result. The research procedure consisted of 4 stages: preliminary, preliminary research, research implementation, and final research. In the preliminary stage, we observed the school and students and then took preliminary data. The initial stage of the research was done by searching and making the instrument for the study. The implementation of the research was done by observing the students' cognitive structure by applying the Learning Cycle 8E approach and collecting the resulting data. In the final stage of the study, we conducted a data analysis and drew conclusions based on these data. The data from the free word association test will give three categories of student, which are 'understand', 'misconception', and 'did not understand'. The structure of the cognitive data from the concept maps will display whether the student has a complex understanding of the material or whether they lack understanding. The concept maps were analyzed and investigated for their complexity and holistic structure. Observing students' concept maps, which are complex networks or simple networks, can help the teacher to evaluate the students' understanding (Yaman & Ayas, 2015).

3 RESULT AND DISCUSSION

This study aimed to analyze the cognitive structure of social science students in grade 11 with regard to acid-base material by using the Learning Cycle 8E approach. In the learning process, the acid-base material was divided into three sub-topics, which are the characteristics, indicator, and strength of the acid-base. Chemistry classes were held twice a week.

Learning activities began with the provision of worksheets that contained certain stages according to the principles of the Learning Cycle 8E.

3.1 *Learning Cycle 8E approach*

This study used the Learning Cycle 8E model, which has eight stages of learning in each sub-topic of the acid-base material. The acid-base material in this study was divided into three sub-topics: acid-base characteristics, the acid-base indicator, and acid-base strength. Each sub-topic implemented one cycle of the Learning Cycle 8E approach. Data that was obtained during the learning process through free word association techniques was grouped into three categories of understanding. The three categories of understanding in this study are 'understand', 'misconception', and 'did not understand'. The data obtained through free word association techniques was taken during the explore, elaborate, extend, and explain stages.

A student worksheet was used to obtain the data and this was given before the lesson began. This worksheet consisted of 8 stages, so that teachers could understand and analyze the students' thinking in each sub-topic of the acid-base material. Teachers found that there were obstacles to implementing this approach when students did not have any initial thoughts or pre-knowledge about the sub-topic, which meant that they could not analyze the case study. This happened in the acid-base strength sub-topic. There were 47% of students who were categorized as 'did not understand', because the students did not write words and sentences in the table used in the free word association tests. Because of this, teachers will have difficulty in directing students to the next stage, because the students do not have an initial understanding of the sub-topic. This problem occurred because the students did not study the sub-topic at home or did not get any material on acid-base strength at junior high school.

3.2 *Students' cognitive structure*

Information regarding the students' cognitive structure was obtained after all of the sub-topics of the acid-base material had been taught, and this data can be a source of information for the teacher. Acid has several characteristics, for example it can react with metals such as iron and zinc to produce H_2 gas and change the color of blue litmus to red. Also, the base is slippery and turns the red litmus to blue (McMurry et al., 2014). Based on interviews that were conducted by the researchers, students were able to explain the characteristics of the acid-base. This can be proved by several students' statements below.

> "The acid is acidic, I have ever done an experiment in junior high school if it turns the blue litmus red and the base changes the red litmus to blue."
> (Student 02, January 17, 2017)

> "According to Arrhenius's theory, the acid produces hydrogen ions when dissolved in water while the base produces hydroxide ions when dissolved in water. According to the Bronsted-Lowry theory the acid produces protons while the base receives the proton."
> (Student 30, January 17, 2017)

The interview statements indicate that the students have understood the sub-topic of acid and base characteristics. Student 02 had understood acid-base since junior high school, while student 30 described acid-base characteristics based on the theory that had already been taught by the teacher. Besides the interviews, the cognitive structure data was also collected by using free word association tests and by using worksheets at the explore and elaborate stages of the acid-base strength sub-topic.

Students that did not write words and sentences during the explore stage were categorized as 'did not understand', but if the students could explain the sub-topic correctly they were placed in the 'understand' category. However, if students wrote an explanation that did not match with the textbook or with expert validation, they were placed in the 'misconception' category. According to student 34's free word association test, shown in Table 1 above, the

Table 1. Student 34's acid-base strength table in the elaborate stage.

	Sentences	Words
Acid-base strength	Acid-base strength affects by the quantity of H^+ ions that produced by it compound in the solution.	Solution H^+ ion

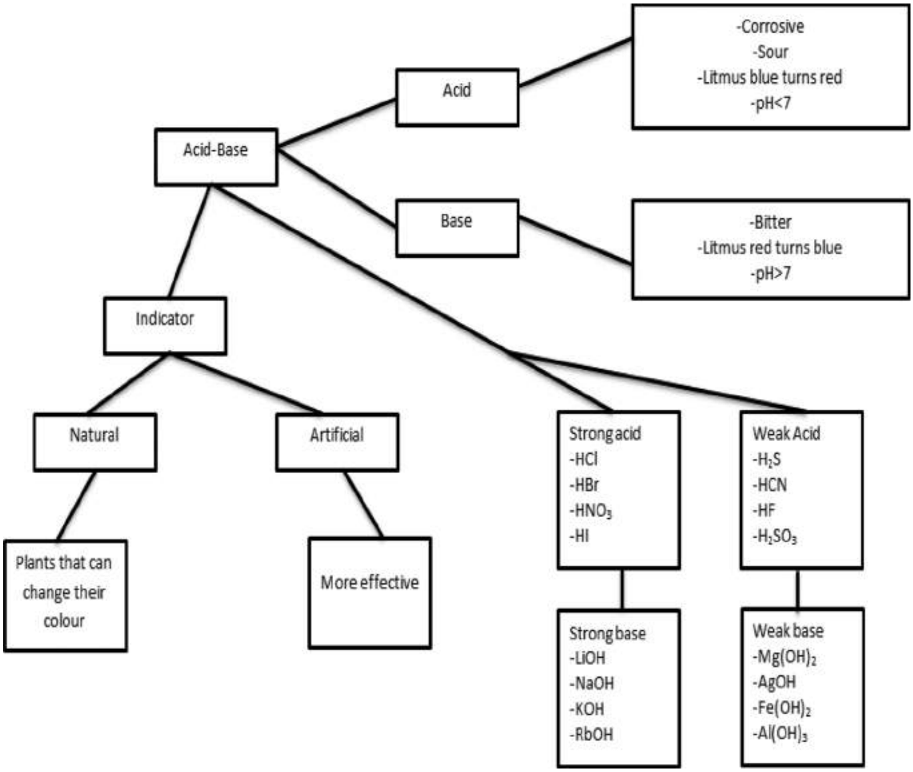

Figure 1. Student 6's concept map.

concept of acid-base strength was influenced by the amount of H + ions that were produced by acidic compounds in the solution. This is consistent with Takeuchi (2006), who explains that strong acids and bases will dissociate perfectly to produce H + and OH ions, while weak acids and bases only partially dissociate or remain as neutral species.

The students' cognitive structure can be identified by using concept maps, as well as free word association tests (Kurt et al., 2013). Concept maps can be used as learning aids that connect various concepts, and this helps students to understand the relationship between each concept in a topic and how to develop a topic. This study used qualitative analysis of the concept maps data. This method means that the researcher can examine the development of the students' learning process and also provide information regarding their difficulties, knowledge, and opinions (Sen & Aykutlu, 2008). Figure 1 is an example of a concept map created by students after they had finished learning the acid-base material.

Based on the concept map in Figure 1, it can be seen that student 6 had three general concepts regarding acid-base material, such as the concept of indicators, strong and weak acid-base examples, and acid-base characteristics. In student 6's concept map, the concept of acid-base characteristics was shown, but not that of acid-base theory. Student 6 was able to write the concept of the acid-base material in the form of symbolic representation, such as the molecular formula of the strong acid-base compound. Student 6 was also able to write a macroscopic representation of the acid-base material, such as the color changes of litmus paper, but student 6 could not relate the main concept with other concepts. The students' pre-knowledge of chemistry in macroscopic representation was based on their daily experiences (Treagust & Chandrasegaran, 2009) so most of the students related their understanding of the acid-base material in the class with their daily experiences in junior high school. This concept map was incomplete because it was lacking an explanation of the microscopic representation of the acid-base material. It can be concluded that student 6 still had difficulties in learning chemistry in relation to microscopic representation. Microscopic representation can be described as atoms, molecules, and ions; such as the concept of hydrogen ion donation as an acid or proton acceptor as a base (Chandrasegaran et al., 2008). All of the concept maps that were analyzed provided valuable information about the students' cognitive structure and their understanding of the acid-base material based on the links and labels that they made in their maps (Ozgun & Sen, 2004). Student 6 was one of the examples in the class that did not have a complex understanding of acid-base materials, because student 6 made limited links and labels on the concept map. All of the concept maps were constructed using non-hierarchic and chain methods (Kinchin et al., 2000), which means that students are not familiar with hierarchical concept maps. Students might have difficulties in linking the general concepts to more specific ones (Bak Kibar et al., 2013).

This cognitive structure provided information about the students' ability to understand the material that had been taught and also their understanding of previous material. Figure 2(a) shows a graph regarding the students' level of understanding, which in general shows that students understand the acid-base characteristics sub-topic. This is proved by the absence of a column in the graph showing the percentage in the 'did not understand' category. Based on the graph, it can be seen that students experienced a decrease in the 'understand' category at the elaborate stage from 80.5% to 75%. But after the elaborate stage, the students' understanding increased until the explain stage. Some students experienced misconceptions after doing the e-search stage and the exchange stage. Figure 2(b) shows that students' understanding improved from the explore to the explain stage. The percentage of students experiencing misconceptions decreased from the explore to the explain stage. In this sub-topic, there were 2.86% of students who 'did not understand', but this decreased to the lowest point (0%) in the explain stage. Therefore, this graph shows us an increase in the students' understanding during every stage of the Learning Cycle 8E approach.

Based on Figure 3, it can be seen that the students' understanding increased significantly during each stage of the Learning Cycle 8E approach. In the explore stage, the largest percentage were in the 'did not understand' category. The percentage in the 'misconception' category decreased at every stage during the Learning Cycle 8E. This fact indicated that the students' level of understanding of the acid-base strength sub-topic was increasing.

The students' cognitive structure data showed that all of the students increased their understanding from the first stage of the Learning Cycle 8E to the final stage. The percentage in the 'misconception' and 'did not understand' categories decreased in each stage of the Learning Cycle 8E. It can be concluded that the Learning Cycle 8E approach could be

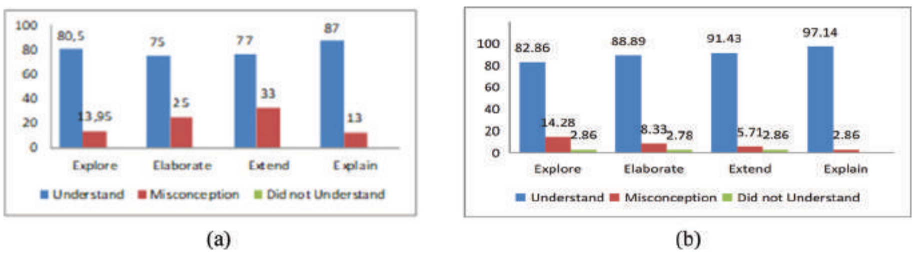

Figure 2. Students' understanding graph regarding the characteristics and indicators of acid-base material.

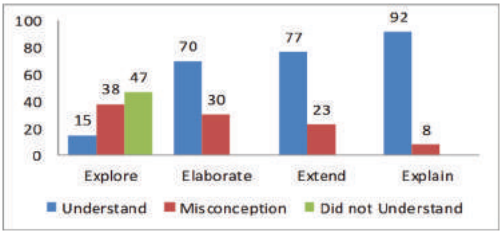

Figure 3. Students' understanding graph regarding acid-base strength.

suitable for decreasing the students' misconceptions regarding conceptual and contextual material, which could make students more active in the learning process.

4 CONCLUSION

This research showed that the cognitive structure of social science students with regard to acid-bases was very diverse. It also showed that social science students show an increase in understanding at every stage of the Learning Cycle 8E approach. This is indicated by the sentences and words that the students used in the free word association tests table in the worksheet. Based on that table, the students' cognitive structure was coded and categorized into 'understand', 'misconception' and 'did not understand', which proves that their understanding of the three sub-topics of the acid-base material increased. Most of the students found it difficult to relate the three sub-topics of the acid-base material into one concept, so it can be concluded that their understanding is not yet very complex. This was proved by the concept maps, which were not highly interconnected.

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Discovery learning model to improve high school students' critical thinking skills

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ABSTRACT: The aim of this research is to improve students' critical thinking skills by using the discovery learning model in a temperature and heat topic. The research was conducted in two cycles. Each cycle was consisted of planning, implementation (action), observation, and reflection. The result of the first cycle is a score of 81 which consists of 50% of students with excellent score, that is $80 < x < 100$, and 50% of students got a very good score, that is $66 < x < 80$. Learning management got a 2.8 score, so it belongs to the "good" category. The second cycle scored 89.08 which consists of 82.35% students with excellent score, that is $80 < x < 100$, and 17.65% students got very good score, that is $66 < x < 80$. Learning management got a score of 3.3, so it belongs to the "very good" category. It can be concluded that discovery learning can improve students' critical thinking ability.

1 INTRODUCTION

Interaction between students causes active learning and encourages students' critical thinking which is one of the goals of the 2013 curriculum. Indonesian Regulation No 19/2005 concerning the national standard of education states that science subjects are intended to obtain advanced competence in science and technology and to cultivate thinking critically, creatively and independently. Critical thinking is an aspect of higher order thinking skills (Lewis & Smith, 1993). According to Robert Ennis (Fisher, 2009), critical thinking is reasonable and reflective thinking that focuses on deciding what to believe or to do. This skill is important in learning for transferring knowledge and applying problem solving skills (Halpern, 1998). Critical thinking is the student's ability to apply their knowledge in new situations to solve problems, to make decisions, or to make critical evaluations (Garcia & Pintrich, 1992). Critical thinking is part of the evaluation process for evidence that has been collected in problem solving (Nickerson, Perkins, & Smith, 1985). Johnson also stated that critical thinking is an ability to evaluate opinions systematically (Johnson, 2007). So, critical thinking is an ability to think systemically and is used to solve problems.

Kurfiss stated that there are three bases regarding critical thinking namely: (1) informal logic or critical thinking as the ability to analyze and construct arguments; (2) cognitive process or critical thinking for constructing a meaning; (3) intellectual development, or critical thinking as a manifestation of the theory of contextual knowledge (Kurfiss, 1988). The dimensions of critical thinking are interpretation, analysis, inference, evaluation, explanation, and self-regulation (Facione, Facione, & Giancarlo, 2000). Interpretation is the ability to understand and express the meaning of experience from various kinds of events, and decision making is based on procedures and criteria. Interpretation includes the ability to categorize and clarify information. The ability to interpret in the world of learning can be assessed from the ability of a person to be able to see the main ideas in a paragraph and the ability of students to restate one's ideas by using their own sentences. Analysis is the ability to identify the true intentions and conclusions by looking at the relationship between questions, concepts, and descriptions to express a belief, decision, experience, reason, information and opinion. For example, students are able to identify implicit assumptions in piece of information or a paragraph, identify similarities and differences between two things and conclude the main idea in the information and then look at the reasons behind it. Inference is the ability to identify the main elements that are needed to develop a reasonable conclusion and to form a hypothesis. Evaluation is an ability to assess the beliefs/truths of a sentence or other information regarding a person's description, perception, experience, and decisions. Someone who has the ability to evaluate is able to make logical judgments about the relationship of existing sentences. Explanation is someone's ability to provide a logical explanation about a result. A person's ability to explain is judged by their ability to describe methods and results, determine the correctness of a procedure, and maintain a causal explanation with good and logical reasons. Self-regulation is a person's awareness to monitor their cognitive activity, the elements used in the activity and to apply analytical and evaluation skills to determine a truth from various perspectives. For example, a person's ability to see a controversial issue based on self-interest (Paul, 1995).

Based on the needs assessment in SMA Labschool Jakarta, students' critical thinking skills were not as expected. Students' critical thinking skills were categorized as "good" with an average of 68.04, 15% of the students were categorized as "excellent", while 39% of the students belonged in the "very good" category, 18% in the "good" category, 21% in the "fair" category, and 6% in the "poor" category. So, there needs to be an improvement in students' critical thinking skills to make students learn actively.

Cahyono stated that discovery-based learning is a teaching method where children acquire their own knowledge, without being told beforehand (Cahyono, 2013). Students observe, classify, make guesses, explain, draw conclusions, and so on to find concepts or principles. The important thing in discovery learning is that students are given the opportunity to conduct experiments, so that their curiosity grows when conducting these, then they find hypotheses and discuss the results obtained from the experiments (Wartono, Hudha, & Batlolona, 2018). Some advantages, according to Roestiyah (2008), are namely: (1) developing readiness and mastery of skills in students' cognitive processes; (2) students gain very deep knowledge; (3) awaken students' excitement of learning; (4) provide opportunities for students to progress according to their respective abilities; (5) able to direct the way students learn so they have a strong motivation to learn; (6) helping students to strengthen their self-confidence with their own discoveries; and (7) the strategy is student-centered. The teacher only acts as a facilitator and helps when needed.

This research was conducted on physics subjects with temperature and heat topic. In temperature and heat topic there are many things that can be developed to spur students' critical thinking skills. For example, students can analyze heat transfer in a thermos, interpret and analyze graphs of experimental results about changes in states of matter, explain the concept of sea breeze and land breeze, and so on.

2 METHOD

The research subjects were 34 eleventh grade students from the SMA Labschool Jakarta consisting of 11 boys and 23 girls. The research was conducted from September to October 2017. The research method used in the research is action research consisting of two cycles. Each cycle consisted of planning, implementation (action), observation, and reflection (Amri, 2010). The procedure for this research used a model developed by Hopkins (1993) in (Aqib, 2007).

Planning, Activities carried out in planning were: (1) designing the learning implementation plan; (2) making an appropriate learning implementation plan using the discovery learning model steps; (3) making the student worksheet; (4) making a test to measure students' critical thinking skills; and (5) making the teacher's learning management observation sheet.

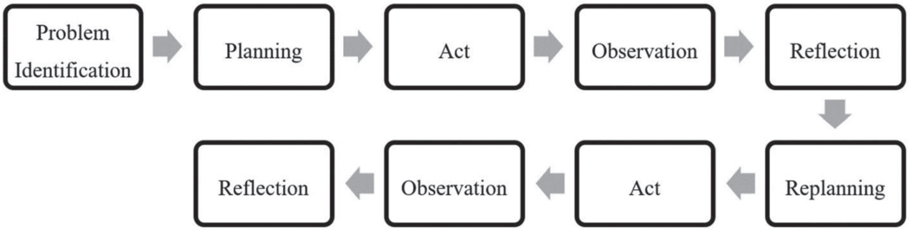

Figure 1. Hopkins' classroom action research model.

Implementations of action at every cycle were planned for two meetings. The first meeting was held in 2 × 45 minutes sessions and the second meeting was held in 1 × 45 minutes session. Cycle I through cycle II were filled with learning activities by applying the discovery learning model. At the end of each cycle the students were given a test to measure their critical thinking skills. The implementation of actions during the learning process was managed using the discovery learning model, with the first step being preliminary activities. In this step, the teacher said greetings, led prayers, prepared learning media, provided apperception by relating to topics that had been studied before, and motivated students in accordance with the topic that would be discussed. The second step was the main activities. At this stage, the teacher provided a stimulus so students would be motivated to think, analyze and identify problems implied by the stimulus. The teacher then formed groups for the experiments contained in the stimulus by using the student worksheet. Through group discussions, students analyzed the results of data from known variables and answered several questions from the student worksheet. The teacher also observed the students' activities. At the end of the activities, students presented the results of their discussion. Then the teacher explained the materials that must be mastered by the students and allocated the assignments. At the end of each cycle, tests to measure students' critical thinking skills were carried out.

Activities observation: monitoring of the teacher's learning management was carried out by observers when the lesson took place using an observation sheet. Management of learning and students' critical thinking skills tests were carried out using tests question.

Reflection: at this stage data from observations of learning activities that have been carried out previously were analyzed. Reflection served to evaluate the teacher's performance and to plan for the next lesson.

The research data were both quantitative and qualitative. The qualitative data was obtained from the observation results of the learning management. The observation sheets were filled out by the observers when the learning takes place, while the quantitative data was obtained from the students' critical thinking tests given at the end of each cycle of this analysis. The processes for analyzing the students' critical thinking was as follows.

a. Student score was the total score from each question.
b. Critical Thinking Score (CTS)

$$CTS = \frac{\text{Student score}}{\text{Maximum score}} \tag{1}$$

c. Critical thinking percentage (% CTS):

$$\%\,CTS = \frac{\text{Student score}}{\text{Maximum score}} \quad 100\% \tag{2}$$

d. Average score was obtained using the formula:

$$\text{CTS} = \frac{\Sigma \text{ learning outcomes of each students}}{\text{The number of students}} \tag{3}$$

e. The mastery of learning outcomes was measured based on the minimum completeness criteria in class XI MIPA 5 of SMA Labschool Jakarta. If the student's score was ≥ 70, it would be categorized as completed and if the student's score was < 70, it would be categorized as not completed.

The learning outcomes category was used; when student's score x ≥ 81, it would be categorized as "excellent"; a score of 66 ≤ x < 81 would be categorized as "very good"; 56 ≤ x < 66 would be categorized as "good"; 41 ≤ x < × 56 would be categorized as "fair"; and x < 41 would be categorized as "poor" (Arikunto, 2007).

3 RESULTS AND DISCUSSION

The learning implementation plan was made using the direct learning model for the temperature and expansion topic. Further learning activities were carried out consisting of preliminary, main and closing activities. At the second meeting, the teacher gave a written test to measure students' critical thinking skills. The result from the first cycle were 50% of students categorized as "excellent", 50% of students categorized as "very good", and 0% categorized as "good", "fair", and "poor". Overall, the students' average score in the first cycle is 81. During the learning process, the research teacher's performance was observed and assessed by the partner teacher. Data from observations can be seen in Table 1.

The researcher then prepared the second cycle with the temperature and heat topic. The lesson was carried out in two meetings. The first meeting was held in 2 × 45 minutes sessions and the second meeting in 1 × 45 minutes session. At the second meeting the students submitted the mind map they had made at home, then they were given a test to measure their critical thinking skills. The results from the second cycle were that 82.35% students belonged in "excellent" category, 17.65% students in the "very good" category, and 0% of students in the "good", "fair" and "poor" categories. The average score of all students in the second cycle was 89.08. These results indicated that students can be categorized as "good". The average physics ability of students increased by 8.08% from the first cycle. The teacher's performance was observed and assessed by peer teachers. The results of observations can be seen in Table 2.

Table 1. Learning implementation result from Cycle I.

Observed aspect	Average score	Category
Planned activity	3	Very Good
Learning implementation skill		
a. Preliminary Activity		
b. Main Activity	2.8	Good
c. Closing Activity		
Time Management	2	Good
Total average score	2.8	Good

Table 2. Learning implementation result from Cycle II.

Observed aspect	Average score	Category
Planning activity	3	Very Good
Learning implementation activity	3.38	Very Good
a. Opening Activity		
b. Main Activity		
c. Closing Activity		
Time management	3	Very Good
Total average score	3.3	Very Good

Table 3. Distribution of student critical thinking ability for each cycle.

	Pre-cycle		Cycle I		Cycle II	
Category	Total students	% total students	Total students	% total students	Total students	% total students
Excellent	5	15	12	50	28	82.35
Very Good	13	39	12	50	6	17.65
Good	6	18	0	0	0	0
Fair	7	21	0	0	0	0
Poor	2	6	0	0	0	0

Table 4. The average of student critical ability each cycle.

Cycle	Average score	Category
Pre-cycle	64.08	Good
Cycle I	81	Excellent
Cycle II	89.08	Excellent

In the second cycle, the learning management was better than the first cycle with an average of 3.3 which belonged to the "very good" category. The result of students' critical thinking skills from each cycle can be seen in Table 3.

Students' critical thinking skill in the "excellent" category increased from 15% in the Pre-Cycle to 50% in Cycle I, and then increased again to 82.35% in Cycle II, while in the "very good" category, students' critical thinking skill increased from 39% in the Pre-Cycle to 50% in Cycle I, and then it decreased in Cycle II to 17.65%. This was because in Cycle II the ability of students had increased in the "excellent" category. In the "good" category there was a decrease from 18% in the Pre-Cycle to 0% in Cycle I and Cycle II. The "fair" category also decreased from 21% in the Pre-Cycle to 0% in Cycle I and Cycle II, and also the "poor" category decreased from 6% in the Pre-Cycle to 0% in Cycle I and Cycle II. That means students who have the ability to think critically in the "good", "fair", and "poor" categories in the Pre-Cycle have improved in Cycle I to the "very good" and "excellent" categories, so that there were no more students in those categories. Then in Cycle II students moved from the "very good" category into "excellent". Based on the results, using the direct learning model can improve students' critical thinking skills. The average students' critical thinking skills from each cycle can be seen in Table 4.

Based on Table 4, the average of the students' critical thinking skills increased from 64.08 in the "good" category in the Pre-Cycle to 81 in the "excellent" in the first cycle. Even so, the researchers improved the learning management so that the average in cycle II became 89.08 for the "excellent" category. The planning stage for Cycle I and Cycle II activities also increased; Learning implementation skills increased from Cycle I (score 2.8) to Cycle II (3.38) and time management increased from Cycle I (score 2) to Cycle II (score 3). There was also an increase in performance by the researchers which was seen from the average score from Cycle I (2.8) which was categorized as "Good" into "Very Good" in the second cycle (average 3).

High school teachers can use the discovery learning model to improve students' physics learning outcomes, in line with the 2013 curriculum that applies in Indonesia which emphasizes the assessment of three domains, namely cognitive, affective and psychomotor.

4 CONCLUSION

Based on these results, it can be concluded that the discovery learning model can improve students' critical thinking skills in the temperature and heat topic by increasing the average students' skills from 64.08 in the Pre-Cycle (good), into 81 in Cycle I (excellent), and increased again to 89.08 in Cycle II (excellent) with the category "excellent" increasing by 233% from the Pre-Cycle to Cycle I and increasing by 449% from Pre-Cycle to Cycle II; The "very good" category increased 28% from the Pre-Cycle to Cycle I, and decreased by 54% from Cycle I to Cycle II; the "good" category dropped by 18%, the "fair" category by 21%, and the "poor" category by 6% from the Pre-Cycle to 0% in Cycles I and II.

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Gamification and its effect to student motivation in physics

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ABSTRACT: Gamification refers to the utilization of game elements and game-design techniques in non-game contexts. This technique has gained grounds in the area of business and marketing but still remains explorable in the field of education, particularly in physics education. Elements of a video game, namely: points, badges, leaderboards, rules and levels, when incorporated in a classroom gives it a gamified structure. This research explored the effects of a gamified environment to the motivation of high school students in physics. The study is anchored on the self-determination theory which claims that humans are inherently active, inquisitive and self-motivated even without external reward. However, extrinsic motivators can be converted to intrinsic motivators if they are "meaningful, pleasurable and consistent with a person's worldview. To determine if gamification has effect on the student motivation in physics, overall means of pre-survey and post-survey student responses to the Physics Motivation Questionnaire II (PMQII) were compared as well as the individual means for the five factors of motivation indicated in the 25-item questionnaire. A paired-sample t-test was done to deter-mine if there was significant difference between the individual component of student-motivation. Results revealed that with the utilization of the gamified instruction, career motivation, grade motivation and self-efficacy were increased. However, there was no statistical evidence that the intrinsic motivation and self-determination of the students were increased. This suggests that while gamification causes positive effects on some aspects of student motivation, some care should be taken when incorporating gamification elements to classroom setting.

1 INTRODUCTION

Physics helps us to understand how the world around us works. It deals with fundamentals, and helps us to see the connections between seemly disparate phenomena. Its application is overwhelming. Despite the overwhelming significance of Physics to our educational system and to our advancing society, still many students find the subject abstract and difficult, thus achieving poor grades. Consequently, a number of studies have been done to address this concern in physics education both locally and internationally. Among the most recent innovations explored internationally is the implementation of gamification in a classroom setting. Gamification is the use of game-based mechanics, aesthetics and game-thinking to engage people, motivate action, promote learning and solve problems. This technique started off as a form of re-ward system and gained grounds in the business world, eventually penetrating the field of education.

The first example of gamification came in 1896 when stamps were sold to retailers and then used to reward loyal customers. This was all put into motion by marketers that claimed great success and results in reinforcing buying behavior and company engagement. In the 70 s the theory began to form with Thomas Malone publishing, "What Makes Things Fun to Learn: A Study of Intrinsically Motivating Computer Games" in 1980. After this work was published, companies, such as American Airlines, Holiday Inn and National Car Rental, began implementing reward systems for their customers.

While gamification has been present ever since, it was not until an IT expert, Nick Pelling, coined the official term in 2003 when he started his consulting company that tried to gamify hardware solutions. However, it was not a common term until the year 2010 (Werbach and Hunter, 2012). This does not mean that the principles of gamification were not utilized before 2002, but that there was not a common name for it prior to its coinage. Karl Kapp et al. (2014) defined gamification as using of game-based mechanics, aesthetics and game-thinking to en-gage people, motivate action, promote learning and solve problems while Werbach and Hunter (2012) simply delineates it as the use of game elements and game-design techniques in non-game contexts. There is no one definition for gamification but one thing is conspicuous and that is that gamification aims to bring fun into non-game contexts. Motivation is defined as "a human psychological characteristic that add to a person's degree of commitment (Badu, 2005). Macrewzki (2013) further emphasized that gamification is not like serious games as they not the games designed for a primary purpose other than pure entertainment. Motivation is a desire to do something (Kim and Lee, 2008), an action (Potter and Ware, 1987), an inner drive (Locke and Baum, 2006) which is dependent upon the fulfilment of fundamental, innate psychological needs for competence, relatedness, and autonomy (Thijs, 2011). In the context of educational setting, student motivation naturally has to do with students' desire to participate in the learning process. Although students may be equally motivated to perform a task, the sources of their motivation may differ. A student who is intrinsically motivated undertakes an activity "for its own sake, for the enjoyment it provides, the learning it permits, or the feelings of accomplishment it evokes" (Lepper, 1988). An extrinsically motivated student performs "in order to obtain some reward or avoid some punishment external to the activity itself," such as grades, stickers, or teacher approval (Lepper, 1988). The term motivation to learn has a slightly different meaning. It is defined by one author as "the meaningfulness, value, and benefits of academic tasks to the learner—regardless of whether or not they are intrinsically interesting" (Marshall, 1987). Another notes that motivation to learn is characterized by long-term, quality involvement in learning and commitment to the process of learning (Ames, 1990).

Several researches found out that gamification has a positive effect on students in terms of motivation (Birch, 2013; Harrison and Anderson, 2012; Rose, 2015; Rojas and Fraser, 2013). Buckley and Doyle, (2014) also recognized congruent findings in their research. Interestingly, the results of the investigation done by Hanus and Fox (2015) revealed that students in the gamified course showed less motivation, satisfaction, and empowerment over time than those in the non-gamified class. They further explained that the increased competition that gamification brings about could harm student motivation. This is the main focus of this study, to find out the effect of gamification to the motivation of students in Physics.

2 METHOD

2.1 *Materials and procedures*

The participants in this study were the 167 grade 9 high school students of President Sergio Osmeña High School. A 25-statement Physics Motivation Questionnaire II (PMQII) was administered twice, pre-survey and post-survey. The gamification plan was conducted over the entire 4th Grading period of the School Year 2016–2017. It began on January 13 and ended on March 17 of 2017. The researcher executed the plan during the regular Science class meetings with each of the section of participants. The gamified class structure did not disrupt the regular Science classes held by the researcher except that the elements of game, namely: quests, rules, points, badges, and leaderboards, were incorporated in the daily class routine. The following describes the gamification process that transpired.

2.2 *Preparation of quests per lesson*

Traditional class activities and assignments were turned into quests—short learning activities that will take no more than 20 minutes to complete each. An hour-long regular Science learning session was converted into 3 to 4 mini quests per day. Each main quest was accomplished by every student/group at their own pacing provided they finish all of them before the scheduled administration of quizzes. Students who succeeded at a level had the choice to either move on to the next level or to try to raise their score. At the same time, students who failed the task or those who were dissatisfied with their scores, had the opportunity to learn from their mistakes and tried again until they succeed.

2.3 *Allocation of Experience Points (XP)*

The teacher associated each quest with a certain number of experience points (XP) relative to the level of difficulty. Gamers got to the top of the leaderboard by earning XP. Completing each quest earned them 1,000 points while the challenging ones racked up to 5, 000. Incentive XP was given to a student or group of students who finished their tasks ahead of time or pursues bonus challenges. The teacher associated each quest with a certain number of experience points (XP) relative to the level of difficulty. Gamers got to the top of the leaderboard by earning XP. Completing each quest earned them 1,000 points while the challenging ones racked up to 5, 000. Figure 1 below shows the number of points students had to acquire before they could be promoted to the next level. Incentive XP was given to a student or group of students who finished their tasks ahead of time or pursues bonus challenges.

2.4 *Making of badges and rewards*

Badges (Figure 2) and rewards were awarded to individual students who advanced to higher levels or exhibit exemplary skill or behavior while doing the quests. The teacher also implemented a class-wide reward system where everyone celebrated individual and collaborative accomplishments. This hoped to keep them engaged and prod them to work together in the accomplishment of quests, a common practice of gamers who team up in order to achieve goals.

2.5 *Presentation of leaderboards*

Leaderboards (Figure 3) are physical scoreboards showing the names and current scores of the leading gamers. They were installed onto the wall of every classroom and updated every week to spur the spirit of healthy competition in class. Top 10 scorers, for every class, were

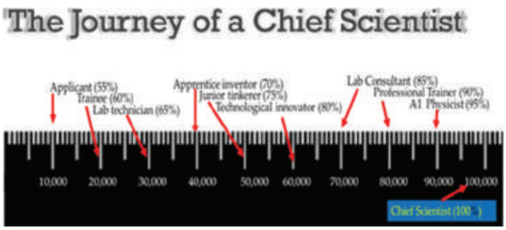

Figure 1. Gamification Storyline.

Figure 2. Badges given for every level reached.

Figure 3. Sample of the weekly Leaderboard.

recognized in the classroom and were also notified through their facebook accounts each passing week.

3 RESULT AND DISCUSSION

The researcher adapted the Physics Motivation Questionnaire II (PMQII) that was developed and validated by Glynn, S.M., & Koballa, T.R. (2006). The 30-item PMQII assesses six components of students' motivation to learn science in college or high school courses: intrinsically motivated science learning, career motivation, grade motivation, self-determination for learning science and self-efficacy. The mean of each component in the administration of the survey prior to gamification was compared with corresponding mean in the post-gamification administration. The results of the paired sample t-test on the 5 components of student-motivation in Physics identified by the developers of PMQII are shown in the tables below.

Table 1. Intrinsic motivation.

	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	t	df	Sig. (2-tailed)
Pre_Gamification_PMQII – Post_Gamification_PMQII	0.06645	0.55874	0.4298	–0.01840	0.15130	1.546	168	0.124

Table 2. Career motivation.

	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	t	df	Sig. (2-tailed)
Pre_Gamification_PMQII – Post_Gamification_PMQII	0.0714	0.3464	0.0347	–0.1478	0.18440	1.321	145	0.000

Table 3. Self-efficacy.

	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	t	df	Sig. (2-tailed)
Pre_Gamification_PMQII – Post_Gamification_PMQII	0.9451	0.4780	0.0135	–0.2411	0.2445	2.114	125	0.000

Table 4. Grade-motivation.

	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	t	df	Sig. (2-tailed)
Pre_Gamification_PMQII – Post_Gamification_PMQII	0.8311	0.3221	0.0412	–0.6415	0.3844	1.101	160	0.000

Table 5. Self-determination.

	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	t	df	Sig. (2-tailed)
Pre_Gamification_PMQII – Post_Gamification_PMQII	0.5446	0.7450	0.0214	–0.6410	0.7488	1.045	134	0.314

All of the components gleaned a p-value lower than 0.05 except for two, namely, intrinsic motivation and self-determination. This shows that there were statistical evidence showing that gamification increases student motivation, specifically in career, grade motivation and self-efficacy. However, there was not enough evidence shows that by gamifying Physics instruction, self-determination and intrinsic motivation were significantly increased.

4 CONCLUSION

This study suggests that while the gamified Physics instruction seems to contribute to the increase in career motivation, grade motivation and self-efficacy of the students, it may also cause decrease in their intrinsic motivation and self-determination. Caution must be taken when utilizing gamification techniques in teaching. Thus, it is strongly endorsed that future researches explore thoroughly the aspects of gamification that are beneficial to student motivation and those that may do more harm than good.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

The socio-scientific issue in a cross-context biology lesson: How far it goes from the lens of a teacher's and her students' experiences?

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ABSTRACT: This research is aimed to figure out the way one biology teacher and her students perceive their experiences about a Socio-Scientific Issue (SSI)-based instruction in a biology classroom. The research was interpretive in nature, using a case study design by which one SSI, in the context of mobile phones and health problems, was developed and implemented. Data of both the teacher's and the students' perceptions of SSI-based instruction were collected through observations as well as interviews and analyzed descriptively in a frame of an explanation building mode strategy. The research findings respectively represent the extent to which students perceive their experience in SSI-based learning in relation to four dimensions, including contextualization of SSI, their involvement in as well as attitude toward SSI-based learning and SSI-learning objectives. Regarding the teacher's experience, there are three aspects that need to be considered for SSI implementation in Indonesia. Thus, the implication of the research for further study is discussed.

1 INTRODUCTION

Over the decades, socio-scientific issues (SSI)-based learning has been a topic of great interest in global science education research. SSI represents issues where a conflict between scientific knowledge and social considerations emerges and requires a multi-perspective reasoning to solve it (Sadler, 2009). Genetically Modified Organisms (GMOs), global warming, natural resources sustainability and nuclear energy application are issues that are representing SSI and have been occurring in our global community. Whilst it has been well-developed and carried out in a large number of studies in a global context, however, there is only a very limited number of SSI research that could be accounted in the context of Indonesia (Subiantoro, 2011).

Lots of research on SSI-learning implementation have been carried out for numerous purposes, such as contextualizing of and enhancing student participation in science learning (for example, Ottander & Ekborg, 2012), or improving scientific knowledge, reasoning skills, decision making and argumentation skills (for example, Chowning et al., 2012; Dawson & Venville, 2009). Moreover, an important contribution of SSI-based learning is its role in supporting the scientific literacy achievement. There is a strong relevance between SSI and scientific literacy goal orientation in science education practice as scientific literacy is a required skill for resolving many science-related dilemmas that could be occurred in daily life context (Sadler, 2011).

However, according to the PISA 2015 results of the international scientific literacy achievements, Indonesian students stay at the lowest achievement groups (OECD, 2016), and this shows that to date scientific literacy remains to be a big issue for Indonesian students since they keep struggling to compete at the international level. Nevertheless, this represents a great challenge for the science education research community in Indonesia to take various effort into account for improving Indonesian science education quality as well as students' scientific literacy skills. Hence, introducing SSI in science (including biology) education practice may have a strong advantage to support the effort.

Promoting SSI-based learning as an innovation in science education practice in Indonesia requires an insightful understanding of the way the science teachers will play their role in SSI teaching. As Van den Akker (1988) asserted, that the degree of successful implementation of a science instruction innovation is strongly related to how far a teacher realizes the spirit of, and their role-taking behavior, toward the innovation idea and practice. Understanding the way students (will) perceive such innovation may also have a meaningful contribution for the SSI teaching and learning practice. According to Fraser (2001), understanding a learning environment where teacher and students work together could provide a useful idea for better science classroom quality, either for the teacher roles or student achievements.

This research was designed based on the pedagogical framework of SSI-based instruction. Levinson (2006) developed an established epistemological framework related to the learning environment in which controversial SSIs can be implemented. Three strands of the framework that include: 1) categories of reasonable disagreement, 2) communicative virtue, and 3) the modes of thought, comprise a pedagogical model of SSIs. The first strand, categories of reasonable disagreement, refers to what students will learn by studying SSIs that implicitly state the role of contextualization of scientific discourse as a main part of SSIs. The second strand, communicative virtue, represents a framework for discussing activities in which students may share their ideas with each other. This sharing of ideas is the best way to enact different perspectives and reasoning toward conflict and is one of the criteria in SSIs learning (Lee et al., 2012). The modes of thought, the third strand, accentuates what students could achieve when dealing with SSIs. The modes of thought represent higher order thinking patterns that include scientific knowledge and reasoning related to ethical considerations (Zeidler & Nichols, 2009). However, the modes of thought essentially cannot be viewed as being limited to both thinking and reasoning processes but may be expressed as an argumentation or a decision-making skill, as well as epistemological awareness (Albe, 2008; Venville & Dawson, 2010). The epistemological framework above led to the identification of the SSIs-based instruction elements. The first aspect based on the first strand—the categories of disagreement—is contextualization of the science topics in terms of the SSI. Students' involvement, as well as their attitudes toward SSI-based learning, are aspects that arise from the strand of communicative virtue. The last strand, the modes of thought, is defined by the aspect of the SSI-based learning objective.

Since only a very limited number of studies have put their concern on students' perceptions (for example Eastwood et al., 2011; Feierabend & Eilks, 2010), this research is conducted to provide a more meaningful picture of teacher and student perceptions of SSI-based learning in science education practice, particularly in a frame of SSI education as an innovation in a biology classroom in Indonesia. Thus, the research question underlying this study was: how do biology teachers and students perceive their experience on SSI-based learning in their biology classroom?.

2 METHOD

This research was basically designed to understand a biology teacher's views as well as reflections on how the teacher perceives an innovation regarding SSI-based biology instruction. Hence, this research is framed within the interpretive paradigm and carried out using a case study design (Treagust et al, 2014). A female biology teacher named Mrs. Dwi (pseudonym) who has been teaching for about 15 years has voluntarily participated in this research. She allowed her one-Grade 11students in a public senior high school in Yogyakarta City, Indonesia, to be involved as the subjects of the study. An SSI-based lesson plan in the context of mobile phone use and social health problems was developed by both the teacher and the author. Besides being aligned with the biological topic of the anatomy and physiology of hearing, the issue is also related to a physics context, including the characteristic of electromagnetic wave frequency, and its interference and radiation. Therefore, this issue represents a cross-context biology lesson applied in this study. Based on the lesson plan developed, the teacher implemented the SSI-based instruction using a panel group discussion. Data about the teacher's and the students' perception of their SSI-teaching and learning were collected through semi-structured interviews and supported by observation during the lesson. To support the theoretical propositions that guided the study, an explanation-building mode was applied for data analysis in interpreting the pattern of data (Burns, 2000; Yin, 1994). In order to gain the trustworthiness of the research, member checking was applied, by which participants were asked to check the validity of interviews translations, and to provide any comments on the interpretation provided by the researcher.

3 RESULT AND DISCUSSION

3.1 *Teacher's experience*

There are three key dimensions of the teacher's perceptions underlying the analysis approach in this research, including the necessity of SSI in the biology classrooms, factors that influence SSI-based instruction and teacher beliefs (Lee et al., 2006). According to interview findings, before SSI-teaching implementation, the teacher perceived the necessity of SSI-lesson from the point of view of its educational advantages, as represented by the following excerpts:

Interview #1
Researcher : *"Did you see a possibility of SSI implementation in your biology class?"*
Mrs. Dwi : *"I believe it [SSI] could be implemented"*
Researcher : *"What may support your thoughts?"*
Mrs. Dwi : *"I consider my students tend to update their lifestyle, socially, I mean. Using contact lenses, for example. But, it seems that they are aware of the risk. I suggest, learning through SSI may help them to be more aware, realize, know what they really need, have the reason for using it"*

Although it was not explicitly stated as the necessity of the SSI-lesson, the teacher's words in the above excerpts considerably reflected the way she viewed the importance of SSI for her biology classroom. She asserted the potential role of SSI to help her students to have biology knowledge, social considerations related to the issue, and to take their reason into account. Reviewing the teacher's reflection after SSI-teaching practice shows her perceptions, which looked more profound regarding the advantages of the SSI-based learning, particularly in terms of an increased level of engagement from the students. These were reflected by the excerpts below:

Interview #2
Researcher : *"Did you see something interesting about SSI-learning in your biology classroom?"*
Mrs. Dwi : *"I see my students were looked more attracted. Seems it because they felt free, different with their common learning pattern"*
Researcher : *"Do you think it relates to the context?"*
Mrs. Dwi : *"I think so, and maybe they feel bored to my teaching way as well"*
Researcher : *"What about student achievements?"*
Mrs. Dwi : *"Students are looked really encouraged to express their social consideration and responsibility, like "L" [a name of student] who wanted to participate in community service for the campaign the issue. Overall, I consider my students became more aware of social dimension upon the topic being learned"*

According to the above excerpts, the teacher perceived key aspects of SSI-lesson advantages in relation to the student activities. Mrs. Dwi focused on her student engagement in the SSI-lesson, as she noticed that in SSI-learning, her students were "… become more aware of social dimension upon the topic being learned". Thus, the reflection shows an extent to which the teacher gained a wider point of view to consider SSI-learning advantages, or necessary, for her biology classrooms. Following the first dimension above, the teacher stated that defining the issue that evolved in society, as well as having relevance to the biology topic, and also exploring relevant scientific information about the issue, were viewed as two main factors that needed to be considered in SSI-based learning in her biology classroom. Following these topic-related factors, she became aware of pedagogical aspects as important factors, including an appropriate teaching approach or model, student characteristics and teaching skills and creativity. Having an experience in SSI-teaching practice may lead the teacher to take the factors into account more deeply, as occurred from Mrs. Dwi's expression below:

Interview #3

Researcher : *"Do you think SSI-teaching that you have implemented is in alignment with our curriculum needs?"*

Mrs. Dwi : *"To some extent. But, as you know, our [Indonesian] curriculum is mainly oriented toward national exams, and the teacher must teach all topics or concepts required. To be honest, I am actually interested in SSI-teaching, as it is relevant to the science-technology-society approach. But we have limited time as we have to consider the final exam"*

Researcher : *"What is your regular teaching pattern?"*

Mrs. Dwi : *"It depends on the topic. However, according to my colleagues here in the school, a teacher could not be called a teacher unless she/he is able to teach by lecturing"*

Researcher : *"Does it mean that this teaching culture [lecturing] influences the way students learn?"*

Mrs. Dwi : *"Definitely. The teacher is delivering the concepts and perhaps the student receives the knowledge. They [students] are accustomed to this pattern. They have a book, but if they are not being encouraged to read, they will not do that. They prefer to be taught by lecturing"*

It is revealed by Mrs. Dwi's words that the teacher is facing a dilemma as, on the one hand, she is actually encouraged to teach about SSI, but on the other hand, she is also aware of the demands of the final examination. This may become more challenging because there is an extent to which the teaching culture in her school influences her perceptions of the way she needs to choose to teach her biology classes. Thus, this school orientation and culture represent factors that may also influence SSI-teaching practice.

3.2 *Students' experiences*

What can be deduced from observation during the lesson, particularly in the introductory session, is that there was a lack of attention paid by the students. While the teacher provided a few chances for students to ask a question or give an opinion, it seemed that students did not intend to express any particular response. It is suggested that certain factors might lead students to be not really attracted. Hence, a review of students' reflections through interviews after the lesson revealed potential factors that may have influenced the way the students perceived their involvement at the beginning of the lesson, as shown in the following excerpt:

Interview #4

Researcher : *"What we learned [yesterday] began with a social issue related to biology. Have you ever learned biology like we did [based on SSI] before?"*

Student A : *"No, we have no experience like that"*

Researcher : *"Was it your first experience?"*

Student A : *"Yes, as most commonly our lesson is based on our book and sometimes our teacher asks questions"*

Researcher : *"Have you tried to reconsider biology topics that you have learned in your daily life?"*

Student A : *"Usually we see [observe] a phenomenon and further we discuss it in the class"*

Researcher : *"Did you find any difficulties?"*

Student A : *"It made me surprised because usually we just learn in an ordinary way, where the teacher mostly explains the topic based on the textbook, but suddenly we learn about something different, it was strange"*

Interview #5
Researcher : *"Compared to teaching and learning as your teacher usually does, what do you think about your learning experience like we did (with SSI)?"*
Student M : *"What we do usually is just listen to what our teacher explains. It is different from what we did yesterday, as we cooperated in a group discussion. Besides, we will understand more about the topic"*
Researcher : *"Found any difficulties?"*
Student M : *"Instead of difficulty, it was really interesting for me, because we were not only learning about biology but also about social aspects. The issue encouraged me to explore broader matters. So, it was not really difficult for me"*

According to those excerpts, it can be pointed out that the way the students were usually taught (by book-based discourse or teacher's lecturing or explanation) and the lack of experience on learning with social-related problems might lead to a lower degree of involvement at the lesson. However, contrary to this, the SSI-learning implemented in this class did accommodate students to be more engaged. The following excerpts support this point of view:

Interview #6
Researcher : *"About the issue, do you think it influenced your understanding about the biological concept being learned?"*
Student B : *"I think yes, and I saw it was more than biology since we talked about social impact too. We were encouraged to seek relevant information that we need to understand and, further, we need to convey our ideas to others."*
Researcher : *"What about the discussion that we did? Do you think you were engaged or motivated to share your idea?"*
Student B : *"Yes, the different opinion in our group encouraged me to share our ideas, and what is interesting is, it could lead a debate"*
Researcher : *"How was your friend involved?"*
Student B : *"Different opinions encouraged us to express our ideas, and the interest generated a debate"*
Researcher : *"Was it challenging you?"*
Student B : *"Yes, how we stand upon our opinion or idea, even though it might be wrong"*
Researcher : *"Better on what? – Any factors that support your idea and determine if it [idea] is true or false?"*
Student B : *"By information about the opinion which I looked for before, that underpinned the truth of my opinion. Otherwise, if my opinion is definitely different with most others, so maybe it [my opinion] was wrong"*

The above excerpts considerably highlight some essential findings regarding student engagement with the SSI-learning. These are including:

1. A valued meaning of SSI-learning was reflected on how students dealt with SSI-group activity, such as being more engaged in discussion, challenged to share better ideas or argument and interest in having a debate about the issue. These represent attitudes expressed by the student during their SSI-instruction.
2. There is also a perception of SSI-learning objectives that could be achieved by students. It includes an awareness of seeking information to support ideas or arguments about the issue. Moreover, students also perceived other learning objectives besides biological knowledge, including social values of the topic and the application of biology concepts.
3. An emergence of self-regulated learning perspectives stated by students in regard to their learning experience was also revealed. It mainly relates to the way their biology teacher taught them, as well as about limited experience on learning with seeking and examining scientific information.

4 DISCUSSION

This research was basically carried out to get an insightful image of a biology teacher's and her students' experience about the implementation of an SSI-based instruction in their biology classroom. Instead of figuring out each party's perceptions solely, the research would like to provide a comprehensive understanding based on both—teacher and student—perspectives about how the SSI-learning environment could be implemented, and the factors that need to be considered for further development in science (biology) education practices in Indonesia.

These research findings show that both the teacher and her students share a common view in regard to SSI-learning advantages in their biology classroom. This can be highlighted firstly based on the role of contextualization of SSI as asserted by the teacher's perception (in interview #2) and a student's perspective (in interview #5). Since SSI promotes social consideration that makes it different from the science-technology-society (STS) approach (Zeidler et al., 2005), it could empower students with a real-life experience of the biological knowledge and engage them into a social-like interaction in their learning activity. This looks meaningful as students' expressions in interviews #4 and #5, for instance, show less of the learning environment in which they could be able to look at the different sides of the biological topic. Thus, this highlight supports the key role of SSI in providing meaning-making activity in science education within the situated learning perspective (Sadler et al., 2009).

Besides the contextualization of the biological problem, a higher level of learning activity perceived by students could be pointed out as an essential advantage of SSI-learning. Reflected from interviews #2 and #6, as the SSI involves a controversial problem where students need to stand between scientific knowledge and social consideration, it encourages students to have more concern on their way of thinking. Seeking relevant information, conveying the ideas and reviewing the opinion are some considerations asserted by students in their SSI-learning activity. Furthermore, their excerpts also reflect their attitude toward the SSI-learning environment and the values of SSI-based learning for their learning achievements, including metacognitive views.

It is considerably shown by many studies that SSI implementation promotes a positive trend for students' learning achievements and could be a strong vehicle for teachers implementing it as an innovation movement in the science classroom. However, although this could not be put as a general view, based on the findings of this study, school orientation and culture seem to be a great challenge for teachers to keep their motivation and belief in further SSI-implementation in Indonesia.

5 CONCLUSION

This case study research reveals two main points about a biology teacher's and her students' perceptions of SSI-based instruction in a biology classroom in Indonesia. First, from the lens of students' experiences, there are four key dimensions of SSI-based learning that could be figured out, including the role of contextualization of SSI, student involvement, student attitude in SSI-learning and SSI-learning objectives or achievement. Second, three key points could be perceived based on the teacher's experience, including the necessity of SSI, factors influencing SSI-implementation and teacher belief in SSI-teaching. Hence, in the global context, these findings may have a strong implication and need to be considered for the further effort of SSI-implementation in science education research.

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Teacher support material in physics for the explicit-reflective instruction of the nature of science

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ABSTRACT: Nature of Science (NOS) is one of the components of scientific literacy that is poorly represented in science curriculum materials in the Philippines. Thus, the main goal of this study was to find out how the Nature of Science (NOS) would develop basic scientific literacy through the developed Teacher Support Material (TSM) for the explicit-reflective instruction of the nature of science for K to 12. The Student Understanding of Science and Scientific Inquiry (SUSSI) revealed that both the student and teacher respondents held naïve views on scientific laws versus theories, social and cultural influence on science. Based on the findings of NOS, teacher support material was designed, developed and validated. The material was implemented to Grade 9 students where the participants demonstrate changed levels of NOS literacy using the Test of Basic Scientific Literacy (TBSL). On the other hand, the use of TSM was effective in enhancing the scientific literacy of students. Suggestions for further studies were made, which include the use of explicit-reflective instruction of NOS in the present curriculum as an innovative approach of promoting common and accurate views of NOS in science classrooms.

1 INTRODUCTION

How can we say that we produce a scientifically literate populace? How can we say that we have achieved scientific literacy or are in the process of achieving it? We need scientifically literate Filipino citizenry possessing advanced skills in reasoning, creative thinking, decision-making and problem solving. Therefore, people must acquire critical thinking abilities that will enable them to make sound decisions and informed choices. Thus, the present curriculum puts emphasis on the development of scientific literacy at the end of junior high school.

Scientific literacy includes, as one of its components, the nature of science (NOS). Teaching the nature of science concepts in the K to 12 curriculums is seen as a pathway to achieving scientific literacy (Lederman et al., 2013). Science content and its nature must be understood by the learners. The nature of science is as important as any other science facts and principles, yet it rarely appears as a specific element in the curriculum (McComas, 2006). Ignoring the importance of NOS may affect the understanding of science as a discipline and as a meaningful context for the subject matter that we expect students to learn (Lederman, 2006). NOS understanding permits students to understand how science works and eventually bridges the gap between facts of science and processes of science (Huling, 2005). Thus, the country should consider the goals and outputs of science education to supply citizens who can apply science on real-world phenomena.

Relatively, several studies mentioned in the literature contribute to the evidence of the effectiveness of explicit-reflective instruction. However, such NOS instruction is not present in the country's K to 12 curriculums. NOS as one of the very important components of scientific literacy, as mentioned in the learning competencies, but NOS aspects' accessible to K to 12 are still poorly represented in the Philippine curriculum materials (Cagas, 2012). Kruse (2008) even emphasized that discussing the nature of science implicitly is problematic for it may communicate inaccurate NOS messages. In fact, few pieces of literature on

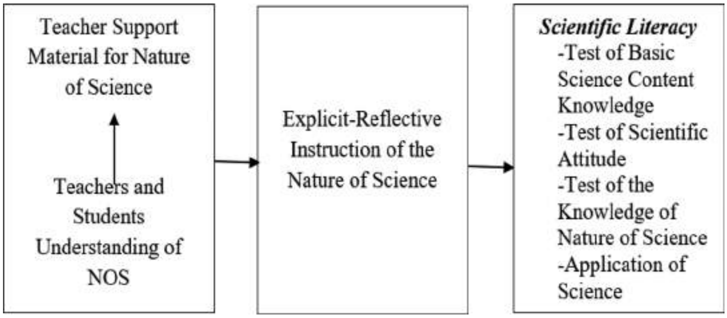

Figure 1. The framework of the study.

explicit-reflective NOS instruction, specifically in the Philippines, are found. In addition, there is no support material to develop NOS for teachers, and no support material is available for NOS instruction to students either. NOS teacher support material in this study is a teaching aid, other than the textbook, capable of addressing the specific needs of students and representative of the NOS issues.

As shown in Figure 1, this study looked into how basic scientific literacy in terms of basic science content knowledge, scientific attitude, knowledge of the nature of science and application of science would be enhanced through understanding the nature of science directed by a developed Teacher Support Material (TSM) grounded on initial inputs, such as teachers' and students' understanding of NOS and information on students' scientific literacy.

2 MATERIALS AND METHOD

The participants in the assessment of NOS views included 13 Grade 9 science teachers and 277 students enrolled in three government-owned secondary schools in one of the divisions in the Department of Education (DepEd) South Luzon, for the school year 2014–2015. The 24 item Likert-type Filipino-translated Student Understanding of Science and Scientific Inquiry (SUSSI) was administered to the participants (Liang et al., 2008). The Likert items in the SUSSI contain positive and negative items in each of the six NOS aspects. The positive items represent views consistent with the National and International Science Education Reform documents, whereas the negative items represent common student understandings of NOS that are not consistent with the Standards documents (Liang et al., 2008). The views were categorized into three: naïve, transitional and informed views. Eight teachers and 86 students were chosen for the interview, which commenced after every administration of the SUSSI questionnaire. The interview questions were taken from the open-ended questions of the SUSSI questionnaire. The construct validity of the interview schedule was established through discussions with a science expert. All ethical considerations were observed in this study.

The NOS views of the participants in the first phase of the study were used as a baseline for information to design the NOS lessons. The activities were geared to change the identified inaccurate NOS views by emphasizing the different aspects of NOS, as well as by the explicit-reflective instruction through the Nature of Science debriefing. Official documents from DepEd (Grade 9 Learner's Manual (LM), the Teacher's Guide (TG) and the corresponding learning competencies) guided the determination of what students should know about science content and what learning activities should be performed by the students to achieve the learning competencies. From such documents, we crafted the instructional design of NOS lessons customized to the K to 12 students, inclusive of the guidelines on how to use the materials. The overall design was pegged using the 5E instructional model. The face and content validity of the material was established after the evaluation of a panel of three experts who were teaching NOS and/or knowledgeable about NOS-related research. They validated the TSM using an expert's assessment checklist.

One Grade 9 science teacher and 140 Grade 9 students of a purposively selected fourth school implemented the TSM in the school year 2015–2016. The experimental design was employed to assess the effectiveness of the support material in enhancing scientific literacy. The try-out teacher was briefed on the support material and requested to prepare and conduct the lesson using the given guidelines and materials. The implementation of the support material for the experimental part of the study was subdivided into three phases: pre-implementation, implementation and post-implementation. In the pre-implementation phase, the test of basic scientific literacy was administered to all the try-out students present at the time of the administration to understand how the nature of science views affects their attainment of basic scientific literacy. In the implementation process, the teacher delivered the ten lessons in physics, which included uniformly accelerated motion, free fall, projectile motion, impulse and momentum, the law of conservation of momentum, work, power and energy, the first law of thermodynamics, the second law of thermodynamics, electrical energy generation, transmission and distribution. For one quarter, the support material for the explicit-reflective instruction of NOS was used. The learning activities suggested were performed by the students and the NOS debriefing was handled by the try-out teacher. Formative and summative assessments were given by the try-out teacher. The encountered difficulties were noted in the teacher's log book. Lastly, in the post-implementation process, the students took the Test of Basic Scientific Literacy (TBSL) (Uzoamaka, 2012). The TBSL is made up of 60 items divided into four sections—A, B, C and D. TBSL was adapted from Laugksch (2002) and modified by the researcher (Uzoamaka, 2012). The modification was done by including more items from aspects of basic sciences, which includes biology, chemistry and physics. Section A consists of 30 multiple choice items which tested the basic scientific content knowledge. Section B is the test of scientific attitude, which consists of a 10 item structured questionnaire of Likert-type response. Section C is a 10 item structured questionnaire also of Likert-type and was constructed to test the student's level of knowledge of the nature of science. Lastly, Section D tested the application of scientific knowledge and principles. In order to determine the level of scientific literacy of the respondents, all raw scores generated from different tests in each of the component parts of the TBSL were collected to obtain a total value out of 140 points. The mean scores were determined to reflect the extent to which the student-participants have acquired scientific literacy. The grading was as follows: mean scores from the following: (1) 20–60 indicates a low level of scientific literacy; (2) 61–100 indicates a high level of scientific literacy, and (3) 101–140 indicates a very high level of scientific literacy. The TBSL was administered before and after the experimental part of the study to further evaluate the material and to check whether the material enhanced the participants' scientific literacy level.

The statistical tools used were mean and standard deviation for the expert's assessment checklist, the scoring guide for SUSSI and dependent t-test to compare the pretest and post-test science literacy test scores in TBSL of the student-participants. We also transcribed and coded all qualitative data for triangulation.

3 RESULT AND DISCUSSION

3.1 *Assessing the participants' NOS views*

Assessing the nature of science views of the students and the teachers provided the researchers with baseline information on the level of the nature of scientific understanding of the participants that served as a basis for classifying them as naïve, transitional or informed, as shown in Figure 2. The different aspects shown in Figure 2 refer to the following: (1) observations and inferences, (2) change of scientific theories, (3) scientific laws versus theories, (4) social and cultural influence on science, (5) imagination and creativity in scientific investigations and (6) methodology of scientific investigations.

Table 1 shows the percentages of NOS views in each category through the nature of science interview protocol. Specifically, a "not classifiable" response means there is no response; the participants stated that they do not know; the response does not address the prompt, or the response cannot be classified based on the rubric descriptions.

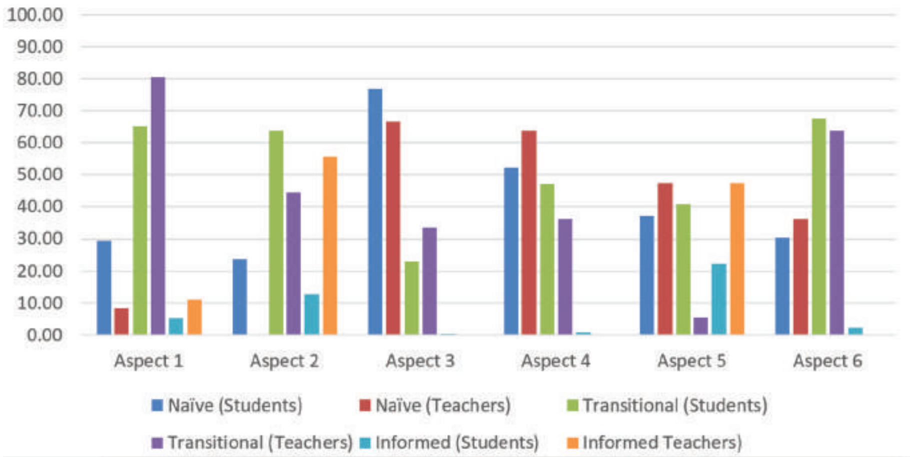

Figure 2. NOS views of student and teacher-participants in the SUSSI Likert-items.

Table 1. Percentages of naïve, transitional, and informed nature of science views of the student and teacher-participants gathered through the interview.

	Student-Participants				Teacher-Participants			
	Over-all Percentage				Over-all Percentage			
NOS aspect	N	T	I	NC	N	T	I	NC
1. Observations and Inferences	14.63	64.63	0.00	20.74	0.00	100.00	0.00	0.00
2. Change of Scientific Theories	26.83	56.09	0.00	17.08	25.00	62.50	12.50	0.00
3. Scientific Laws vs. Theories	58.54	9.76	0.00	31.70	75.00	12.50	12.50	0.00
4. Social and Cultural Influence on Science	19.51	64.63	0.00	15.86	12.50	50.00	12.50	25.00
5. Imagination and Creativity in Scientific Investigations	13.41	73.17	0.00	13.42	37.50	50.00	0.00	12.50
6. The Methodology of Scientific Investigations	20.73	47.56	0.00	31.71	87.50	12.50	0.00	0.00

The SUSSI revealed that the student-participants and teacher-participants had more naïve views in scientific laws vs. theories, and social and cultural influence on science. Naïve views are views that are not consistent with the NOS views accessible to K to 12 students thus, having inadequate views of NOS (Liang et al., 2008).

Almost 77% of the student-participants as shown in Figure 2, aspect 3, strongly believed that scientific laws are more certain than theories, or theories became laws when they are proven correct. For example, some learners said:

> *'Scientific theory is not yet proven while scientific law can be used today.' (S5)*
> *'Scientific theory will change but scientific law will not change.' (S13)*

This result may suggest that the participants hold a strong belief that there is a hierarchy between theories and laws and/or laws are already proven and cannot be changed. In fact, naïve views are the most common in the distinction between scientific laws and theories, with most students perceiving that scientific laws are more certain than theories (Pace & Farrugia, 2015).

On the other hand, almost 52% of the student-respondents agreed that science is universal and not affected by culture and society. Results of the interviews revealed that 20% of the student-participants believed in the universality of science, which makes the discipline unaffected by culture and society. The participants even believed that culture and society do not affect how scientists establish the truthfulness of scientific ideas. They even explained that:

'Scientific studies have an accurate basis that cannot be affected by their culture, belief and society.' (S28)

The findings showcase that most learners seem to have a **'naïve view'** on the social and cultural influences on science (Lematla, 2011). She also found that in the open-ended responses of the participants that most learners indicate that society and culture do not affect scientific research because they believed that science is universal and independent of society and culture.

Apparently, the teacher-participants held naïve views in scientific laws versus theories and social and cultural influence on science. Although the majority of the teacher-participants acknowledged that scientific theories may also be changed when existing evidence is reinterpreted, only 12.5% provided a valid explanation and example.

'Scientist theories may be changed because of scientific advances. When a new theory comes, then old theories may be falsified. Example: Geocentric to Heliocentric.' (T3)
'Yes, it is possible that scientific theories may change. In the development of atomic theories, Aristotle believed that matter is made up of fire, water, air and earth, until sub-atomic particles were discovered.' (T5)

Consequently, the teacher-participants believed that theories become laws and laws are not subject to change. There is a misconception in the distinction between laws and theories as can be seen from the responses below:

'Theories are just theories, they may be changed, whereas laws have been proven and just need to be executed.' (T1)
'Theories have not yet been accepted universally while laws are already proven and accepted universally.' (T2)
'Theories and laws are based on experimentation. But theories do not have strong evidence.' (T8)

Consistently. Erdogan et al., (2006) also found that almost all the participants (94%) believed the so-called hierarchal relationship between laws and theories. In addition, the teacher responses above are similar to the reasons mentioned by Liu & Lederman (2007). They conducted a study with 54 Taiwanese pre-service teachers using Views of the Nature of Science (VNOS)-C and found out that all the participants held the misconception that laws were proven and more reliable.

The teacher-participants also held more naïve views in social and cultural influence on science (Shim et al., 2010). The study also revealed that there are more naïve responses (63.89%) than transitional views (36.11%). The teacher-participants believed that science is not affected by the society and culture in which it is practiced.

'Society and culture do not affect scientific research since it is based on scientist observations.' (T5)

3.2 *Instructional design and development of the Teacher Support Material (TSM)*

Based on the findings on NOS views, the aspects where the teachers had naïve and transitional conceptions were given emphasis to clarify their misconceptions of these NOS aspects.

3.3 *Validation and reliability*

The support material was assessed by experts from the STEM faculty from the National Center for Teacher Education as to its objectives, content, organization and presentation, materials/methods and evaluation. They provided both quantitative and descriptive validation. The experts rated the support material 'very acceptable' as to objectives, content, materials/methods and evaluation, while they rated organization and participation as 'acceptable' with a weighted mean of 4.07. We found it necessary to consider the organization and presentation of the 10 lessons of the teacher support material.

Table 2. Paired samples statistics for NOSLit.

Pair	n	Pre-test mean	Post test mean	Mean	SD	t-value	p-value
Pre-Test and Post Test TBSL	87	76.22	81.11	–4.897	10.926	–4.180	0.000*
Pre-Test and Post Test TBSL Section C	86	30.45	32.12	–1.663	5.139	–3.000	0.004*

*Significant @ $p < 0.05$.

3.4 *Enhancing scientific literacy using the TSM*

3.4.1 *Scientific literacy*

The TBSL with the sub-components, a test of basic science content knowledge, a test of scientific attitude, a test of the knowledge of the nature of science, and application of scientific knowledge were used to find out if scientific literacy was enhanced. The purpose of the test was to determine whether there was statistical evidence that the mean difference between the paired observations on a particular outcome was significantly different from zero. The paired samples statistics and paired samples t-test for TBSL as a whole and the test of the nature of science knowledge (Section C of TBSL) are shown in Table 2.

Apparently, the TBSL mean score after the implementation ($\bar{x} = 81.11$) was greater than the TBSL mean score before the implementation ($\bar{x} = 76.22$). The t-test confirmed the significant difference ($p = 0.00007 < 0.05$) between the TBSL pre-test and post-test scores, as shown in Table 2. This result is consistent with the result reported by Mahatoo (2012) that the intervention to determine the impact of NOS infused lessons on students' Scientific Literacy (SL) scores had a large impact on the students' SL scores, resulting to enhance students' content knowledge and process skills in science, which concurs with that of many studies conducted that sought to enhance students' SL following implicit or explicit instruction.

The researchers also looked into the test of science knowledge and the test of scientific attitude components. The NOS view of the participants through a paired t-test for Section C of the TBSL (Test of Knowledge of the Nature of Science) from which we observed a significant increase in the TBSL Part C mean score ($p = 004 < .05$). It appears that there is a significant difference in the pre- and post-test scores of the test of knowledge of the nature of science in the TBSL. Uzoamaka (2012) defined mean score from 31 and above as high performance in this section and mean scores from 0–30.99 as low performance. Table 3 shows that the participants' NOS knowledge changed from low performance to high performance. Even so, we infer that there is a need to unpack the standards all the way to the evaluation and explore the factors affecting the students' gain in understanding the nature of science. In addition, teachers should have better training in NOS.

4 CONCLUSION

The main objective of this study was to find out how NOS would develop scientific literacy through the support material developed for explicit-reflective instruction on the nature of science for the K to 12 curriculums. The findings point to the fact that generally, the student-respondents and the teacher-respondents held naïve views on scientific laws versus theories and social and cultural influences on science. Thus, teachers and students should be given support in NOS teaching and learning.

The test of the knowledge of the nature of the science component of the TBSL revealed that the support material can slightly change their nature of science views. The researcher still infers that there is a need to unpack the standards all the way to the evaluation. In addition, teachers should have better training in NOS. In addition, it was difficult to change students' NOS views for a quarter of a school year (approximately 2.5 months) of TSM implementation. Based on the findings of the study, we may infer that there is a significant difference in the pre-test and post-test scores on the test of basic scientific literacy. Thus, the use of the teacher support material for the explicit instruction on the nature of science is effective in enhancing the scientific literacy of the students. These findings could provide directions for curricular and instructional efforts, and for student learning. This study can also help in thinking about considering NOS as an explicit domain in the Philippines' science curriculum learning competencies, using the explicit-reflective teaching approach and providing sample support material for NOS integration.

This study did not dig deeper on the factors that influence modification or the change of NOS ideas. Future researchers can focus on exploring the factors affecting students' gain in understanding the nature of science to propose teaching practices that may help develop students' views of NOS. Future researchers may also look for ways to improve the widely-used explicit-reflective approach. In addition, you may consider providing teachers with professional development seminars or workshops about NOS with after care support to help them acquire more sophisticated NOS knowledge that they can impart to their students. Some teachers may know it already or may have some background about it, thus, retooling must be applicable to them.

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Development of a teaching-learning sequence on contact forces using bridging analogies

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ABSTRACT: This study aimed to develop a Teaching-Learning Sequence (TLS) on normal force, surface friction force, and tension force using bridging analogies (Camp & Clement, 2010) and investigate its effect on students' conceptions to promote conceptual understanding. This is so since traditional methods of physics teaching do not usually consider students' debilitating alternative conceptions; thus, failing to engender conceptual change. AType-3 developmental concurrent-nested mixed methods research design was used in which the target alternative conceptions on the three contact forces were based from the literature, and the quantitative data set provided a supportive role to the qualitative data. The quantitative data included a conceptual inventory in determining students' initial and final conceptions. The qualitative data gathered from focus group discussions, journal entries, activity sheets, and voting sheets helped in describing students' conceptual changes. The study involved an intact heterogenous General Physics 1 class of Grade 12 students (n = 42). The results revealed that there were correct and incorrect conceptions before and after the implementation, and that the bridging cases were successful in promoting conceptual change. The study also affirmed the resistance of alternative conceptions which harbor among students.

1 INTRODUCTION

Science education is a key player in national development prompting countries across the globe to include it in their national agenda. Improving students' performance in science is thus a major concern of policy-makers and educators. Correspondingly, they make educational reforms and specific curricular policies guided and informed by studies which measure students' performance. A popular study that gauges students' performance in science and mathematics is the Trends in Mathematics and Science Study (TIMSS). Filipino students' performance in the TIMSS is dismal. In the 2003 TIMSS, Philippines ranked 23rd out of 25 countries in elementary science and mathematics and placed 43rd out of 45 countries in high school science (National Education for Statistics, 2004). Students' performance in the National Achievement Test for the school year 2005–2010 is as dismal. The NAT results show that only 47.06%, at the average, possesses a satisfactory mastery of basic competencies for the five consecutive years (The K to 12 Basic Education Program, 2012).

Students' poor performance in science shows that they have a poor conceptual understanding of scientific concepts. There are several factors to consider in explaining why students have poor conceptual understanding in science. Two major reasons are discussed here. First, it is an established fact that science is a difficult discipline—the difficulty roots in the abstractness, complexity, and unfamiliarity of several science concepts (Devecioglu-Kaymakci, 2016). Secondly, previous instructions are also contributory to students' conceptual understanding. Mintzes and Chiu (2004) published 14 claims synthesized from various studies about conceptual development, cognition and learning. Two of these claims say that

(1) teachers frequently subscribe the same incorrect views as their students, and (2) incorrect views spring from direct observation and formal class intervention. In addition, previous instructions may not be effective since teachers failed to consider students' prior knowledge. As posited by Meheut and Psillos (2004), the failure to know what students know may mean failure to let students learn. Despite these reasons, students attempt to describe and explain different phenomena in the physical world based on their knowledge and experience. As a result, many alternative conceptions form and harbor in students' mental network and even bring about alternative compound conceptions.

Physics education research has reported that some students come to class with debilitating alternative conceptions. Unfortunately, traditional methods of physics teaching do not usually consider these alternative conceptions and fail to promote conceptual understanding (Richland & Simms, 2015). Researchers over the years have affirmed that teachers are a strong causal factor in shaping the quality of teaching-learning in schools (Archibald, 2006; Darling-Hammond & Baratz-Snowden, 2005; Harrison & Treagust, 1993). Vital to promoting conceptual understanding is the ability of teachers to design teaching-learning sequences that provide students the appropriate engaging activities to personally construct knowledge. This implies that teachers' ability to plan lessons towards enabling the teaching-learning process should be developed and emphasized. More so, the pedagogical ideas, specifically the teaching strategy, a teacher plays a key role in fostering conceptual understanding to address the two major concerns pointed out previously: (1) abstractness, complexity, and unfamiliarity of scientific concepts; and (2) failure to consider students' prior knowledge.

A teaching strategy which considers students preconceptions and makes scientific concepts concrete, simple, and familiar is bridging analogies. Clement (1993) pioneered the use of bridging analogies primarily to foster conceptual change among students. According to him, bridging analogies is a teaching strategy which considers an intermediate case that shares features with what students know and the target concept. Murray, Schultz, Brown, and Clement (1990) posited that bridging analogies engenders active learning and bars passive acceptance of information. Additionally, they identified two conditions in topic selection if bridging analogies is to be used: (1) topic areas must be qualitative and conceptual; and (2) there are deep-seated alternative conceptions that exist in students.

Similarly, Duit, Roth, Komorek, and Wilbers (2001) said that "the use of analogies as learning aids is recommended …in cases where students' pre-instructional conceptions and the science concepts are incompatible, that is, where conceptual change is necessary (p. 284)." The difficulties students have with normal force, surface friction force, and tension force are prime examples (Clement,1993; Camp and Clement, 2010; Abak, Eryilmaz, Yimaz and Yilmaz, 2001; Singh, 2007; Carvalho and eSousa, 2005; Demirci, 2005; Halim, Young and Meerah, 2014). Common pitfalls of students are the failure to recognize that solid and rigid objects do not exert forces, and friction is not a force which does not have a direction. Needless to enumerate further other alternative conceptions, there is a need to replace them with scientifically correct one by implementing constructivist teaching strategies which may result in more effective and meaningful learning, particularly conceptual change.

Dagher (1994), in his review of analogy studies, showed that analogical teaching strategy allows students to effectively learn by considering their preconceptions and making concepts concrete, simple, and familiar. In other words, bridging analogies may transform alternative conceptions to scientific ones by mapping similarities between what students know and the target concept. Nevertheless, conceptual understanding is not quickly achieved. So, a series of coherent and interlaced lessons must be appropriately planned, developed, implemented, and evaluated. These aspects then address the two main problems being underscored.

The primary purpose of this study, therefore, was to develop a teaching-learning sequence on contact forces namely normal force, surface friction force, and tension force using bridging analogies and investigate its effect on students' conceptions. This study bridged the gap between the theory and practice of constructivism in the actual classroom intended to contribute to the growing body of knowledge in conceptual change and bridging analogies in the local context since detailed descriptions on students' conceptual changes has scant journal presence (Rosaroso, 2015).

2 METHOD

2.1 *Research design*

This study used a type-3 developmental concurrent-nested mixed methods research design involving an intact group. The main focus was to develop a teaching-learning sequence on normal force, surface friction force, and tension force using bridging analogies, and investigated its effect on students' conceptions. A Type-3 developmental design was used since the study was non-cyclic (Richey, 1994). Meaning, the researcher may base target alternative conceptions from the literature and follow a single-phase track—design, develop, and evaluate—without conducting a needs analysis, and the final results may not be used to modify the prepared teaching-learning sequence. A concurrent-nested mixed methods design is a research design in which one data set provides a supportive role in a study based primarily on the other data set. In this study, the quantitative data provided support to the qualitative data. The quantitative data included a conceptual inventory (pre-test and post-test) to determine the initial and final conceptions of students. The qualitative data such as semi-structured interviews, focus group discussions, students' journal entries, activity sheets, and voting sheets helped the researcher describe the conceptual changes of students. Since the researcher was the teacher of the intact class, another teacher was present to serve as an external observer. The rationale for collecting both quantitative and qualitative data was to bring together the strengths of both forms of research to corroborate the results from two different perspectives.

2.2 *Research environment*

The study was conducted at a local university in Dumaguete City, Negros Oriental. The university is a non-profit and non-sectarian private educational institution. The university has two campuses: the main campus and north campus. The study was conducted in the north campus because the senior high school department is located there. The university fully integrates technology in the teaching-learning process. Students from Grade 4 to senior high school are required to have an iPad to technologically aid and facilitate learning.

2.3 *Research participants*

This study involved one heterogenous physics class of Grade 12 STEM (Science, Technology, Engineering, and Mathematics) students that were purposively chosen among 11 sections. The class had 42 students. The students would have to take General Physics I, a specialized subject in their curriculum, which was handled by the researcher. From the class, three focus groups were formed to gather in-depth information to support the quantitative data. Each group was composed of three students and was a mixture of a high, an average, and a low-performing student. The selection of the members of each focus group was made in such a fashion to represent the class according to academic performance fairly. However, the effectiveness of the bridging analogies was not correlated with their academic performance. The selection of the members of the three groups was based on their average grades in Grade 10 science and mathematics.

The members of the focus groups were given other names for the study. Paul, Simon, and Cesar were the students with high academic performance. The students with average academic achievement were John, Peter, and Rose. Lastly, Mary, Elizabeth, and Kate made up the low-performing group.

2.4 *Research instruments*

Different instruments helped the study to identify and describe students' conceptual changes. To assess students' conceptual understanding, reasoning, and application of the concepts of normal force, surface friction force, and tension force before and after the implementation of the TLS, a conceptual inventory was used. The conceptual inventory is a 20-item multiple test guided by the works of Clement et al. (1989), Camp and Clement (2010), and Garcia et al. (2009). Moreover, the items that were included in the conceptual inventory aimed to identify common alternative conceptions. In each multiple-choice item, students were asked to provide their answer, an explanation or justification of such answer, a vector diagram of the forces present, and their confidence level, in a scale from 1 to 4, of their answers. Also, the study also used voting sheets. This instrument is a sheet of paper in which students write their "votes" or answers to questions about the target problem and other bridging cases. The primary use of the voting sheets was to serve as a form of feedback mechanism. Through this, the teacher was given valuable information on students' conceptions and how they changed during the implementation of the TLS.

Semi-structured interviews were conducted to the focus groups. The interviews included a pre-interview which covered pre-requisite concepts related to normal force, surface friction force, and tension force and post-interview which focused on the following concepts: (1) existence of normal force; (2) "equality" of normal forces; (3) existence of surface friction force; (4) direction of surface friction force; (5) "uniformity of tension force; and (6) changes in direction of tension forces. A focus group discussion was conducted after every lesson to keep track of students' conceptions especially conceptual changes. Also, after every lesson, students were tasked to write reflections and insights on a learning journal called *My Daily Dose of Physics*. The journal provided specific areas for students to write their discoveries or learning, difficulties, and parts of the instruction that helped them learn new concepts and overcome certain alternative conceptions.

Lastly, the researcher developed a teaching-learning sequence. This instrument is composed of a series of 5 lessons on normal force, surface friction force, and tension force interlaced with a common teaching strategy called bridging analogies created by Camp and Clement (2010). One of the bridging analogies used is presented in Figure 1. In the TLS, each lesson had corresponding activity sheets and homework sheets. In the activity sheets, procedures and guidelines of the group and individual activities were included. Specific questions about the activities were part of it, too. The homework sheets gave the students the opportunity to apply concepts to different cases, reinforce their learning, and search for other resources to find answers.

2.5 *Research procedure*

This developmental study followed a four-phase course. The four phases were Design Phase, Pilot-Testing Phase, Field-Testing Phase, and Analysis Phase. The Design Phase involved the planning, developing, and producing the teaching-learning sequence. The national curriculum

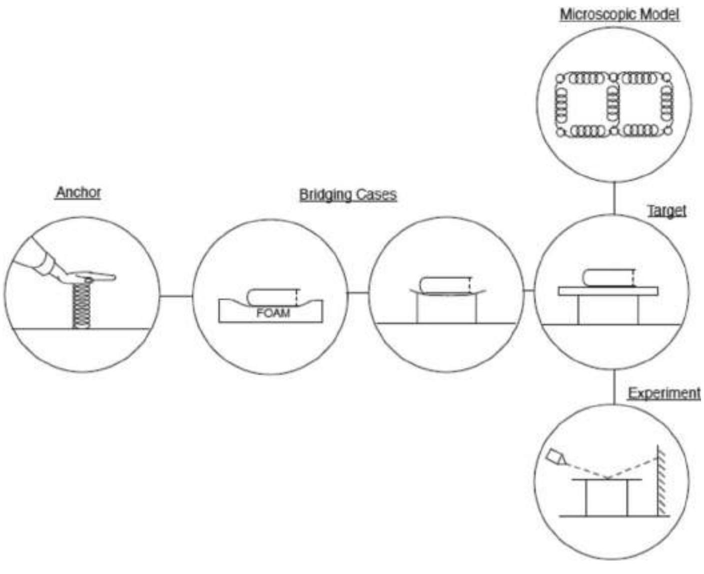


Figure 1. Bridging analogies for normal force adopted from Camp and Clement (2010).

guide for the senior high school was the primary reference for the target competencies and specific lesson objectives. Principally, the lessons that were developed in the sequence were anchored on the works of Camp and Clement (2010). Students' preconceptions were identified through a conceptual inventory designed to surface alternative conceptions. The pre-test was given to give the researcher the time to determine areas of lessons which needed emphasis. In addition, the researcher adopted the so-called design brief by Leach, Ametller, and Scott (2010). Design brief was created to make the design aims explicit and objective for a fragment of science teaching, rationalizing the choices and decisions that have been made. Design brief is comprised of three components: (1) context for the designed teaching-learning; (2) detailed content aims; and (3) pedagogic strategies and sequencing of topic contents. The target alternative conceptions considered in the development of the TLS were based on available literature. Aside from the nature of the study, alternative conceptions are also deemed as universal. Meaning, it may hold true to the participants of the study. Correspondingly, as per the results of the pre-test, the students kept the identified alternative conceptions from the literature. The selection of alternative conceptions that were included as areas of emphasis was appropriated to the conceptual scope of the bridging analogies by Camp and Clement (2010). Consequently, in the vast array of alternative conceptions available in the literature on normal force, surface friction force, and tension force, the following alternative conceptions were considered:

1. Normal Force
   a. Solid and rigid objects do not exert forces.
   b. When a pair of objects thrust on each other, the bigger mass exerts a greater force.
   c. When a pair of objects interacts, the "stronger" or harder object pushes with a greater force than the "weaker" or softer object.
   d. Motion implies active force; so, no motion implies no force at all.
2. Surface Friction Force
   a. Friction does not act in a particular direction.
   b. The magnitude of the surface friction force on a static object is greater than the net force applied to the object parallel to the surface.
   c. Static friction is always at the maximum value.
   d. Friction is not a force, but some influence which interferes with motion.
3. Tension Force
   a. The tension in a rope is the sum of the magnitude of the forces acting on both ends of the rope.
   b. Strong ropes pull with more force than weak or stretchable ropes.
   c. Walls or posts that are rigid do not exert a force on a rope tied to them.
   d. Change in angle (like in pulleys) implies change in tension force.

These alternative conceptions served as one of the bases for the construction of the learning demands in the TLS. At the culmination of the initial printing and production of the teaching-learning sequence, hardbound copies were given to the thesis adviser and two other science high school teachers for critique and validation. The comments and suggestions of the critic-teachers were constructively considered to revise and improve the sequence before the next phase.

The next phase was the Pilot-Testing. In this phase, the validated teaching-learning sequence was carried out to 15 college teacher-education students. The purpose of the pilot-testing was for the researcher to establish familiarization on the flow of each lesson and observe how time-management could be improved. Also, possible modifications were expected to surface to better the teaching-learning sequence. At the end of the second phase, the 15 students were asked to give feedback on their experiences of the activities. Points to improve was taken constructively such that necessary changes were imposed to the TLS.

The third phase was the Field-Testing. This phase included three stages. Firstly, the researcher observed the participating class for three meetings. The observations gave the idea to the researcher as to the general behavior of the class since the researcher would substitute the original instructor for weeks. After which, pre-interviews and writing of pre-instruction journals were conducted. Then, the TLS using bridging analogies was implemented. In this stage, various data were collected as lessons progressed and through the research instruments (journals, home works, activity sheets, recordings, etc.). As part of research ethics, the students were informed ahead that the results would be kept confidential. Lastly, a focus group discussion among purposively selected students was conducted. The focus groups were continuously interviewed as the research ran. Students' conceptual changes were then identified at the culmination of the TLS through the post-test and post-interviews.

The last was the Analysis Phase. Here, the results and/or substantive data of the focus group from the pre-test and post-test, interviews, journals, activity sheets, voting sheets, home works, recordings, and observation notes were consolidated to present the correspondence and connect of student's initial and final conceptions. This was to track and describe the conceptual changes of the students. The learning gain of the rest of the class was informed by the results of the pre-test and post-test. Their learning gain was identified and analyzed using the normalized gain (Hake's formula).

3 RESULT AND DISCUSSION

In this study, results were classified into three major sections: (1) students' initial conceptions on normal force, surface friction force, and tension force; (2) students' conceptual changes during the implementation of the teaching-learning sequence and; (3) students' final conception on normal force, surface friction force, and tension force. The identified initial conceptions are then classified as correct conceptions and alternative conceptions. These initial conceptions were integral in the identification of areas of emphases during the development of the teaching-learning sequence and description of how students' conceptions on normal force, surface friction force, and tension force changed during and after the implementation of the developed teaching-learning sequence.

Table 1. Percentages of students' responses in the pre-test and post-test.

	Percentage of students' answer per choice (%)											
	A		B		C		D		E		No answer	
Item No.	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	21.43	0	4.76	5.26	30.95	0	16.67	84.21	26.19	10.53	0	0
2	21.43	5.26	28.57	13.16	33.33	36.84	9.52	18.42	4.76	18.42	2.38	7.89
3	7.14	10.53	38.1	15.79	23.81	60.53	14.29	7.89	16.67	5.26	0	0
4	7.14	13.16	52.38	44.74	23.81	5.26	4.76	0	21.43	36.84	4.76	0
5	19.05	7.89	9.52	26.32	7.14	31.58	38.1	21.05	35.71	13.16	4.76	0
6	11.90	15.79	38.1	39.47	4.76	0	4.76	2.63	28.57	39.47	4.76	2.63
7	14.29	36.84	26.19	7.89	19.05	15.79	4.76	2.63	9.52	36.84	7.14	0
8	19.05	13.16	7.14	5.26	11.91	52.63	45.24	21.05	2.38	7.89	7.14	0
9	33.33	10.53	7.14	7.89	40.48	21.05	9.52	52.63	2.38	2.63	7.14	5.26
10	11.90	13.16	42.86	13.16	14.29	2.63	14.29	63.16	26.19	5.26	14.29	2.63
11	4.76	18.42	26.19	13.16	14.29	10.53	19.05	44.74	19.05	13.16	9.52	0
12	4.76	18.42	7.14	0	9.52	18.42	38.1	44.74	38.1	15.79	21.43	2.63
13	45.23	18.42	2.38	7.89	19.05	60.53	2.38	7.89	2.38	0	19.05	5.26
14	7.14	39.47	2.38	7.89	19.05	2.63	11.90	5.26	11.9	42.11	14.29	2.63
15	28.57	7.89	7.14	0	9.52	5.26	33.33	31.58	33.33	50	16.67	5.26
16	14.29	50	4.76	0	47.62	26.32	7.14	10.53	7.14	10.53	14.29	2.63
17	16.67	65.79	7.14	5.26	19.05	13.16	21.43	7.89	21.42	5.26	16.67	2.63
18	26.19	5.26	7.14	2.63	7.14	2.63	9.52	0	9.52	86.84	11.90	2.63
19	52.38	33.33	26.19	58.97	2.38	0	4.76	0	4.76	2.56	14.29	5.13
20	14.29	8.11	2.38	8.11	9.52	0	26.19	67.57	26.19	13.51	19.05	2.70

Correct answer per item is in red. n = 44.

Table 2. Identified common initial conceptions in the pre-test.

Students' common initial conceptions		
Normal force	Surface friction force	Tension force
✓ Normal force has equal magnitude and opposite direction of the component of the gravitational force. (NF1) × Solid objects do not exert forces. (NF2) × Weight and applied force along the y-axis are not collinear forces. (NF3) × When two stationary objects push on each other, the stronger or bigger or harder one exerts the larger amount of force than the weaker or smaller or softer one. (NF4) × Normal force is the summation of all forces along y-axis and/or x-axis. (NF5) × The force of gravity "penetrates" through objects such that soft objects have high penetrability. (NF6)	× Smooth surfaces do not cause moving objects to come to a stop. (SF1) × Moving objects stop because they ran out force. (SF2) × The magnitude of the surface friction force on a static object is greater than the force applied to the object parallel to the surface. (SF3) × Surface friction force together with the force of gravity acts on the same direction of the force applied to the object parallel to the surface. (SF4) × Normal and gravitational force act along the x-axis. (SF5) × Normal force, not surface friction force resists motion. (SF6) × The system of interest is the set of forces acting indirectly upon an object in a given situation. (SF7)	✓ Tension forces are the pulls exerted stretched strings or ropes on the bodies to which they are attached to; are equally transmitted along the direction of the string or rope. (TF1) × Tension force is only present at the ends of a stretched rope or cable. (TF2) × Tension force in both ends of a rope are equal but not in the middle point of the rope. (TF3) × The tension force in a rope is the sum of the magnitude of the forces acting on the rope. (TF4) × Trees that are rigid do not exert a force on a rope tied to them. (TF5) × Change of direction of the rope (bent) implies a change in the magnitude of the tension force. (TF6) × Tension force in both ends of a rope is not equal. (TF7) × The tension of a massless rope is not equally transmitted along the rope or medium. (TF8)

Items with a check mark (✓) indicate correct conception. A wrong mark (×) indicates alternative conception.

3.1 *Common initial conceptions on normal force, surface friction force, and tension force*

The 20-item conceptual inventory revealed students' common initial conceptions on the three contact forces included in the study. A choice which was selected by at least 20% of the class was considered as a common initial conception. Hence, there may be other conceptions that may be identified. This mechanism was adopted since the researcher could not account for all responses of the students due to time constraints.

As allotted in the table of specifications, eight items were about normal force, four items were about surface friction force, and eight items were about tension force. More specifically, items 2,3,4,8,9,10,16, and 17 assessed students' initial conceptions on normal force, items 5,6,7, and 11 assessed students' initial conceptions on surface friction force, and items 1,12, 13, 14, 15, 18, 19, and 20 assessed students' initial conceptions on tension force. In each item, corresponding alternative conceptions were embedded in all distracter-choices. The respective percentages of students' responses in each item in the pre-test and post-test are shown in Table 1.

As shown in Table 2, the students have both correct and incorrect conceptions. However, it must be noted that the majority of the identified common initial conceptions were alternative conceptions.

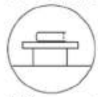
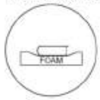
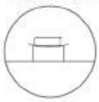
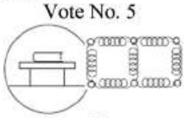
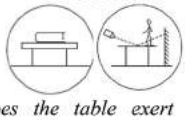
3.2 *Students' conceptions during TLS implementation*

The conceptions of students during the TLS implementation were identified from the voting sheets in which the series of bridging analogies were presented as closed-ended questions. Moreover, students were asked to explain their answer and rate their make-sense score.

The data indicated that majority of the students had alternative initial conceptions across all lesson areas. In the overall track of student's conceptual changes across all lesson areas, it may be interpreted that conceptual change was achieved by most of the students after the series of bridging analogies. However, it was found out also that not all the bridging analogies used in each lesson contributed to the conceptual change of the students. To provide clarification and explanation to students' conceptual changes during the implementation of the TLS, focus groups' responses to the interviews after each lesson, journal entries, and their explanations in the voting sheets and responses on the different activity sheets were used.

A sample of the summary of the votes made by the students is shown in Table 3. Across all five lessons, the pattern of the student's conceptual changes is similar to what is presented

Table 3. Sample of a voting sheet to trace conceptual changes during TLS implementation.

Vote Number and Question	Yes	No	Total
Vote No. 1  *Does the table exert an upward force on the book?*	45.24%	**54.76%**	100%
Vote No. 2  *Does the spring exert an upward force on the hand?*	**92.86%**	7.14%	100%
Vote No. 3  *Does the foam exert an upward force on the book?*	**83.33%**	16.67%	100%
Vote No. 4  *Do the flexible meter sticks exert an upward force on the book?*	**90.48%**	9.52%	100%
Vote No. 5  *Does the table exert an upward force on the book?* *(after presentation of springy model)*	**83.33%**	16.67%	100%
Vote No. 6  *Does the table exert an upward force on the book?* *(after experiment with laser light)*	**95.24%**	4.76%	100%

n = 42.

in Table 3. Majority of the students demonstrated a subscription to alternative conceptions in every first vote. Through the stages of the lessons in which different bridging cases were used, significant changes were seen in their responses such that more students were making the correct vote. Consistently, at the last vote which had the same question in the first vote, the majority of the students, if not all, made a correct vote.

3.3 *Students' final conceptions after TLS implementation*

The final conceptions identified are those conceptions which were targeted in the respective lessons. This is so to see the effect of the TLS with bridging analogies as far as engendering conceptual change among students is concerned. Meaning, there may be prevalent conceptions, categorized as a choice selected by at least 20% of the class, that is not discussed. The final conceptions are shown in Table 4.

Table 4. Identified final conceptions in the post-test.

Students' common final conceptions		
Normal force	Surface friction force	Tension force
✓ Normal force has equal magnitude and opposite direction of the component of the gravitational force. × When two stationary objects push on each other, the stronger or bigger or harder one exerts larger amount of force than the weaker or smaller or softer one.	✓ Surface friction force acts opposite to the direction of the applied force applied to the object.	✓ Tension forces are the pulls exerted stretched strings or ropes on the bodies to which they are attached to; are equally transmitted along the direction of the string or rope. × The tension of a massless rope is not equally transmitted along the rope or medium.

Items with a check mark (✓) indicate correct conception. A wrong mark (×) indicates alternative conception.

Table 5. Students' normalized gain per item.

Item number	Percentage of Students with correct answers in the pre-test (%)	Percentage of students with correct answers in the post-test (%)	Normalized Gain (g)
1	16.7	84.21	0.81
2	4.8	18.42	0.14
3	23.8	60.53	0.48
4	7.1	36.84	0.32
5	7.1	31.58	0.26
6	12	15.79	0.04
7	19	15.79	–0.04
8	11.9	52.63	0.46
9	9.5	52.63	0.48
10	14.3	63.16	0.38
11	19	44.74	0.32
12	38.1	44.74	0.11
13	19	60.54	0.51
14	7.1	39.47	0.35
15	4.8	50	0.47
16	14.3	50	0.42
17	16.7	65.79	0.59
18	38.1	86.85	0.79
19	26.2	58.97	0.44
20	26.2	67.57	0.56

In Table 5, students' gain per item is presented. Gains of $g < 0.30$ are characterized as low gain, $0.30 < g < 0.70$ is considered medium gain, and $g > 0.70$ is classified as high gain. The normalized gains indicate the effect of the developed teaching-learning sequence particularly the percentage of students responded with correct answers in the pre-test versus the percentage of students responded with correct answers in the post-test per respective items clustered according to the three main topics included in the study. Many of the items got a medium to high gain. However, item number 7 got a negative gain. The situation given was a block of wood is pulled with a constant force F_a on a rough horizontal surface by a rope which makes an angle of 25^0 with the horizontal, and the block does not slide. Students were asked to give the correct expression for the sum of the force components acting in the x-direction. Although students had correctly discriminated surface friction as a force acting opposite to the direction of the applied force applied to the object, they were not able to correctly and expressively write it as $F_{Applied} - F_{Friction} = 0$. The students instead answered $F_{Applied} + F_{Friction} = 0$.

4 CONCLUSION

The developed teaching-learning sequence on normal force, surface friction force, and tension force using bridging analogies engendered conceptual change among students. However, certain alternative conceptions on normal force and tension force remained unchanged. Overall, the students had a medium gain after the developed TLS was implemented which indicated that was effective in promoting conceptual change among students.

With the results of the study and experience of the researcher in using bridging analogies, it is recommended that a study must be conducted to investigate which part of the bridging analogies has the most significant effect in fostering conceptual change. Moreover, in the TLS, adding lessons about the general characteristics of force as a vector quantity and how to draw a free body diagram may help students prepare for the discussions of normal force, surface friction force, and tension force. It is also suggested that the teacher may integrate technology in the discussions by using computer simulation especially on how surface friction force occurs at the microscopic level. Furthermore, future researchers must address the limitation that discounts the presence of a component-based presentation of normal force particularly in the transition from the book-table case to car-hydrant case. Lastly, physics educators are encouraged to create more bridging analogies in other areas of physics aside from mechanics.

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Measuring Indonesian chemistry students' Higher Order Thinking Skills (HOTS) in solving chemical kinetics questions

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ABSTRACT: Identification students' understanding of chemistry concepts is generally carried out by giving questions as to what is presented in lectures and textbooks, which commonly provide just one solution to each problem. The emphasis on Higher Order Thinking Skills (HOTS) question type is generally less of a priority. This study aims to identify Indonesian students' HOTS in solving chemical kinetics questions. 379 chemistry students from Haluoleo University participated in this research. Students' HOTS was assessed by using a chemical kinetics HOTS instrument in the form of pictorial and algorithmic-type questions. By comparing students' answers to both types, the students' HOTS is revealed. This study shows that Indonesian students' HOTS is not well developed.

1 INTRODUCTION

In many studies, the term higher-order thinking is classified as Higher Order Thinking Skills (HOTS), Higher Order Cognitive Skills (HOCS) and cognitive skills. However, the term Higher Order Thinking Skills (HOTS) is preferred in this study. According to Zohar (2004), the term HOTS is purposefully unestablished in a single definition. Resnick (1987) explained that a HOTS question has several characteristics, including non-algorithmic, more complex, multiple solutions, involving judgment and interpretation, multiple criteria, effortful and often involving uncertainty. Zoller & Pushkin (2007) stated that students with good HOTS can show academic achievement, can be successful, can shine in their social interaction and can earn emotional, social and economic maturity. Similarly, Whimbey in Zoller & Pushkin (2007) claimed that thinking skills instruction proved useful, not only in developing students' academic achievement, but also in making them into good problem solvers in different situations in their daily lives.

The crucial role of teaching and the evaluation of HOTS in science education has been concluded from many literature resources by Zoller & Dori (2002). Therefore, the change of paradigm of chemistry learning in university from LOCS to HOCS should be promoted, both in teaching and learning, and in assessment (Zoller et al., 1999). Furthermore, they confirmed that HOTS assessment will help students become confident and independent learners.

HOTS questions will train students to think creatively and critically, therefore these are essential for future study and employability (Habiddin & Page, 2016). This study aims to investigate chemistry students' ability in answering chemical kinetics HOTS questions. The knowledge regarding students' HOTS will help chemistry educators to promote HOTS, as well as to improve the quality of teaching and learning in chemical kinetics.

2 METHOD

Students' HOTS ability in this study was reflected by students' ability in answering chemical kinetics questions, which were generally displayed pictorially. The HOTS instrument used was in the form of equivalent algorithmic and pictorial questions with 11 questions in total. 379 chemistry students from two Indonesian universities participated in this study. Those students are: 197 first year chemistry students from Universitas Negeri Malang (UM), 63 second year chemistry students from Universitas Haluoleo (UHO), 63 second year chemistry students from Universitas Negeri Malang (UM) and 56 third year chemistry students from Universitas Negeri Malang (UM).

Students' answer in each question was graded with 0 (zero) as the lowest score and 10 as the highest score. Furthermore, those answers were categorized within 4 groups including WNA, *l*PCA, *u*PCA and CA. WNA (wrong or no answer) refers to students' totally incorrect answer with the score 0. *l*PCA (lower–partially correct answer) refers to students' answers that were graded from 1 to 4. *u*PCA (upper–partially correct answer) refers to students' answers that were graded from 5 to 8. CA (correct answer) refers to students' answers that were totally or almost totally correct and graded with the score of 9 or 10. In addition, students' answers were also analyzed descriptively and reflected the correct scientific concept to interpret whether the students' experience was misconception or not.

3 RESULT AND DISCUSSION

3.1 *Numerical description of students' responses*

Students' answers in each question were graded and categorized within 4 groups (WNA, *l*PCA, *u*PCA and CA) according to the criteria as explained in the method section above. The total number of students in each group of students in each category in each question is presented in Table 1 below.

The shaded yellow in Table 1 shows the category in which the number of students is the highest among other categories in each group of students in each question. The table shows that WNA is the most dominant category in each group in each question. For UHO 2nd year students, in particular, WNA is the highest category in each question. This implies students' lack of knowledge of chemical kinetics concepts. This also indicated that those students hold some misconceptions. *u*PCA and CA categories were often shown by UM 3rd year students only, while *l*PCA was dominantly shown by UM 2nd year students.

3.2 *Description of Indonesian students' HOTS*

Students' HOTS in solving the chemical kinetics questions is described in each task below.

Task 1: Reaction mechanism, intermediate and catalyst

The majority of the UM first year students (48.72%) gave *l*PCA. A high number of UHO year 2 students (37.33%) also gave *l*PCA. Those students generally gave the correct answer for question part (a) only. Yet, they could not determine the species that act as intermediate (part b) and catalyst (part c). Some students within this group assumed that a catalyst only increases the rate without being involved chemically in the reaction. In addition, that an intermediate is a substance/reactant that is not found in the final product is also found. This confirms the previous study that students got into difficulty in differentiating between the terms of the intermediate and activated complex (Kolomuç & Tekin, 2011; Tastan & Boz, 2010).

5.13% of the year 1 UM students showed *u*PCA. This number is only slightly different from the number of second year UHO students (6.67%) who also gave *u*PCA. The high number of this category was shown by 37.50% of the year 2 UM students and 50% of the year 3 UM students. Those students answered correctly for Q1 part (a). For Q1 part (b), many students within this group generally answered correctly regarding the species acting as

Table 1. The percentage of students' answer.

		Number of students (%)										
		1	2	3	4	5	6	7	8	9	10	11
Student	Category	Question number										
UM	WNA	46.15	58.97	33.33	79.49	100	100	51.28	100	92.31	84.62	84.62
1st year	*l*PCA	48.72	17.95	5.13	7.69	0.00	0.00	28.21	0.00	0.00	2.56	0.00
	*u*PCA	5.13	20.51	15.38	7.69	0.00	0.00	15.38	0.00	0.00	5.13	7.69
	CA	0.00	2.56	46.15	5.13	0.00	0.00	5.13	0.00	7.69	7.69	7.69
UHO	WNA	56.00	81.33	76.00	77.33	100	100	97.33	100	96.00	100	50.67
2nd year	*l*PCA	37.33	8.00	0.00	5.33	0.00	0.00	1.33	0.00	0.00	0.00	6.67
	*u*PCA	6.67	10.67	4.00	16.00	0.00	0.00	1.33	0.00	0.00	0.00	5.33
	CA	0.00	0.00	20.00	1.33	0.00	0.00	0.00	0.00	4.00	0.00	37.33
UM	WNA	8.33	20.83	16.67	33.33	95.83	87.50	20.83	95.83	54.17	91.67	29.17
2nd year	*l*PCA	41.67	41.67	8.33	12.50	0.00	0.00	20.83	4.17	4.17	8.33	8.33
	*u*PCA	37.50	37.50	16.67	37.50	0.00	12.50	50.00	0.00	4.17	0.00	25.00
	CA	12.50	0.00	58.33	16.67	4.17	0.00	8.33	0.00	37.50	0.00	37.50
UM	WNA	6.25	0.00	0.00	25.00	6.25	87.50	68.75	100	50.00	100	18.75
3rd year	*l*PCA	0.00	12.50	0.00	0.00	0.00	12.50	6.25	0.00	0.00	0.00	0.00
	*u*PCA	50.00	87.50	0.00	56.25	6.25	0.00	12.50	0.00	0.00	0.00	0.00
	CA	43.75	0.00	100	18.75	87.50	0.00	12.50	0.00	50.00	0.00	81.25

WNA: wrong/no answer.
*l*PCA: lower grade of partially correct answer.
CA: correct answer.
*u*PCA: upper grade of partially correct answer.

a catalyst. However, the misconception that a catalyst only increases the rate without being involved chemically in the reaction was still found among those students. This misconception is found among first and second year students, but none among third year students.

The term intermediate was the most difficult for students. Some misunderstandings regarding this terminology are revealed. For instance, B is intermediate, as it reacted in step 1 and unchanged in step 2. Other students assumed that C is intermediate as it reacts in the lowest number or concentration. AB and AC were also considered as intermediates, as they both contain two different elements.

Another question for this task was given in Q8 and in the form of algorithmic type. Both questions (Q1 and Q8) are not equal in terms of the identified concept and also the expected difficulty level. In this Q8, students were expected to determine the rate law based on the mechanism with a fast-initial step. None of first year UM and second year UHO students gave neither CA nor PCA. Those students totally do not have the knowledge to answer this question. Surprisingly, even all third year UM students (100%) gave WNA. Only 4.17% of the second year UM students gave *l*PCA. However, how this student arrives at the correct answer is unusual.

Task 2: The relative rates and half-life of the first-order reaction

Low number of second year UHO students (8%) and third year UM students (12.50%) gave *l*PCA. A slightly higher number of first year UM students gave *l*PCA at 17.95%. Meanwhile, almost half of second year UM students (41.67%) also gave *l*PCA. Those students generally only gave the correct answer for Q2 part (a). However, when answering the next parts, students got into difficulty.

20.51% and 10.67% of the first year UM students and second year UHO students respectively gave *u*PCA. The high number of students giving *u*PCA are shown by second and third year UM students with 37.50% and 87.50% respectively. Those students generally understood correctly the ratio of the concentrations for containers (i)–(iii), which is 5:2:4. They

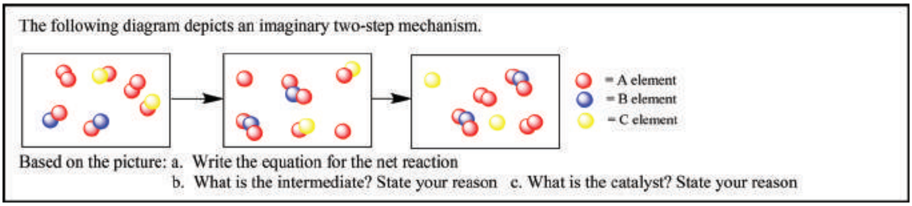

Figure 1. Question 1 (Q1).

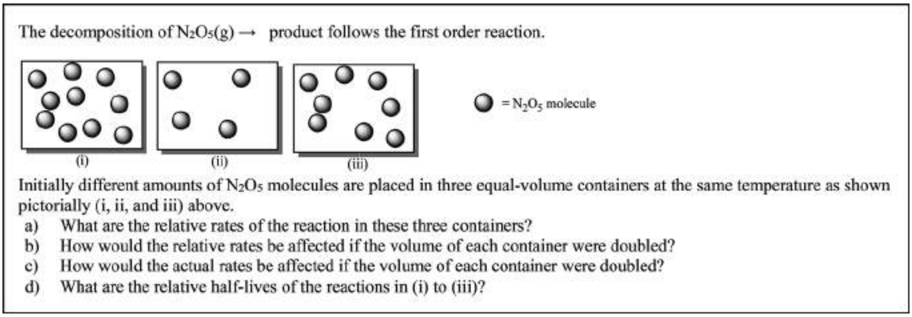

Figure 2. Question 2 (Q2).

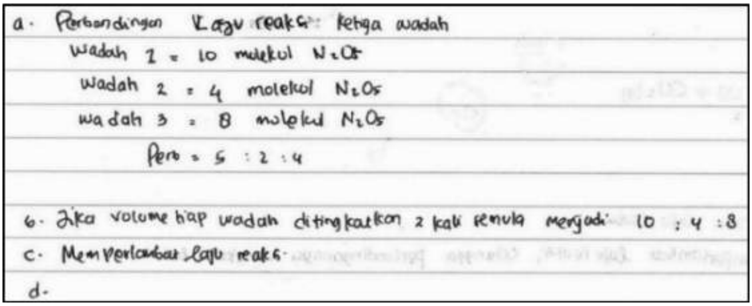

Figure 3. Example of students' answer to Q2.

also generally understood that, in spite of doubling the volume, it would halve each of the concentrations, but the ratio of the concentrations for containers (i)–(iii) would still the same. However, an unusual answer among this group was found, as given in Figure 3 below.

Q2 part (c) was answered correctly by students with PCA. However, a small fraction of students in this group still believed that doubling the volume of the containers increases the rate of reaction. Q2 part (d) was the most difficult for those students with PCA. This part basically requires the same knowledge to answer the previous parts of the question. However, the addition 'half-life' in the question roots students' mistake. To answer this part, students should realize that the half-life is independent of the initial concentration of the first-order reaction. These students' difficulties indicate that students' HOTS is inadequate to answer such analytical questions. Some students' misunderstandings are found in this question. Some students assumed that the increase in volume increases the reaction rate. On the other hand, the decrease in volume decreases the reaction rate. This misunderstanding was shown by students with WNA, *l*PCA and *u*PCA.

An equivalent question for this task was given in Q7 in the form of algorithmic type. WNA is still a dominant category in all groups except the second year UM students at 20.83%. Again, the misconception that the increase in volume increases the reaction rate was also found in Q7. Some students also assumed that the decrease in concentration of second-order reaction increases the reaction rate. The numbers of students giving CA, PCA and WNA between the two HOTS questions, including Q2 (pictorial) and Q7 (algorithmic), are almost equal. This indicates that students' HOTS in this task is not affected by the type of question.

The dependence of reaction rate on concentration

This task was represented by Q4 and Q3. Q4 below is a three part (a, b and c) question, which was presented in pictorial style. Parts (a) and (b) only need Lower Order Thinking Skills (LOTS), while part (c) requires HOTS. All in all, part (c) of the question was not intended to assess students' answer whether the rate will increase or decrease. The main point is how students gave such an analytical explanation to justify their answer scientifically. Students with PCA generally answered Q4 part (a) and part (b) correctly. However, students got into difficulty when answering part (c). Some students left the answer sheet blank, meaning that they had no idea how to answer this HOTS question.

The misconception that was found among some students with WNA and PCA is that the increase in volume increases the mobility of molecules and leads to the increase in the reaction rate. In contrast, the decrease in volume decreases the mobility of molecules and leads to the decrease in the reaction rate. Another misconception is that the change in volume does not affect the reaction rate, as only the change in concentration will influence the reaction rate. This misconception indicates the students' lack of knowledge regarding the relationship between volume and concentration. These such misconceptions were found among all participated groups including first, second and third year students.

An equivalent question for this task was given in Q3 in the form of algorithmic type. This question demands the same level of thinking as LOTS with question part (a) and (b) of the pictorial one. The results show a significant difference with the results of the pictorial one. All third year UM students gave CA. CA is also dominant for first and second year UM students with 46.15% and 58.33% respectively. Meanwhile, only 20% of the second year UHO students gave CA. The high numbers of students giving CA implies that those students have adequate knowledge regarding the dependence of reaction rate on concentration. So, this emphasizes that students' wrong answer of part (c) for the pictorial one (Q4) is rooted by lack of students' HOTS.

Regardless of the high number of students giving CA, the misconceptions as found in the equivalent pictorial question is also uncovered in this algorithmic question. Some students argued that the increase in the concentration of $S_2O_8^{2-}$ decreases the reaction rate. On the other hand, the decrease in concentration of $S_2O_8^{2-}$ increases the reaction rate. In addition, the reaction rate for experiment 2 and experiment 3 cannot be predicted from the information provided in the question is also found. As in the previous misconception of the equivalent pictorial question, those students argued that the reaction rate depends on the concentration only. This misunderstanding is completely surprising as the concentrations of $S_2O_8^{2-}$ and I^- have been provided in the question. Students' misconceptions regarding the dependence of rate on concentration have been reported by many previous studies (Cakmakci, 2010; Cakmakci & Aydogdu, 2011; Kirik & Boz, 2012).

Task 4: Determining the time needed for reactants with different reaction orders to be halved

This task was represented by Q10 and Q5. Q10 describes the successive half-lives of nitrogen dioxide to nitric oxide and oxygen at a certain temperature. The starting material is given in the left box at t = 0 minutes. The first half-life is given in the middle box at t = 20 minutes. Furthermore, in the last box, students are expected to determine if the second half-life of the reaction is (a) zero, (b) first or (c) second order.

Students with WNA generally left the question blank. Students with *l*PCA generally answered Q10 part (b) correctly but not for part (a) and (c). While students with *u*PCA answered either parts (a) and (b) correctly or part (b) and (c) correctly. A typical misunderstanding uncovered is that students' use the equation for the half-life of a first-order reaction to finding out the half-life of a zero-order reaction and do not realize that they are different.

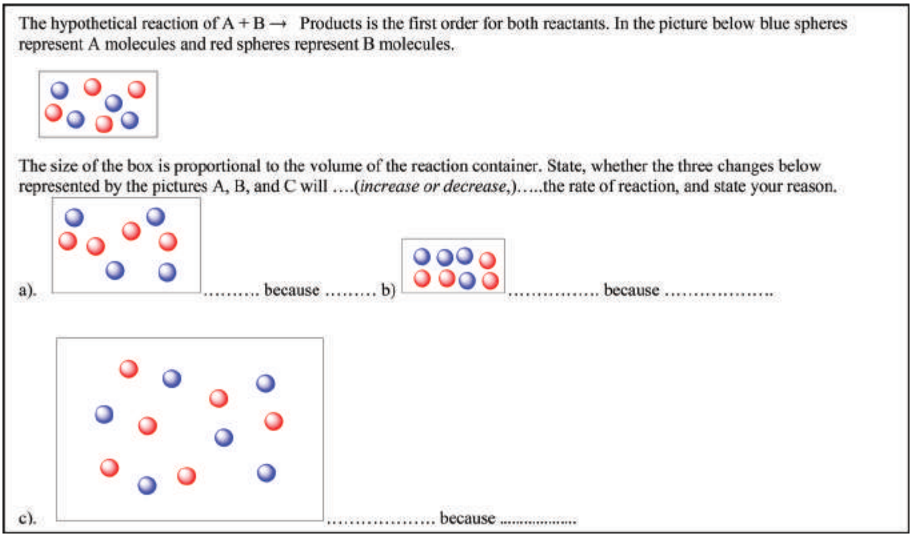

Figure 4. Question 4 (Q4).

Task 5: Determining rate law using initial rate method

This task was represented by Q9 and Q11. In Q9, WNA is a dominant category among the first year UM and second year UHO students with 92.31% and 96% respectively. Meanwhile, about half of the second year UM students and third year UM students showed WNA with 54.17% and 50% respectively. None of the students in most groups gave *l*PCA and *u*PCA except the second year UM students with 4.17% in each category. Only a low number of the first year UM and second year UHO students gave CA with 7.69% and 4% respectively. The second and third year UM students gave the significant number of CA with 37.50% and 50% respectively.

Task 6: Rate constant and reaction order

Students with PCA commonly can calculate the order of reaction, but they cannot calculate the rate constant. They tend to use the equation $r = k[A]^2$ to calculate the rate constant. They don't realize that two variables were unknown, including rate (r) and rate constant (k). Students with good HOTS ability should derive the rate equation to answer the question. Students have to use calculus to derive the integrated rate law of second-order reaction from the rate equation $r = k[A]^2$. Therefore, the rate constant (k) can be determined whether using $\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$ or using $t_{1/2} = \frac{1}{k[A]_0}$. However, the majority of students did not arrive at this stage.

All in all, students' responses to the questions imply that students' HOTS is inadequate. In some questions, only a small number of students gave analytical answers. It seems that Indonesian students are not familiar with questions that demand critical thinking skills to be solved. This inadequate ability is shown when students faced a question that demands making judgment and interpretation and also involves uncertainty, as defined by Resnick (1987). For example, in Q4 because no numerical information (uncertainty) is given regarding the increase in the volume of the container, the effect on the reaction rate cannot be determined exactly. This uncertainty demands that students make a judgment based on their scientific knowledge. This finding confirms the similar result uncovered by Habiddin & Page (2016). The inadequacy of students' HOTS can be attributed to many factors. The ineffective instruments used to promote HOTS is one of the factors that contribute to the issue (Ghani et al., 2017). Practicable instruments that have been used and found to be transferable in promoting HOTS ability are Marzano's Taxonomy of Learning (Toledo & Dubas, 2016) and concept

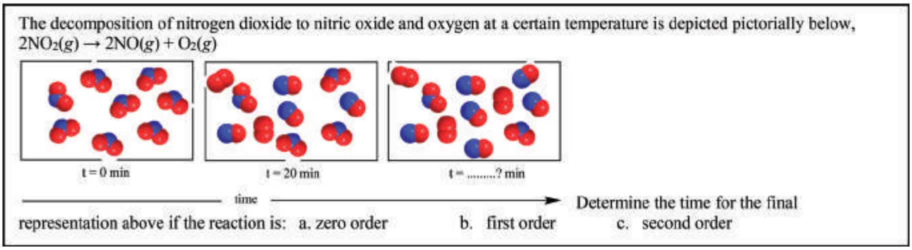

Figure 5. Question 10 (Q10).

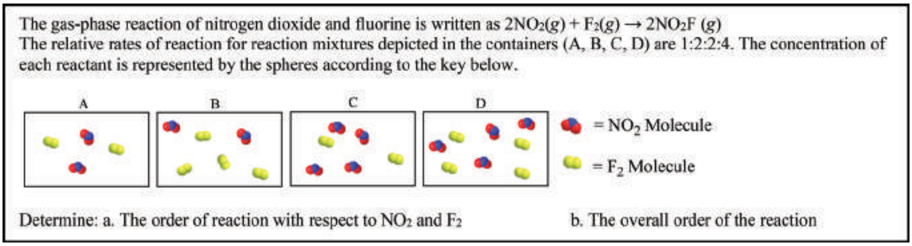

Figure 6. Question 9 (Q9).

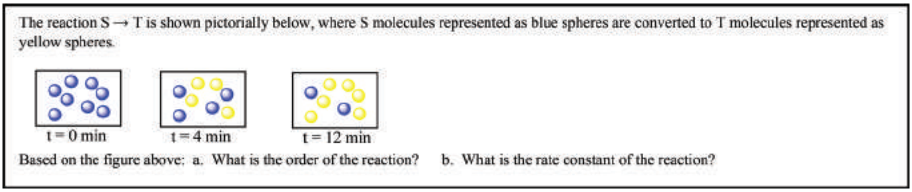

Figure 7. Question 6 (Q6).

mapping (Ghani et al., 2017). A constructivist-based strategy, such as active learning (Kim et al., 2013), is also a recommended way to promote this ability.

4 CONCLUSION

This study shows that Indonesian first year chemistry students' ability regarding the HOTS question is inadequate. In all three questions, the number of students that gave the correct answer (CA) is very low. Some students provided the partially correct answer (PCA). Meanwhile, the number of the student that gave wrong/no answer (WNA) is always the highest. This suggests that students need to be trained to be familiar with such HOTS type questions. The low ability of students' HOTS exists in both types of questions (algorithmic and pictorial). However, whether the type of question influences students' ability in answering the question needs to be explored more. The low ability of students' HOTS also exists among first, second and third year Indonesian students. However, to make a general conclusion regarding the difference of students' HOTS between first, second and third year students is inadequate in this study due to insufficient participants, particularly for the third year students.

This study suggests that students' HOTS must be promoted in all aspects of chemistry teaching and learning. For this purpose, Zohar & Dori (2003) emphasized that students must be frequently given HOTS tasks in teaching and learning. Chemistry teaching and learning strategy can also contribute to promoting students' HOTS. For instance, the active learning strategy can improve student' critical thinking (Kim et al., 2013). Mathematical operation weakness was also at the root of students' mistakes in answering questions. Often students understand the concept but are wrong due to mathematical operation. In other cases, students tend to use numerical operation to solve even a simple conceptual question.

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ScEd-ALS Project: The use of pedagogical intervention in developing hypermedia science based on learning style

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ABSTRACT: Many of the unsolved treatments for learners at junior high school level in science subjects are treated more with remedial tests without adequate scaffolding. The use of computer-based media can provide treatment as well as strong assistance to improve students' conceptual understanding with variations in their learning styles. This research reports four classifications of pedagogical intervention used in the development of a Hypermedia Science Education Adaptive Learning System (ScEd ALS) based on the VARK Fleming learning style with Adobe Flash CS 6 software. This research employs a qualitative method based on interviews, observation, questionnaires and documents analysis. This article focuses on the stages of developing instructional documents on the development of hypermedia. The pedagogical intervention on media is classified into four different learning styles: visual, aural, read/write and kinesthetic. The visual emphasizes on colors and film/animation demos. The aural focuses on music and hearing narration from experts that leads to discussion. Meanwhile, read/write is more focused on the look of an article as information. Kinesthetic emphasizes a demonstration in the form of animated film. Validation from experts gave a good response to media. Media, by considering aspects of pedagogy and variations in learning styles, is very important to facilitate students in gaining meaningful knowledge.

1 INTRODUCTION

Since the curriculum of 2013 was applied in junior high school, science majors and focuses on integrated thematic learning adjusted to the student's level of development, and the learning process is also adjusted with the competency characteristics, which began introducing subjects by maintaining the integrated thematic in science subjects (Indonesian Ministry of Education and Culture, 2016). The principle of integrated science learning is to combine several fields of the subject or relevant concepts altogether (Lamanauskas, 2010; National Research Council, 1996). This combination highlighted the natural principal of science education as a product, process, attitude, application and creativity. It is expected that the understanding of science by students will be in a holistic and meaningful way.

This integrated thematic process includes both the design and the learning process itself. There are four integrated science models: connected, webbed, shared, and integrated (Forgarty, 1991). The selection of the models is adjusted to the basic competencies and combined concept. The integrated model has the characteristics of concepts in overlapping basic competencies or only intersecting the concepts that were taught. Different from the integrated model, the shared model can be operated on the concepts of a basic competency that has an intersecting concept. The advantages of these two models are that students can have a more complete, efficient and contextual understanding of the concept. The webbed model has characteristics that the concepts in basic competencies are related and taught through a theme-based material, which is one of the advantages of this model. Meanwhile, the connected model teaches concepts on basic competencies that are linked to concepts in other basic competencies. Web models see problems not just from one field of study (Indonesian Ministry of Education and Culture, 2013).

The obstacles faced in the implementation of science learning may due to several reasons, namely, (1) not many concrete examples of integrated science learning tools, (2) not yet obtained a complete understanding of integrated science learning along with the steps of developing (Anjarsari, 2013).

The results of the 8th grade integrated science learning interview at a junior high school in South Tangerang were carried out in an integrated manner. Integrity could be found on the lesson plan, but when learning every basic competency, the delivery would be separated between biology and physics. At the beginning or at the end of every lesson, students were given examples combining two different concepts or basic competencies. Integrated science learning on the concept of motion (35%) and simple machine (55%) still finds the high level of remedial among the students (Zulfiani et al., 2018). This case is similar to Yuliawati (2013) who reported that the obstacles of implementing integrated science learning in junior high schools include the implementation of learning and the availability of the science teaching materials that contain themes in physics, chemistry and biology studies. Another research from Taufiq et al., (2014) resulted that the role of integrated science learning media characterized by environmental awareness has become learning aids that could improve learning outcomes and environmental awareness characters. This concludes that the role of media can be used as an important source for teaching materials (Shabiralyani et al., 2015; Smaldino et al., 2008; Alvermann et al., 2018).

The management of students who were considered as failed according to their grade in learning lacks serious attention and preparation from teachers and the school itself. In schools, managing the failed students is often handled with remedial tests. The increasing number of students who passed the minimum grade after the remedial test is not caused by the level of the student's competency. In fact, the quality and the level of difficulties on the test are low and loose supervision is the main cause.

The low learning outcomes and the level of learning completeness of the students are caused by the selection of incorrect learning stimulus or mono stimulus by the teacher (Zulfiani et al., 2018). Each student has a different background, habit, intellectual and physical ability. These differences affect the ability of students in responding to the learning stimulus chosen by the teacher. The way students responded to the stimulus given by the teacher in the classroom is known as the learning style. Learning styles of students may vary from one to another and most teachers do not pay a lot of attention to these learning styles when teaching. When a teacher chooses only one stimulus from one of the learning styles, students who have different learning styles will have difficulties in accepting and understanding it. Relevant research results indicate that learning style is one of the factors that significantly influenced the success of students to learn (Ramírez-Correa et al., 2017; Aragon et al., 2002; Zhu et al. 2018; Shah et al., 2017).

There are many models to detect learning styles. Some of the collected learning styles models include Paramythis, & Loidl-Reisinger, (2004); Kolb et al., (1988); Dunn & Dunn (1978); Myers-Briggs Type Indicator (Avsec, & Szewczyk-Zakrzewska, 2017). The VARK model gives visual, aural, reading/writing and kinesthetic styles (Fleming, 1995). The VARK model is one of the learning styles that is used in the presentation and organization of contents in e-learning courses. This certain learning style is highly popular and is included in the acceleration class (Scheurs & Moreau, 2006). The VARK model's main strength is the simplicity and attractiveness for many people (Maycock, 2010). Students use all of these four learning styles—visual, aural, read/write and kinesthetic—to obtain information. However, there is only one or a combination of some styles that are dominant.

This dominant style determines the best way for someone to learn new information by filtering what must be learned (Schreurs & Moreau, 2006). In VARK, identifying learning styles involves the use of the instrument for detecting the learning preferences (Dunn & Griggs, 2003). The instrument consists of 16 questions and there is only one answer for each. Each of the answers corresponds to one of the four learning styles inside the classes. Responses are arranged based on categories and maximum values are used to determine the learning style of the respondents (Fleming, 1995).

Students needed stimulus based on their preferred learning style. The provision of learning methods, strategies and approaches in each class will make it difficult for the teacher. The teacher must serve all of the learning styles of the students simultaneously, which is rather impossible to do optimally. This is why the use of computer media to assist in learning can help to overcome the problems mentioned above. The use of computers or computer-based instructions could help teachers in serving the students with the low ability that could not pass the grade to learn with their respective learning styles and improve learning outcomes optimally at the same time.

We have developed science learning media—The Science Education Adaptive Learning System (ScEd ALS)—which refers to the Minnesota Adaptive Learning System (MAIS) program based on Robert Tennyson (1984), who designed artificial intelligence in computer-based learning. Adaptive e-learning systems that accommodate VARK Flemming's learning styles are reported by Peter et al., (2010). The results of their research explain the iLearn platform that is implemented to overcome the problem of personalization systems in managing, learning and providing learning experiences to students. Similarly, the research of Wang et al., (2008) emphasizes the relationship of learning content with learning styles in adaptive learning according to the pedagogical processes. The results of teaching and students agree that the colony adaptive learning system based the learning style is useful as an additional learning part. Özyurt et al., (2013) also report that the integration of learning styles in the adaptive system on UZWEBMA (Turkish abbreviation of Adaptive and INtelligent WEB based MAThematics teaching–learning system) mathematics subjects gives a positive response and strengthens traditional learning in the classroom.

Thus, the research question in this current study is how the pedagogic interventions based on visual, aural, read/write and kinesthetic learning styles are developed in hypermedia Science Education Adaptive Learning System (ScEd-ALS).

2 METHOD

The research used a qualitative method through interviews, observation, questionnaires and documents analysis. Interviews were conducted with three junior high school science teachers in Tangerang Selatan. During the interviews, the researchers obtained a number of documents, including curriculum documents, such as lesson plans, questions about the assessment of science, student's worksheets and science practice guides for grade 8. To analyze the findings that are obtained through the interviews and documents, the researchers observed that there are practices of integrated science learning activities in three schools. Student perceptions questionnaires were also distributed regarding the perceptions of integrated science learning and the use of computer-based media for 30 students of the eighth grade of junior high school.

The results of the interviews, observation and document analysis regarding the integrated science learning in the grade 8 of junior high school focus on the low level of completeness of learning science, especially in the concept of motion and simple machines. The remedial process is carried out by assigning students to read further assignments for a remedial test.

The development of hypermedia is later called Science Education Adaptive Learning System (ScEd-ALS), which focuses on VARK Fleming learning styles (specifically, V for Visual, A for Aural, R for Read/Write and K for Kinesthetic). The first stage of media development is the characteristics of document analysis in the VARK Fleming learning styles and integrated science materials for motion and simple machine concepts. All material designs that will be presented in the form of media include pedagogic interventions/teaching actions arranged in a storyboard. A pedagogic intervention that appears in the media is specific to a certain learning style. After the storyboard is set, reviewing and validating the materials will be ready to be composed to the hypermedia. The effectiveness of the hypermedia ScEd-ALS has been reported by Zulfiani et al., (2018). The stages of research are shown Figure 1.

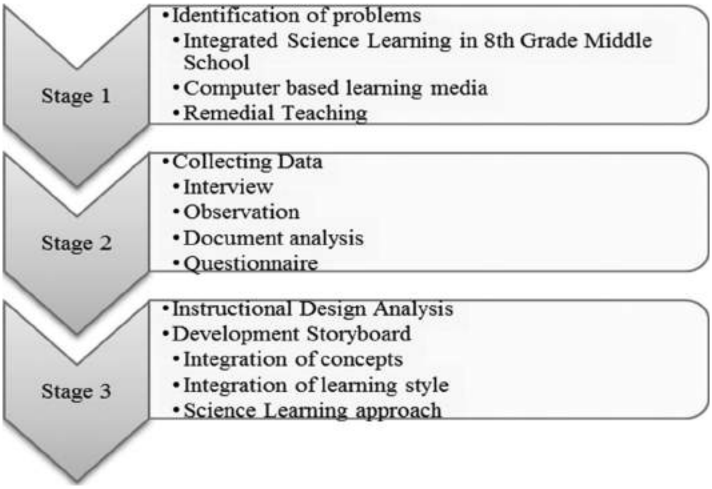


Figure 1. Stage of research.

3 RESULT AND DISCUSSION

3.1 *Teacher's perception of integrated science learning in junior high school*

Science learning in junior high school recommended integrated science learning. This refers to the government regulations that learning science in junior high school is integrated, contextual and holistic. The results of teacher interviews from three different schools in South Tangerang have implemented integrated science learning referring to the 2013 curriculum for a period of 5–6 hours per week. Based on the lesson plan documents, the evaluation of science subjects combines physics and biology concepts that are taught by one teacher.

Constraints related to the teacher education background still exist, namely teachers who were science education graduates, but from biology education or physics education only. The implication in teaching related to this matter is shown when the teachers have difficulties in the field of study that is not based on their educational background. Incompatibility of academic background is also reported from the research of Ristiana & Pujiyanto (2014) as an obstacle in implementing integrated science learning in junior high schools in Surakarta resulting in the lack of the mastery of integrated science materials. The results of the research also include identifying the teacher's obstacles in deciding the right theme to combine the integrated science learning. Besides that, not all science materials in the 8th grade was carried out with an integrated model, since each material had certain characteristics. The same findings reported by the University of Vermont (2018) showed that 8th grade science teachers without a science education background tended to be less able to practice inquiry-oriented science teaching and teaching activities involving students in science projects.

However, there has been an effort from teachers to improve their pedagogical and material skills by participating in training programs through school clusters in the area, as well as attending science education-themed seminars.

> "Training to improve the quality of teaching held at the cluster and programmed level. I am also used to attend science education-themed seminars and other seminars" (Teacher "A" Interview, March 2017).

At the 8th grade of junior high school there is still a high level of incomplete learning outcomes, such as the concept of plant tissue, motion and simple machines. The remedial process is carried out by the teacher in various ways, namely by giving assignments, learning opportunities and then conducting a remedial test. In one school, it was found that they had used IT facilities in the assignment of tasks by using Google Classroom as part of the remedial process. Regarding the use of IT, all of the three schools are accustomed to using it, such as in the delivery of material, images, animation in certain media software applications and PowerPoints.

> "The role of media is very important. There are also advantages and disadvantages in using media especially with home assignments, for example, when using Google Classroom, if the students do the task, we as the teacher cannot guarantee exactly whether the students really do it". (Teacher "B" Interview, March 2017).

All of the three teachers agree that the use of computer-based learning media, whether in regular lessons or in remedial, is paramount. The existence of computer-based learning media attracts the students' interest in image visualization, an activity that can facilitate the construction of a good student understanding. Teachers admitted that each student has their own variation of learning styles and media could help them in understanding the lesson.

> "Every student has their own way of learning, some of them use visual, auditorial, and kinesthetic. The use of media to connect with these various types of learning styles is an effective thing. Media is important to simplify concepts that are difficult to demonstrate using realia, Media is helping students perceive the concept in an easy way". (Teacher "A" Interview, March 2017).
>
> "Media utilization is very interesting because by using computer-based media, it helps to give interesting visualization and a fast response by producing an equal variation of the students learning styles". (Teacher "C" Interview, February 2017).

The results above are in line with Lestari (2015) who reported the effectiveness of a computer-based tutorial method in learning media and science learning (Sutarman, 2015) that could improve the student learning outcomes. Contrary to the findings above, Prasetyaningsih & Wilujeng (2016) reported that science teachers at Pati Junior High School did not fully consider the application of information through computer technology in science learning.

3.2 *Students' perception of integrated science learning in junior high school*

Table 1 below shows the students' perception in relation to the implementation of integrated learning in secondary schools. The gender of the informants were 19 females (67%) and 11 males (37%).

Students gave positive responses to the integrated science learning in school by using computer-based learning media, such as PowerPoint and Prezi. This learning media can improve thinking skills in scientific concepts. Students are pleased with media-based learning that

Table 1. Students' responses.

	Response									
	Strongly disagree		Disagree		Neutral		Agree		Strongly agree	
Indicator	N	%	N	%	N	%	N	%	N	%
Use of computer-based learning media in schools	0	0	2	6	2	7	21	70	5	17
Material packaged in computer-based media makes it easy for students	0	0	0	0	4	13	23	77	3	10
Computer-based media related to everyday life	0	0	2	7	3	10	18	60	7	23
Computer-based media displays images, videos and evaluations	0	0	2	7	5	16	14	47	9	30
Use of computers for entertainment	0	0	4	13	7	23	14	47	5	17
The use of computers at home for tasks at home	0	0	1	3	3	10	16	54	10	33

Table 2. Pedagogical interventions with learning styles.

	Visual	Aural	Read/write	Kinesthetic
Pedagogical Interventions	Interesting display, images, and background	Music, back sound, narration, chatting (y/n questions)	Article (text), many readings and information	Making a button click
	There are diagrams, experimental graphs.	Hearing expert narratives (eliminate videos)	Reading the user guide, read the trial narration	Demonstration (film or animation)
	Reading dialogues. Repeating the same text repeatedly (several times)	Draw or sketch. (predict)	Rewriting, making a resume	Trying acting. Requesting to demonstrate again
	Planning an experiment	Explaining the activities in the program (provide a field for explanation)	Showing the parts in the material in the form of images	Practicing (conducting experiments). Ask students to experiment and report in the program
	Make predictions	Discussion in the form of sound. (question in the form of sound)	Make an experimental plan	Direct practice.
	Showing a demo in the form of a film or animation	Recording the material explanation	Read conclusions from others (synopsis)	Action (direct practice)
	Shows parts of the picture	Expert narration explanation	Demonstrate through analogy	Must be the scientific explanation, make sense.
	Flowchart, mind maps	Lots of communication	Reading instructions	Direct practice
	Interpretation skills	Speaking loudly and remembering it	Looking for outside information	Practice then decides
	Relevant writings are presented	Discussion	Finding the idea from a reading	Practices that have been done
	Making mind maps	Explaining directly	Writing down directions in detail	Practice
	Paying attention to aesthetics	Additional information from several experts	Reading a complete explanation of an information	Direct act
	Using graphs	Getting expert explanations and discuss them	Written review (summary of the results of his work) Review the results of his writing	Inquiring about the experience that has been done about the material
	Getting visual through diagrams. Graph comparison.	Discussion and hearing others opinion	Detailed explanation	Direct proof (action)
	Explaining through a diagram, a chart that is given information	Discussion, listening to lectures.	Using a module system	PBL, videos, practices
	Making diagrams or graphs	Writing important words. (reviewing what has been done)	Rewriting and reading it over and over again (with the same content)	Gathering real examples, material phenomena. (picture)

includes pictures and video material with several evaluations. Students like to learn science media that is related to their daily life. Students are accustomed to using computers/laptops for playing games. These positive responses from the students are in line with the research of Friski & Parmin's (2013) in which the use of computer-based integrated science learning on the concept of sounds could improve the student's grade up to 88.8%.

3.3 *Pedagogical interventions*

The media development process begins with the preparation of the storyboards. The storyboards contain concepts/materials that are arranged in stages form a media display. In this study, the compilation of storyboards developed a pedagogical intervention/teaching action,

Table 3. Storyboard with pedagogic intervention based on development of hypermedia learning styles.

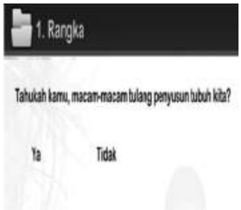
Competence Achievement Indicators

3.1.1 Identifying the types of bones that make up the human motion system
3.1.2 Describing human bones

Visual

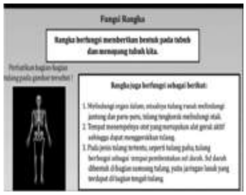
– ***Did you know that the human body is composed of bones? What is the function of bones for our body?***
• Presented human skeletons.
• Described words about the bone function
• Students are directed to observe the human skeleton
– *Do you know that human bones are various?*
• Presented images of various bones based on their shape and size.
• The breastbone is clicked so that the breastbone is enlarged. (flat bones)
• The upper arm bone is clicked so that the bones of the upper arm are enlarged. (long bones)
• The backbone is clicked so that the spine appears to be enlarged. (irregular bones)
• The radius of the fingers is clicked so that it looks enlarged. (short bones)
– *How is the size and shape of the bones?*
Give an explanation about the shape and size of the bone were not the same.

Aural



– ***Do you know that the human body is composed of bones? What if there are no bones in our body?***
– ***Listen to the following explanation!***
• Students are directed to listen to recorded materials with the descriptions of bone function for the body
– ***Do you know, the various bones of our body?***
– ***Pay attention to the following audio, and note the picture!***
• Students are directed to listen to recorded materials with the of the types of bones accompanied by pictures and writings of the names of the bones.

Read/write



– ***Did you know that the human body is composed of bones? What if there are no bones in our body?***
– ***Read the following frame parable like a tent and its frame!***
• Students are directed to read writing about bone function for the body.
– ***Do you know, the various bones of our body?***
– ***Read the following explanation, and pay attention to the picture!***
– Students are directed to listen to recorded material descriptions of the types of bones accompanied by pictures and writings of the names of the bones.

Kinesthetic

– ***Did you know that the human body is composed of bones?***
– ***Watch your friend beside you, why can he sit upright?***
• Given an explanation of bone function.
– Do you know what kind of bone is in your hands, fingers and cheeks?
– ***Touch the bones of the forearm, fingers and the cheekbones.***
– ***What do you feel? Are these bone sizes the same or different?***
• Presented pictures of various Bones based on their shape and size.
– There is an explanation that the shape and size of the bone were not the same among others.

which was followed by four VARK Fleming learning styles—Visual, Aural, Read/Write and Kinesthetic. The results of the document analysis study show that the pedagogical interventions were consistent with the characteristics of the four learning styles (Zulfiani et al., 2018) as shown in Table 2 below.

Based on the characteristics of the four learning styles, four variations of pedagogical interventions were then adjusted according to the motion and simple machines concept learning indicators are shown in Table 3.

3.4 *Hypermedia ScEd-ALS using Adobe flash CS 6*

The development of hypermedia ScEd-ALS used professional Adobe Flash software and Ispring QuizMaker. Both have functions and time placement in program design. Adobe Flash's professional CS 6 creates templates, such as background and animation, supporting the process at the beginning to the end of making the media. In addition, Ispring QuizMaker is used to create evaluation questions after the objectives of the media are resolved.

3.5 *Validation of experts and trials*

Validation of media and material experts provides a valid response (Zulfiani et al., 2018). There are two aspects of media assessment, namely software engineering and communication (visual-media). While the assessment of material experts includes six aspects of assessment, namely: (1) Suitability of images, animations, observation videos and explanatory videos with material (2) Clarity in explaining physical formulas and organ parts through text or video learning, (3) Clarity of sample questions on each material, (4) Accuracy of answers to evaluation questions on each material (5) Accuracy of answers (systematic) and not misconceptions on each material (6) Scope and depth of material. After testing one to one, limited trials that obtained the highest effectiveness were those with learning styles kinesthetic (100%), aural (63%), read/write (55%) and visual (20%).

4 CONCLUSION

Hypermedia provides a solution to the complexity of integrated science material in 8th-grade junior high school students, the tendency of student information technology literacy and the variety of student learning styles. This study describes an integrated science learning design that uses pedagogic interventions with four visual learning styles, for example visual, aural, read/write and kinesthetics. This learning design framework is packaged in the form of storyboards that are validated by material experts and media experts, which then becomes a reference in making hypermedia. Hypermedia ScEd ASL is declared valid by experts, and hypermedia kinesthetic effectiveness is the highest response compared to the other three types of hypermedia (Zulfiani et al., 2018). The media, therefore, can be suggested as a scaffolding before a remedial test is carried out for students who experienced mastery problems in learning science.

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Study of Project-based Learning (PjBL) on self-efficacy and academic achievement of pH range natural indicator learning in chemistry classrooms

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ABSTRACT: This study aims to analyze the effect of Project-Based Learning (PjBL) on self-efficacy and academic achievement of pH range natural indicator learning in chemistry classrooms. Natural indicators used are the flowers, fruits and vegetables in daily life. The method used is a quasi-experimental method with a pretest-post-test non-equivalent control group design. The subject of the study consisted of 37 students (as an experiment class) who were given instruction through PjBL and 36 students (as a control class) who were given instruction through conventional learning. Observation sheet, self-efficacy questionnaire, and academic achievement tests were used to assess the students' self-efficacy and academic achievement. N-Gain, percentage, mean and t-test were employed to treat the data. The results showed that there is a positive influence of PjBL on self-efficacy and academic achievement of pH range natural indicator learning in chemistry classrooms with the enhancement but no sign. In the experiment class, however, self-efficacy and academic achievement was better than the control class in the different performance measures. It is suggested that PjBL is an effective strategy in teaching chemistry.

1 INTRODUCTION

Self-efficacy of the young generation is needed to build a better country. Furthermore, Bandura (1993) explains that self-efficacy is one of the values that must be owned by the nation's children in the 21st century as a tool to answer the increasingly complex challenges of the future. Filcik, et al. (2012) suggest that higher self-efficacy can support academic achievement. Self-efficacy can support the skills in the 21st-century through the description of the disposition of the knowledge and skills aspect, which is a prerequisite for achieving success in global competitiveness in the future. The 21st-century learning framework expects values as a result of learning (Partnership for 21st-Century Skills, 2011).

Nowadays, Project-based Learning (PjBL) believed can affect students' performance in the process of teaching and learning, therefore research on learning strategy continues to be developed by educational experts. This is aligned with Sanjaya's opinion (Komalasari, 2010), which states that a learning goal can be achieved effectively and efficiently with the implementation of a learning strategy. Asbjornsen (2015) stated that PjBL has been widely recognized as one of the approaches for effective learning. PjBL is a learning strategy that has the characteristics to solve problems in daily life; these characteristics make students learn more actively while developing their potential (Bandura, 1997). PjBL is also one of the learning strategies based on student-centered learning. Student-centered activities in PjBL can enhance students' performance on learning a subject-matter (Bas, 2011).

Related research about PjBL has been done by Chen & Chan, 2011; Chen & Hernades, 2015; Goldstein, 2016; Gachanja, et al., 2016) and their studies showed that the implementation of PjBL influences students' performance to develop self-efficacy and academic achievement. The effect of PjBL on undergraduate students' achievement and self-efficacy beliefs toward science teaching have been conducted (Bilgin, et al., 2015). The results showed that the students' learning achievement of the experiment class using PjBL had a significant improvement than students of the control class. Based on his results, Ilter (2014) suggested that research on PjBL should be done more broadly using PjBL as an approach that can develop concept understanding and improve academic motivation. Hence, PjBL is an effective strategy in teaching chemistry.

Generally, topic pH range indicator at high school is still using synthetic indicators. In fact, indicators can be made from the flowers fruits, and vegetables in daily life as natural indicators. In Indonesia, natural indicators, flowers, fruits, and vegetables, are very easy and inexpensive to get in daily life. It is suggested that changing synthetic indicators with natural indicators are better (Ali, 2009). It is an opportunity for researchers to conduct a research on the implementation of PjBL to improve self-efficacy and academic achievement on the topic pH range natural indicator at high school.

Teaching chemistry through natural indicators can give opportunities to the students to develop student-centered learning and a home-based laboratory. The students can make natural indicators themselves at home through tasks of the project (Ali, 2009). Hence, suitability between PjBL and natural indicators learning in chemistry classrooms are better. The syntax of PjBL is shown in Figure 1.

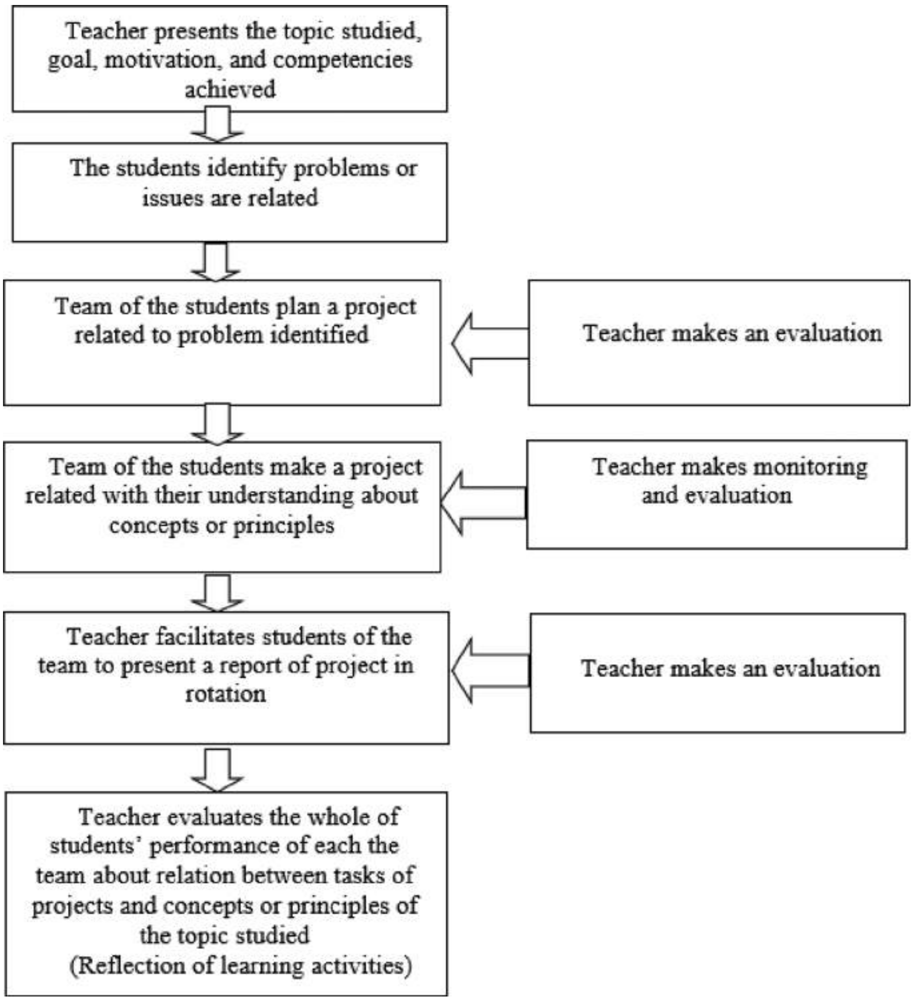

Figure 1. Syntax of PjBL.

The formulation of the problem to be studied in this study is "How can the implementation of project-based learning (pjbl) improve students' self-efficacy and academic achievement on the topic of pH range natural indicator?" These general issues are outlined into several specific study questions as below:

1. How do the enhancements improve self-efficacy of experiment and control group students through the PjBL model on the topics of the pH range natural indicator at high school?
2. How do the enhancement improve the academic achievement of experiment and control group students through the PjBL model on the topics of the pH range natural indicator at high school?

The purpose of this study is to analyze the implementation of PjBL to improve student's self-efficacy and academic achievement on the topic of the pH range natural indicator at high school.

2 METHOD

This study was used the quasi-experimental method with a pre-test-post-test non-equivalent control group design. The subject of the study consisted of 37 students (as experiment class) who were given instruction through PjBL and 36 students (as control class) who were given instruction through conventional learning. The instruments of research used include an observation sheet, self-efficacy questionnaire and academic achievement test. The enhancement of self-efficacy and academic achievement was measured based on differences of score pre-test and post-test using the formula of N-Gain. The difference between two means were analyzed by using t-test in significant degrees of 0.05 (Hake, 1999).

The subject consisted of 73 students in class XI of one of the high school in Bandung that are studying pH range natural indicator. In Indonesia, natural indicators, like flowers, fruits and vegetables, are very easy and inexpensive to get in daily life. Natural indicators used are the flowers, fruits and vegetables in daily life, such as roses, mangos teen and turmeric. The data for this study was colleted by test, observation worksheet, interview guidness and questionnaires. Academic achievement changes are calculated based on differences between score pre-test and post-test using the N-gain formula. N-gain was obtained from the calculation then translated according to criteria proposed by Hake (1999), as shown in Table 1.

The initial stage of this study started by giving the students a pre-test of pH range natural indicator. Thus questions before being given to the subjects were first validated by five expert judges who work as lecturers and senior chemistry teachers, based on the validation obtained that the questions are valid. The questions were tested on students as the subject of research who have learnt about pH range indicator to test the reliability of the questions. Reliability question is calculated by using the Cronbach Alpha, based on the calculation obtained questions reliability is 0.86, it is indicated that the questions have a high level of reliability. The second stage of this study is to implement PjBL in learning. Furthermore, in the final stages of this study, students are given a post-test to measure their potential development and lastly students are given a questionnaire. Question is containing the students' responses to the implementation of PjBL in learning.

Table 1. N-Gain score classification.

N-Gain score	Interpretation
N-Gain > 0.70	High
0.30 < N-Gain > 0.70	Medium
N-Gain < 0.30	Low

3 RESULT AND DISCUSSION

3.1 *Self-efficacy*

The experiment class has a greater improved self-efficacy than the control class students. According to Hasheminasab, et al. (2014), self-efficacy is a prerequest to creativity that is identical to problem-solving and originality. The experiment class students experience significantly more self-efficacy enhancement because they have a stronger basic conceptual understanding than the control class students. This is aligned with Khasanah, et al., (2015) who states that in the group activities of PjBL, students' self-efficacy and academic achievement have improved simultaneously; the enhancement self-efficacy of experiment class in the medium category, and control class in the low category. The improvement of students' self-efficacy for each category class and the aspects of self-efficacy can be seen in Table 2 and Table 3.

3.2 *Academic Achievement*

The academic achievement of the students who were subjected in this study was measured using a multiple-choice test. The differences in the pre-test and post-test scores of students are used to describe the students' academic achievement after learning through PjBL, whether their academic achievement has increased significantly or not. Based on the calculation using the formula N-gain, it is shown that the academic achievement of students generally has increased, as shown in Table 4.

Based on data above, it can be observed that there was an enhancement of academic achievement in the pH range natural indicator lesson of the experiment class and the control class in the medium category (Ali, 2009). Thus it can be concluded that PjBL is an effective instruction. This is aligned with Araban, et al. (2014) who states that a good learning approach is able to motivate students to understand the content of the material they are studying. PjBL is a learning approach that provides a positive impact on increasing student motivation (Chigurupati, et al., (2002). Besides that, the sequence of activities contained in the PjBL also plays a role in improving students' academic achievement (Dalgety, et al, 2003). Students' activities during the implementation of the PjBL process, such as reading, filtering and evaluating various sources of information, assessing others' opinions from different

Table 2. The score of students' self-efficacy.

		Students' self-efficacy		
Class	Statistic	Pre-test	Post-test	N-gain
Experiment	$\bar{x}$	90.03	134.95	0.45
	Dev std	17.16	11.54	0.07
Control	$\bar{x}$	95.86	123.50	0.30
	Dev std	7.78	13.74	0.13

Table 3. The score of students' self-efficacy to each aspect.

		Cognitive			Psychomotor			Applying daily life		
Class	Statistic	Pre-test	Post-test	N- gain	Pre-test	Post-test	N-gain	Pre-test	Post-test	N-gain
Experiment	$\bar{x}$	28.59	44.84	0.47	30.95	45.73	0.46	30.49	44.38	0.42
	Dev std	5.40	3.71	0.09	7.03	4.30	0.12	7.21	5.44	0.13
Control	$\bar{x}$	29.36	41.75	0.37	33.81	43.50	0.32	32.69	38.25	0.18
	Dev std	4.22	4.94	0.13	4.33	5.44	0.20	5.41	6.11	0.18

Table 4. The score of students' academic achievement.

Class	Statistic	Pre-test	Post-test	N-gain
Experiment	$\bar{x}$	40.90	79.82	0.66
	Dev std	10.56	7.11	0.11
Control	$\bar{x}$	41.11	63.15	0.39
	Dev std	19.22	15.65	0.12

perspectives, applying abstract concepts to real situations and finding solutions to problems in groups has made students more active (Imawoto, et al., 2016). Furthermore, Klein (2009) suggests that students' activeness in PjBL provides a great opportunity for these students to maintain their knowledge over the long term.

Table 4 shows that scores for the concept of the pH range natural indicator, and degrees of dissociation to experiment are higher than 75. This indicated that students' academic achievements have improved. It also indirectly showed the students' ease of understanding the materials, which is due to the many phenomena in daily life related to the pH range natural indicator that can be observed (Shaine, 2014). Besides that, the topic of the pH range natural indicator required experiment activities, such a pH test. Natural indicators are substances that can be used to pH test in daily life (Uzuntiryaki & Aydin, 2009).

Meanwhile, the concept of indicator reaction has a low score is caused students difficult to understand that concept it is aligned with the statement of Phatton (2012), which suggests that many students difficult to write the equation of indicator reaction. Besides that, other reasons for the difficulty is that the indicator reaction comes from the Arhenius acid-base theory and the students who were subjected had not studied the material yet. Acid-base is the basic concept of chemistry (Cetingul & Geban, 2005). Students at high school who have studied acid-base material said that acid-base is one of the most difficult to understand (Artdej, et al., 2010).

4 CONCLUSION

The conclusion of this study stated that it was positive influence of PjBL on self-efficacy and academic achievement in pH range natural indicator lesson of high school students with the enhancement but no sign. There was enhancement of self-efficacy in the experiment class in the medium category, and the control class in the low category. There was also enhancement of academic achievement in pH range natural indicator lesson of the experiment class and the control class in the medium category. It is suggested that the teachers can implementing PjBL in chemistry classrooms, especially for the topics related with daily life and that support a home-based laboratory as tasks of the project.

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Analysis of students' cognitive structure of acid-base topics through flow map methods with the Learning Cycle 8E model

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ABSTRACT: This qualitative research study investigated students' cognitive structure of acid-base topics through flow map methods using the Learning Cycle 8E model of teaching. The Learning Cycle 8E consists of engage, explore, e-search, elaborate, exchange, extend, evaluate and explain. The sample of the study comprised 36 students from grade eleven in SMA N 54 Jakarta enrolled in the academic year 2016–2017. Data was generated through achievement test, interviews, flow map, classroom observations, reflective journals and students' worksheets. The results demonstrated that students build their cognitive structure based on their prior knowledge, conceptual understanding and experiences. The Learning Cycle 8E model had an impact on students' cognitive structure development. Observation data confirmed that using the Learning Cycle 8E model decreased students' misconception of acid-base concepts. This establishes the efficacy of the Learning Cycle 8E model in overcoming students' misconception. The Learning Cycle 8E model also affected students' soft skills of collaboration and communication. Students' attitudes of respecting and appreciating differences of perspectives also improved.

1 INTRODUCTION

Chemistry can be taught by three levels of representation: macro, sub-micro and symbolic. It is often labeled as Johnstone's Triangle (Johnstone, 1991) and is also known as chemical knowledge 'triplet' (Talanquer, 2011). Chemistry can be thought of as corners of a triangle. No one form is superior to another, but each one complements the other. These forms are (a) the macro: what can be seen, touched and smelt; (b) the sub-micro: atoms, molecules, ions and structures; and (c) the representational: symbols, formulae, equations, molarity, mathematical manipulation and graphs (Johnstone, 2000). Johnstone (1991) suggested that one reason science is difficult for students is that they find it difficult to understand the submicroscopic level so they face difficulties connected with the three levels of chemistry representation.

Many research studies have clearly demonstrated the importance of cognitive structures in subsequent learning as the building blocks of meaningful learning and retention of instructional materials (Snow & Lohman, 1990). The cognitive structure is a hypothetical construct indicating the organization of concepts in learners' long-term memories and the relationships between them (Shavelson, 1974). In the paradigm of constructivism, knowledge cannot be directly transmitted but must be actively constructed by an individual learner (Bonder, 1986). In order to get meaningful learning, students need to construct their cognitive structures containing their prior knowledge and connect it to the new information. If meaningful learning does not occur, rote learning takes precedence. As a result of rote learning, students are unable to effectively connect new information to their prior knowledge. The analysis of students' cognitive structure can not only show what students know but also help the teacher to gain information about students' mental representation in information processing, in order to determine teaching strategies.

Tsai & Huang (2002) compared five methods of representing students' cognitive structure: free word association, controlled word association, tree construction, concept map and flow map. The research results indicated that the flow map offers more information for the analysis of cognitive structures than the other methods. Therefore, in this study, the flow map method was used to determine the students' cognitive structure.

Learning cycle is one of the teaching strategies that can help students to construct their cognitive structure. Learning cycle, which is an inquiry-based teaching model, is useful for teachers in designing curriculum materials and instructional strategies in science. The model is derived from constructivist ideas of the nature of science, and the developmental theory of Jean Piaget (Piaget, 1970), and developed by Robert Karplus with the Science Curriculum Improvement Study (SCIS) in 1964. The learning cycle of Karplus has three phases. These are exploration, term introduction and concept application (Karplus, 1977). Over the years the learning cycle has been revised and added several phases. The Biological Sciences Curriculum Study (BSCS) developed Learning cycle 5E; it consists of the following phases: engagement, exploration, explanation, elaboration and evaluation (Bybee, 1990). Learning Cycle 7E consists of the following phase: elicit, engagement, exploration, explanation, elaboration, evaluation and extend (Demirdag, et al, 2011). Learning Cycle 8E was developed from the Learning Cycle 3E, 5E and 7E modifications. Learning Cycle 8E consists of the following phases: engage, explore, e-search, elaborate, exchange, extend, evaluate and explain (Ridwan & Rahmawati, 2016). The e-search phase is the phase that makes Learning Cycle 8E difference from the other learning cycle models. It was derived by incorporating the use of technology in the procedure of imparting education. The involvement of the type of technology can be different at different levels according to the needs, interest and preference of the teacher, as well as the students. Learning Cycle 8E inculcates the sense of learning into the students by stimulating their desire to think, explore and get experience, and it also brings about intellectual expertise in the students. Thus, this model is a significant model that provides opportunities to the learners to develop their cognitive structure.

Acid-base topics are a major component of chemistry. If students understand acid-base chemistry in all its guises, it becomes possible to predict and explain the outcomes of a wide range of apparently unrelated reactions. For example, students would be able to connect and integrate seemingly diverse phenomena such as proton transfer, electron transfer and salt hydrolysis. There have been a number of approaches to characterizing how students understand acids and bases in their chemistry. Much of this research has focused on documenting the misconceptions or non-normative ideas that hinder the understanding of acid-base chemistry at high school level (Demerouti et al, 2004). Some reports focus on difficulties with mathematical ideas involving acid-base chemistry, including difficulty with and the meaning of pH calculations, equilibrium calculations and buffers (Demerouti et.al, 2004; Nakhleh, 1994). Others indicate that difficulty with prior knowledge often hinders understanding. For example, Nakhleh & Krajcik (1994) studied students' understanding of acids and bases and reported underlying problems such as the inability to distinguish between a molecule, atom and ion, and how acids and bases are represented. Other researchers (Furió-Más et al., 2005) have reported on how students recognize acids and bases, for example, by looking for the presence of an H or an OH (that is, a surface level feature) to identify acids and bases or by identifying the types of heuristics that more advanced students use as shortcuts when ranking acid strength.

Based on data of learning outcomes in one of the high schools in Jakarta at the end of the first semester of the academic year 2016–2017, only 37% of students achieve the minimum criteria of learning mastery. The minimum criteria of learning mastery in this school was 75. The data showed that students face difficulties in understanding concepts and principles in chemistry. Based on the classroom observation of the first semester of the academic year 2016–2017, Students rely on learning by memorization instead of understanding the topics. For that matter, when students lacked prior knowledge or had a misconception in previous learning it can affect later learning. Regarding this matter, this study aims to investigate students' cognitive structure of acid-base topics through flow map methods using the Learning Cycle 8E model.

2 METHOD

The aim of this qualitative study was to investigate students' cognitive structure of acid-base topics through flow map methods using the Learning Cycle 8E model of teaching. The sample of the study comprised 36 students from grade eleven in one high school in Jakarta enrolled in the academic year of 2016–2017. Data was generated through achievement tests, interviews, flow maps, classroom observations, reflective journals and students' worksheets. Data was collected during the second semester of the academic year 2016–2017.

3 RESULT AND DISCUSSION

3.1 *Learning Cycle 8E mode*

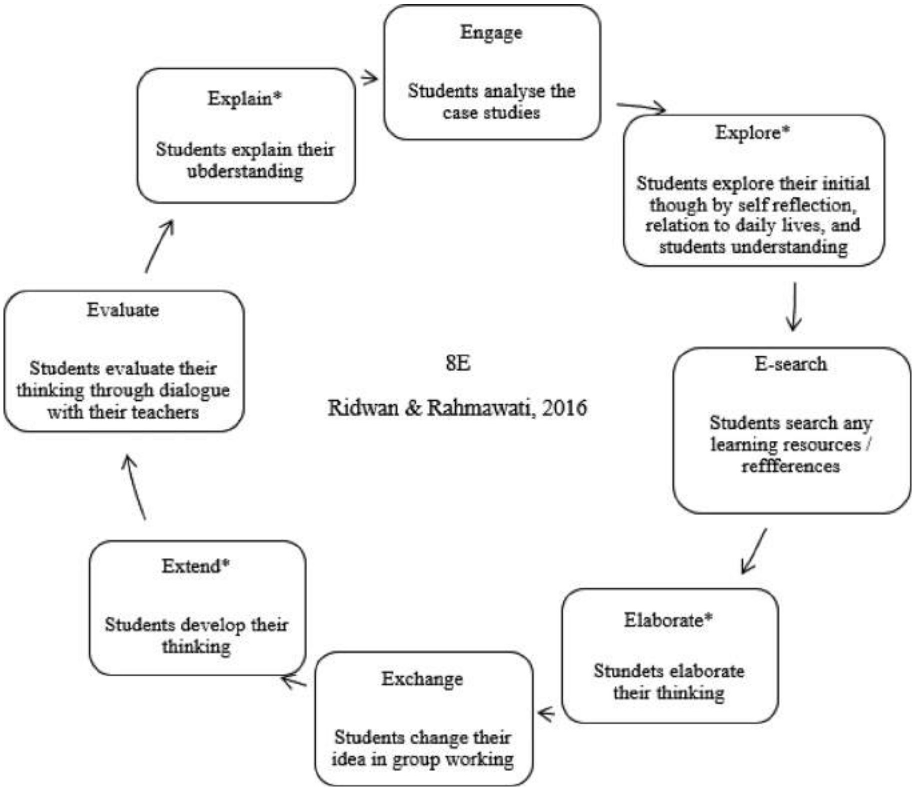

Figure 1. Learning Cycle 8E model of teaching. Reprinted [adapted] from "Analysis Model Mental Siswa dalam Penerapan Model Pembelajaran Learning Cycle 8E pada Materi Hidrolsis Garam," by W. Darmiyanti,, et al., (2017), *Jurnal Riset Pendidikan Kimia. 7(1)*, p. 38–51, Copyright Year by 2017 "Universitas Negeri Jakarta". Reprinted [or adapted] with permission.

3.2 *Engage*

Students analyze a case study that was provided by the teacher. The case study can help students become engaged in a new concept that promotes curiosity and elicits prior knowledge. The case study that is provided by the teacher is the video about the application of acid-base in daily lives. Based on the study, students become engaged in learning the concept of acid-base.

3.3 *Explore*

In this phase, students explore their initial knowledge of acid-base topics such as acid-base characteristics, acid-base theory, acid-base indicators, acid-base strength and pH scale. Students explore their initial knowledge by self-reflection, relation to daily lives and their prior knowledge. The teacher uses flow maps as a tool to obtain the students' initial knowledge. Based on the teacher's observation, it was found that higher achiever students tend to have richer prior knowledge than lower achievers.

3.4 *E-search*

Students search for any learning resources to gain their understanding of acid-base topics. In this step, students are given the opportunity to access and review various learning resources. The learning resources can be electronic media (internet research, spreadsheets, databases, PowerPoint presentations, email) and print media (textbook and students' worksheets). Based on each students' interview and teacher observation, most of students choose the Internet as their learning resources. An information and communication technology at the lesson encourages students to obtain real data, which is necessary to solve any given problem and involve people who have a direct connection with the current educational activities (for example, colleagues from other schools, representatives of scientific circles and those working on similar problems). It allows the educational process time and space beyond the limits of the classroom, allowing it to become maximally open. By the e-search phase, students will learn how to deal with mobile technology in a responsible way, which is an important skill in our modern technological era.

3.5 *Elaborate*

Students elaborate their thinking. Elaboration activity gives students the opportunity to reflect their initial knowledge with learning resources. Based on teacher observation, students tend to compare their initial knowledge with learning resources that they found in the e-search phase.

3.6 *Exchange*

The soft skills that are expected to emerge in this phase are cooperation. The teacher carried out the heterogeneous group division in this discussion where students with different academic achievement were placed in one group. The Constructivist Chemistry Values Learning Environment Survey (CCVLES) questionnaire is used to determine the development of students' soft skills during learning activities. Based on the results of the CCVLES questionnaire, it was found that students had implemented an attitude of respecting and appreciating differences of perspectives.

> *"The learning activity was interesting since there was a practical work of acid-base property, so I know the acid-base properties in several materials around us by observing the reaction. During the group discussion, I get a deeper understanding of acid and base properties. Group discussion can be improved, if the group member becomes more active during the discussion"* (Student 09, Interviewed on January 24, 2017).

Practical work can emphasize students' understanding since they can directly observe the reaction (color changing) of an acid-base indicator. Group discussions can facilitate students to exchange their knowledge within the group.

3.7 *Extend*

In this phase, the teacher can find out the development of cognitive structures after group activities and individual activities. At this phase, students describe their flow map based on the results of group discussions. In the extend phase students connect new concepts with the relevant concept.

> *"In this learning activity, my group discussed the example of the acid-base. After the discussion, I get a deeper understanding of drawing the Lewis structure of some chemicals and determine the Lewis acid-base when it reacts with other chemicals."* (Student 14, interviewed on January 20, 2017).

Based on interview data on January 20, 2017, student 14 related the concept of the Lewis structure to the theory of Lewis base acid in a chemical reaction, so students can expand their understanding on a microscopic scale.

3.8 *Evaluate*

Students evaluate their thinking through dialogue with teachers. The teacher explanation is given at the end of the learning activities. Learning Cycle 8E was developed based on the constructivism approach, so this model of teaching encourages students to develop their cognitive structure.

3.9 *Explain*

The Explain phase provides opportunities for students to connect their previous experiences with current learning. In this phase, students explain their understanding at the end of learning activities. These activities can help students to gain a deep understanding of an acid-base concept.

> *"In the explain phase, I added the acid-base formation on my flow map. From the teacher explanation, Acid can be formed by the reaction between non-metal oxides with water, meanwhile, bases can be formed by the reaction between metal oxides with water."* (Student 08, interviewed on January 20, 2017).

Based on the interview data on January 20, 2017, student 08 knew the formation of acids and bases after receiving the explanation from the teacher. She knows that the reaction between metal oxides and water can form bases and the reaction between non-metallic oxides and water can form acids. The interview data showed that students develop their cognitive structure during the lesson.

3.10 *Analyze students' cognitive structure*

Learning activity in this study is divided into three cycles of the 8E model. The first cycle learns about acid-base properties. The second cycle learns about acid-base indicators. The third cycle learns about the pH scale. The teacher analyzes the student's cognitive structure development in the four phases of the Learning Cycle 8E model, which are explore, elaborate, extend and explain. The data of cognitive structure was collected through the flow maps. The flow maps were analyzed and divided into two categories, which are correct understanding and misconception. The Literature review (Hoe, K.Y. et al, 2016) was used to diagnose students' misconception of acid-base topics.

The graphics illustrated the percentage of students' understanding and misconception in acid-base properties topics in the four phases of the Learning Cycle 8E model. There had generally been a decrease in students' misconception, however, there had been an increase in students' understanding from the explore phase to the explain phase. The highest percentage of students' misconception was found in the explore phase at the 32.30% and the smallest percentage of students' misconception was found in the explain phase at the 8.70%. It can be obtained from the data that students rely on their prior knowledge in the explore phase so that the percentage of students' misconception is higher than in the other phases of Learning Cycle 8E.

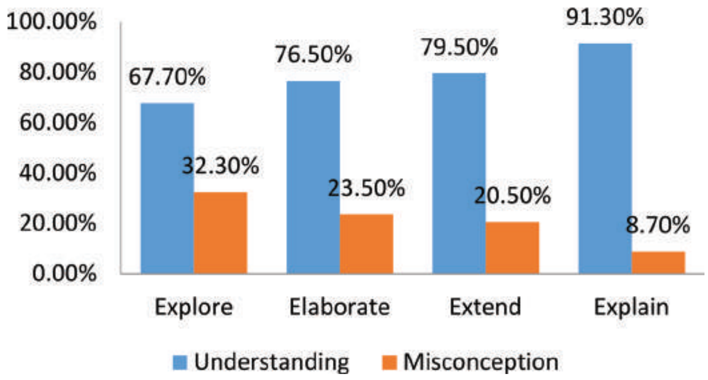

Figure 2. The graphic of students' cognitive structure development in properties of acid-base topics.

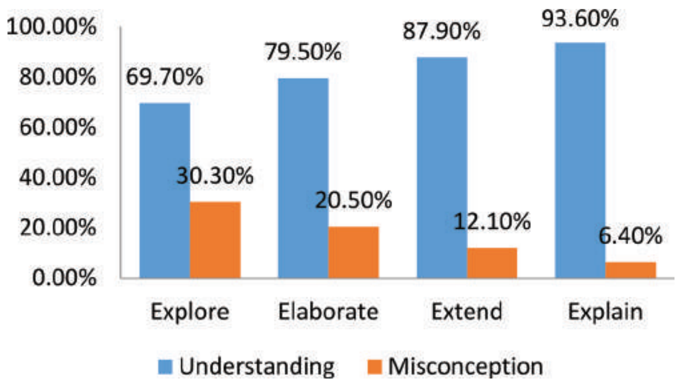

Figure 3. The graphic of students' cognitive structure development in acid-base indicators topics.

The graphics bar showed the percentage of students' understanding and misconception when learning acid-base indicators in the four phases of the Learning Cycle 8E model of teaching. Overall, the percentage of students' misconception and understanding is almost the same as in the previous chart; students' misconception from the explore phase to the explain phase decreased, meanwhile students' understanding from the explore phase to the explain phase increased. The highest percentage of students' misconception was found in explore phase at 30.30%, and the smallest percentage of students' misconception was found in the explain phase at the 6.40%. It can be seen from the data that Learning Cycle 8E can reduce students' misconception.

The graphics bar showed the percentage of students' understanding and misconception of pH scale topics in the four phases of the Learning Cycle 8E model. Overall, the percentage of students' misconception from the explore phase to the explain phase decreased, meanwhile students' understanding from the explore phase to the explain phase increased. The highest percentage of students' misconception was found in the explore phase at 30.30%, and the smallest percentage of students' misconception was found in the explain phase at 9.09%. It can be seen from the research data that Learning Cycle 8E can overcome students' misconception.

In this study, flow maps were used to determine the individual cognitive structure of 36 students about the acid-base topics in the four phases of the Learning Cycle 8E model, which are explore, elaborate, extend and explain.

Figure 5 demonstrated a flow map that comes from a student about the properties of acid-base topics. In the explore phase the student used prior knowledge from the middle school

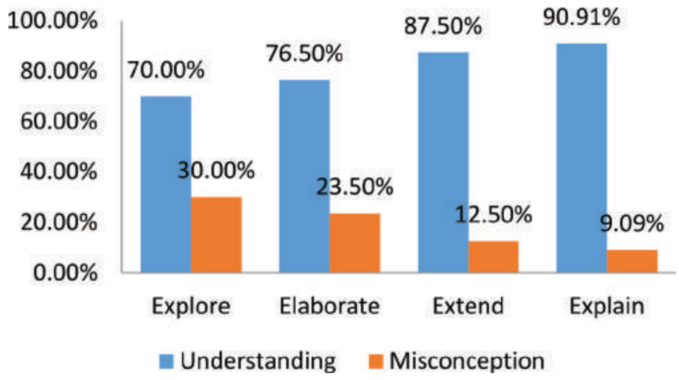

Figure 4. The graphic of students' cognitive structure development in pH scale topics.

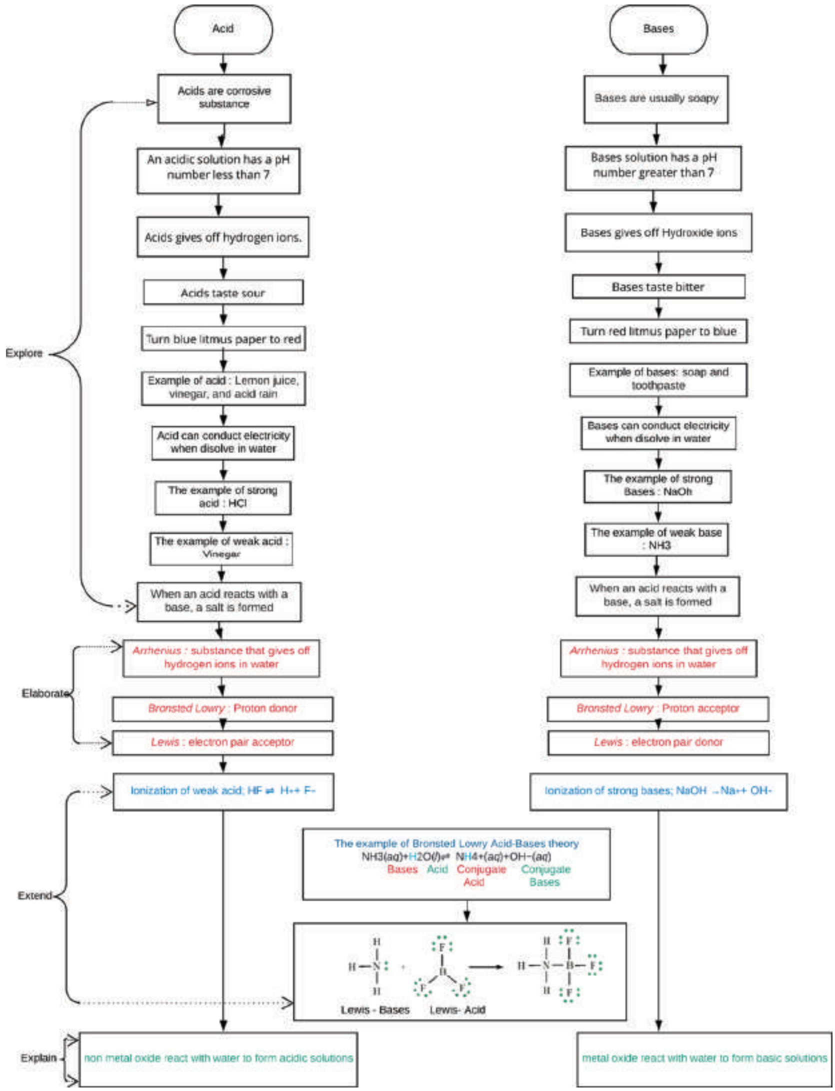

Figure 5. A sample of student flow map in properties of acid-base topic.

level to generate the idea of acid-base properties. In the elaborate phase, the student added the information of the acid-base theory that they got from learning resources. In the extend phase, they student extended the idea of acid-base theory in microscopic scale and used symbolic representation to represent the chemical reactions of several acid-base theories. In the explain phase, the student developed the idea of acid-base formation, after receiving the teacher's explanations.

The Learning Cycle 8E model of teaching had an impact on students' cognitive structure development and can decrease students' misconception of acid-base topics, as stated in the following interview:

> *Interviewer: On your flow map, in elaborate phase is written that acids are a conductor meanwhile alkalizes are an insulator, what do you mean by that?*
>
> *Student 26: During the e-search phase, I used notes from the tuitions class, it stated that acids are conductor meanwhile alkalizes are an insulator, but I don't know whether the statement correct or not.*
>
> *Interviewer: So, after the learning activity, what about your understanding of acid-base conductivity?*
>
> *Student 26: An acid or base, which strongly conducts electricity, contains a large number of ions and is called a strong acid or base.*
>
> *An acid or base, which conducts electricity only weakly contains only a few ions and is called a weak acid or base.* (Student 26, interviewed on January 20, 2017).

Based on the interview data, student 26 experienced a conceptual change from misconception to the correct understanding. In the elaborate phase, student 26 has a misconception and he justifies the conceptual understanding after listening to the teacher's explanation. Thus, in the explain phase student 26 changes his conceptual understanding from misconception to correct understanding.

4 CONCLUSION

Students build their cognitive structure based on their prior knowledge, conceptual understanding and experiences. The Learning Cycle 8E model had an impact on students' cognitive structure development. The use of the Learning Cycle 8E model can decrease students' misconception of acid-base concepts. This establishes the efficacy of the Learning Cycle 8E model in overcoming students' misconception. The Learning Cycle 8E model also affected students' soft skills of collaboration and communication. Students' attitude of respecting and appreciating differences of perspectives also improved.

The implementation of this study has some limitations. Time was the major limiting factor in this study. The Learning Cycle 8E model of teaching takes more time than traditional learning. The learning activities consume more in-class time, and students must spend more time outside of class to conduct the interviews with the researcher. Within the longer time, the teacher needs to find interactive teaching strategies that help students to engage with the lesson. However, we believe that these findings have an added value to the research world in several respects and that they can be transferable to other innovative settings. In addition, it would be interesting to investigate the impact of the Learning Cycle 8E model on teaching in other topics and subjects. Additional empirical research is needed to gain further insight into the impact of the Learning Cycle 8E model of teaching in developing students' cognitive structure and 21st century skills.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

The influence of learning models and critical thinking skills on students' chemical literacy

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ABSTRACT: The purpose of this research is to discover the influence of learning models (Predict-Discuss-Explain-Observe-Discuss-Explain (PDEODE) and Scientific (5M)) learning models and critical thinking skills on students' chemical literacy. The population of the research was students of class XI science at one of the secondary schools in Jakarta. The research instrument used is a critical thinking test and a chemical literacy test in a buffer solution course. Chemical literacy test results were analyzed using the two-way ANOVA method, and then continued with the Tuckey test at a significance level of 5%. The result of the research can conclude that the students' chemical literacy using the PDEODE learning model is higher than using the 5M learning model. There is no significant interaction effect between learning models and critical thinking skills to chemical literacy. The students' chemical literacy with the PDEODE learning model is higher than the 5M learning model for high and low critical thinking groups. It means that the PDEODE learning model can be used in high and low critical thinking groups to increase students' chemical literacy.

1 INTRODUCTION

In the 21st century, everyone is expected to have awareness of global conditions such as having creativity and high innovation, having critical thinking skills to solve problems, having good communication and collaboration skills and having good literacy (*The partnership for 21st century skills*, 2009). Scientific literacy skill is greatly significant for students' thinking development, because everyone requires a scientific process to make a decision, to understand and argue in important issues involving science and technology (Cigdemoglu, 2015).

However, science literacy in Indonesian students is still low. This is evidenced by the assessment data from the Program for International Student Assessment (PISA) in terms of science and mathematics ratings. Based on the results of PISA, measuring student literacy in science in 2015, Indonesian students ranked 66th out of 74 countries (OECD, 2016). It showed that Indonesia has the lowest rank of other countries. The low level of scientific literacy in Indonesia indicates that the students have low levels of critical thinking and analysis. This is because the learning process has not applied meaningful learning so the students find it difficult to improve their critical thinking skills (Dharma, 2008).

The ability to think critically is a process for someone to examine an evidence and to give assumptions based on the opinions and logic of other statements until gaining a deep understanding (Johnson, 2012). Critical thinking skills are not acquired easily. They must be developed and improved in daily life. Therefore, in the learning process, the teachers must guide the students so that they are accustomed in analyzing problems, collecting information as outlined in the hypothesis and seeking relevant sources of information, so that the students can prove the results of the hypothesis based on the results of the experiments (Muharamiah et al., 2015).

Susanto (2015) also stated that students' critical thinking skills can be improved if there is an interactive class by making students as thinkers to get their own knowledge. One of ways that this can be done by the teacher is to prepare learning using the right learning model in order to improve scientific literacy. Based on previous research, one of the learning models that can influence students' critical thinking skills is the Predict-Discuss-Explain-Observe-Discuss-Explain (PDEODE) learning model (Dipalaya & Duran, 2016). The PDEODE learning model is the result of the development and modification of the Predict-Observe-Explain (POE) learning model, which has the characteristics of a cyclical learning model (Khanthavy & Yuenyong, 2009). The POE learning model is based on the constructivism theory, which stated that learning is a process of knowledge formation carried out by students (Costu, 2008). The PDEODE learning model is designed for students to discuss and give arguments based on their perspective. Students are expected to be able to actively engage in thinking, processing concepts and interpreting the learning process.

2 METHOD

The research used a quasi-experimental method, which was Posttest-Only Control Design. The research used two independent variables, learning model as the treatment variable and critical thinking skills as an attribute variable. Each independent variable was divided into two types, the PDEODE learning model and the 5M learning model as factor A, while critical thinking skills as factor B was divided into two groups namely high critical thinking skills and low critical thinking skills. Then, the dependent variable was the chemical literacy skill in terms of cognitive aspects. Therefore, this research used factorial design 2 × 2. The factorial design is described in Table 1.

The population in this research were students of class XI Science of a secondary school in Jakarta in the second semester of the 2017/2018 academic year. The sampling technique used *simple random sampling*, in which the population has the same opportunity to be used as a research sample (Sugiyono, 2015). The sample was class XI Science 3 as an experimental class, which was given the treatment of the PDEODE learning model, whereas class XI Science 4 was a control class, which was given the treatment of the 5M learning model (based on the 2013 curriculum). The total of students in the sample was 36, where each class consisted of 18 students.

The instrument consisted of (1) a critical thinking test in the form of 30 multiple choice questions to measure whether students' critical thinking was high or low and (2) a chemical literacy test in the form of 12 questions to measure students' chemical literacy after the treatment was given using the PDEODE and 5M learning models. The data from these tests was analyzed using normality and homogeneity tests to test the hypothesis. The hypothesis test used two-way ANOVA and continued with the Tuckey test to see the differences in the learning outcomes of students who had high and low critical thinking skills on the application of the PDEODE and 5M learning models.

This research has four hypothesis, there are: (1) there was differences in students' chemical literacy using the PDEODE and 5M learning models, (2) there was interaction between the

Table 1. Factorial design 2 × 2.

Critical Thinking Skills (B)	Learning Model (A)	
	PDEODE (A_1)	5M (A_2)
High (B_1)	A_1B_1	A_2B_1
Low (B_2)	A_1B_2	A_2B_2

Information:
A_1 = the class of the PDEODE learning model
A_2 = the class of the 5M learning model
B_1 = higher critical thinking skills
B_2 = lower critical thinking skills

learning models and the students' critical thinking skills toward students' chemical literacy, (3) the students' chemical literacy with the PDEODE learning model is higher than with the 5M learning model for high-critical thinking groups, 4) the students' chemical literacy with the 5M learning model is higher than with the PDEODE learning model for low-critical thinking groups.

3 RESULT AND DISCUSSION

3.1 *Findings*

The data results were obtained from the critical thinking score and the chemical literacy score on the buffer solution course. Then, the data was grouped into (1) the data of students' chemical literacy that were given learning model (A_1 and A_2), (2) the data of students' chemical literacy that were given the PDEODE model with high critical thinking skills (A_1B_1), (3) the data of students' chemical literacy that were given the PDEODE model with low critical thinking skills (A_1B_2), (4) the data of students' chemical literacy that were given the 5M model with high critical thinking skills (A_2B_1), and (5) the data of students' chemical literacy that were given the 5M model with low critical thinking skills (A_2B_2). The description of chemical literacy data and standard deviations are presented in Table 2.

Based on Table 2, the average of students' chemical literacy tests treated with the PDEODE (A_1) learning model was higher than the students' group that was treated with the 5M (A_2) model. The results of the chemical literacy test of the group of students who were treated with PDEODE (A_1B_1) had the highest average than others. This was supported with the data of the minimum and maximal score in the chemical literacy test and low standard deviations. Furthermore, the hypothesis test was done by two-way ANOVA. The recapitulation of the ANOVA test is presented in Table 3.

Based on the result, F_{count} = 28,784 (between the PDEODE and 5M learning models) was greater than F_{table} = 4,15 at the 0.05 significance level. This indicated that the first hypothesis stated that H_0 was rejected and H_1 was accepted, so that there were significant differences on

Table 2. The average and standard deviation of the treatment group.

Group	N	Mean	Standard deviation	Minimum score	Maximum score
A_1	18	76.44	9.9	60	94
A_2	18	63.78	8.9	50	88
A_1B_1	9	83.78	5.7	78	94
A_1B_2	9	69.11	6.2	60	82
A_2B_1	9	68.89	9.2	58	88
A_2B_2	9	58.67	5.3	50	66

Table 3. The recapitulation of two-way ANOVA results.

Source of variance	Db	JK	RJK	F_h	F_t ($\alpha = 0{,}05$)	Keterangan
Among Column (A) Learning Model	1	1444	1444	28.784	4.15	Significant
Among row (B) Critical Thinking	1	1393.778	1393.778	27.783	4.15	Significant
Interaction (A >< B) Learning Model >< Critical Thinking	1	44.444	44.444	0.886	4.15	Not Significant
In Group (D)	32	1605.333	960.741			
Total (TR)	35	4487.556				

the chemical literacy score among students who were given the PDEODE and 5M learning model. In addition, based on the results of the calculation of the interaction between the learning model and students' critical thinking skills on chemical literacy were obtained $F_{count} = 0,886$ smaller than $F_{table} = 4,15$ at the 0.05 significance level. The result indicated that the second hypothesis stated that H_0 was accepted and H_1 was rejected. It meant there was no significant interaction effect between the learning model and critical thinking skills on students' chemical literacy.

The interaction among students toward alchemic interaction is shown in Figure 1 as follows:

Based on the figure of the interaction pattern, the line between the learning model and students' critical thinking skills were parallel (or not intersected), meaning that there was no interaction between the learning models and critical thinking skills on chemical literacy. Furthermore, the Tukey test was conducted to determine the significance of differences in the mean of chemical literacy students who had high critical thinking skills between students who were given the PDEODE and 5M learning models (A_1B_1 and A_2B_1) and students who had low critical thinking skills who were given the PDEODE and 5M learning models (A_1B_2 and A_2B_2). Further test results from the two treatment groups are presented in Table 4.

Based on the results of calculations using the Tuckey test given above, the value is $Q_h > Q_t$. It means that the third hypothesis showed that H_0 was rejected and H_1 was accepted. In other words, there were significant differences in the value of chemical literacy between those given the PDEODE and 5M learning models in groups of students with high critical thinking skills. The fourth hypothesis also stated that H_0 was rejected and H_1 was accepted, or there was a significant difference in chemical literacy between those given the PDEODE and 5M learning models in groups of students with low critical thinking skills.

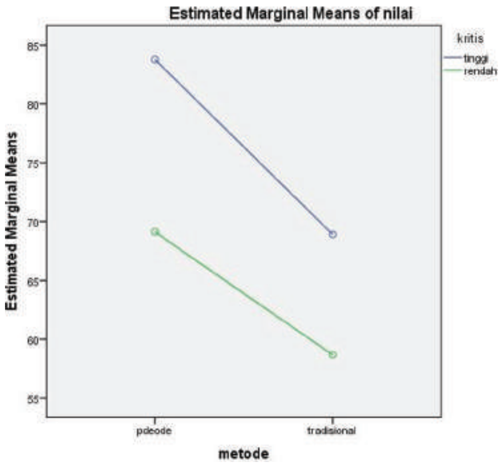

Figure 1. The pattern of interaction between the learning model and critical thinking skills on alchemic literation.

Table 4. The result of Tuckey test.

Group	Q_{count}	Q_{table}
A_1B_1	6.31	4.41
A_2B_1		
A_1B_2	4.42	4.41
A_2B_2		

4 DISCUSSION

The results of the first hypothesis test showed that the value of F_{count} was greater than F_{table} at the significance level 0.05 so that H_0 was rejected and H_1 was accepted. It meant the students' score of chemical literacy who were taught using the PDEODE learning model was higher than the students' score of chemical literacy who were taught with the 5M learning model. The PDEODE and 5M learning models were two different models in terms of the learning stages. In the PDEODE learning model there were learning stages such as predicting a problem, which would be studied. In this way, students' ability in analyzing was developing more. Therefore, this concern could affect students' chemical literacy.

This was in line with Costu et al. (2012) who stated that the PDEODE learning model can develop students' mastery of problems that occur in daily life so that students' understanding in analyzing a problem is getting better. When using the PDEODE learning model, students construct their own knowledge through scientific activities related to daily life, while the teacher acts only as a facilitator. This is in contrast with the traditional learning model that needs the teacher's guidance in learning, and consequently, the students are less active in learning. This is consistent with the findings of Solichah (2014) in that the PDEODE learning model can improve learning outcomes in understanding a better concept.

The findings of the second hypothesis test revealed that there was no significant interaction between the learning model and the critical thinking skills on chemical literacy. No interaction occurred due to base on chemical literacy score, the groups that used PDEODE learning model with high critical thinking skills and low critical thinking skills (A_1B_1 and A_1B_2) had a higher average than the groups that used the 5M (A_2B_1 and A_2B_2) learning model. Consequently, no interaction occurred among learning models and critical thinking skills. It meant that in learning activity, the class that was given treatment using the PDEODE learning model gave a stimulus to the students either with high critical thinking skills or with low critical thinking skills, so that the experimental class had a higher value of chemical literacy compared to the control class. Learning activity using PDEODE makes the classroom environment more meaningful and realistic, so that it can improve students' understanding of concepts and learning outcomes (Sudarmi & Suarni, 2013).

The experimental class that was given the PDEODE learning model became more active in arguing, competing in expressing opinions, such as in predicting a problem, having more discussion, observing to analyze the truth of a topic through practicum and then concluding learning outcomes on learning processes make their critical thinking skills to be developed. Whereas in the control class that used the 5M learning model, it looked less active in the learning process because students were accustomed to being instructed by the teacher. Therefore, students' chemical literacy was lower than the experimental class.

The results of the third hypothesis test stated that H_0 was rejected and H_1 was accepted, so there were differences in the value of students' chemical literacy that were taught using the PDEODE and 5M learning models in a group of students who had high critical thinking skills. It can be concluded that the group of students who used the PDEODE learning model with high critical thinking skills had a higher score of chemical literacy compared to groups that used the 5M learning model with high critical thinking skills. This indicated that critical thinking skills have an important role in the learning process that affects student literacy (Yuni, 2017). Students who had high critical thinking skills increasingly develop their analytical skills because the learning process used the PDEODE learning model. Thus, the students were more active in discussing and expressing their ideas.

The results of the fourth hypothesis test stated that there were differences between the values of students' chemical literacy who were taught using the PDEODE and 5M learning models in groups of students who had low critical thinking skills. However, the differences meant that the value of chemical literacy in a group of students who used the PDEODE learning model was higher than the group of students who used the 5M learning model. Supposedly, students who used the 5M learning model with low critical thinking skills had higher literacy scores than students who used the PDEODE learning model with low critical thinking skills.

According to Dipalaya et al., (2016) the learning process using the PDEODE learning model gives the students the opportunity to express their opinions about their initial knowledge and provide opportunities for students to work together by discussing and arguing. The treatment between groups of students who had high and low critical thinking skills in the class had an impact on students' chemical literacy results, so that the students who used the PDEODE model with low thinking skills had a higher average value compared to the two groups of students who used the 5M learning model and having high or low critical thinking skills.

5 CONCLUSION

Based on the results of this research, the following conclusions were obtained. (1) The students' chemical literacy using the PDEODE learning model is higher than those using the 5M learning model. 2) There is no significant interaction effect between learning models and critical thinking skills on chemical literacy. 3) The students' chemical literacy with PDEODE is higher than with the 5M learning model for high-critical thinking groups. 4) The students' chemical literacy with 5M is lower than with the PDEODE learning model for low-critical thinking groups.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

The influence of Problem Based Learning (PBL) with Information and Communications Technology (ICT) and motivation for critical thinking skills

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ABSTRACT: The purpose of this research is to discover: (1) the difference of students' critical thinking skills using PBL-Flash and PBL-PowerPoint on the equilibrium of ions in a salt solution; (2) the influence of interaction between Problem Based Learning with Information and Communication Technology (ICT) and learning motivation on students' critical thinking skills; (3) differences in critical thinking skills of students using PBL-Flash with PBL-PowerPoint for groups of highly motivated students; (4) differences in critical thinking skills of students using PBL-Flash and PBL-PowerPoint learning for low-motivated student groups. This research uses the experimental method with 2 × 2 factorial design two-lane design. The population of this study are students of a senior high school in Indonesia. The sampling technique uses cluster random sampling. Data collection uses techniques with descriptive questions for critical thinking skills and questionnaires for learning motivation. Normality test requirements use the Lilliefors Test and homogeneity test requirements using the Bartlett Test. the result of the research it can be concluded that: (1) students' critical thinking skills using PBL-Flash is higher than PBL-PowerPoint; (2) There is interaction effect between learning media with motivation to critical thinking skill; (3) students' critical thinking skills with PBL-Flash are higher than PBL-PowerPoint for high-motivated student groups; (4) The students' critical thinking skills with PBL-PowerPoint are higher than PBL-Flash for low-motivated student groups.

1 INTRODUCTION

Professional teachers in the 21st century are teachers who have expertise in selecting methods and learning media to produce a better teaching and learning process. The use of instructional media is needed because it can generate motivation, learning stimuli and bring psychological influence on students so that students understand the material they learn. However, the motivation of students in learning, especially on chemistry subjects is still low. This is evidenced by the average value of UN chemical values in 2017 which is still low at 59.98.

In addition to the low motivation to learn, students' critical thinking skills are still low. This is in accordance with the results of TIMMS IPA SMP/MTs Class VIII year 2011 which states that more than 95% of Indonesian students are only able to think up to middle level or mastery of science at the level of thinking to apply (Highlights from, TIMSS 2011). Critical thinking skills are one of the skills that must be possessed by students in the 21st century (Lai & Viering 2012). The same thing is also expressed by Balistreri who states that critical thinking skills and creative problem solving are the abilities that must be possessed by students to be able to compete in the global era (Balistreri et al., 2012).

Learning innovation is needed so that students are motivated to learn in order to develop critical thinking skills for solving every complex problem (Hassan et al., 2017). One of the innovations of learning in accordance with the 21st century is the utilization of ICT media as an interactive learning media.

In addition to ICT media, the use of learning models is also needed to improve learning motivation and support students' critical thinking skills. Problem Based Learning is one of the learning models that can encourage learning motivation (Keziah, 2010) and can emphasize the students to build their knowledge by critical thinking (Masek & Yamin 2011). Application of the model can also be maximized with the help of ICT-based applications so that it will be more effective in improving students' critical thinking skills (Simbolon et al., 2017).

The use of ICT media with PBL is expected to provide stimulus for students. This is in accordance with the results of the study (Ealy, 2016) which states that critical thinking skills can be stimulated by using visual media, because with visual media learning will be more effective (Turkoguz 2012).

One of the ICT media tools that can be used to achieve PBL is media Macromedia Flash and PowerPoint. Macromedia Flash, which is an interactive learning media that can visualize something abstract so that becomes real, hence it will stimulate students to improve their critical thinking skills (Simbolon et al., 2017). The PowerPoint media is a learning medium that can display the purpose of learning, learning materials, examples in everyday life, as well as exercise questions. With guidance and direction from the teacher, then using the media PowerPoint is expected to improve student learning motivation so as to improve critical thinking skills. By learning using PBL and learning media, it is expected that student participation and activeness in learning will increase so that interest and the motivation to learn will increase.

2 METHOD

This research was conducted at a senior high school in Indonesia. The sampling technique used in this research is cluster random sampling. The sample of the research is students of class XII MIA 3 (experiment class I) and XII MIA 2 (experiment II class). The technique of collecting data was in the form of description and questionnaire. Problem description was used to obtain critical data thinking skills of the students. The questionnaire method in this study was a questionnaire of motivation; students were given motivational questionnaires to determine the upper groups and lower groups. Students were categorized into high motivation groups if the score was in the range of 27% of the highest score and the score is 27% lowest score (Sugiyono 2010). Prior use of critical thinking skills instruments tested, first tested the validity and reliability. The research method used is an experimental method with the 2×2 factorial research design. The research design table can be seen in Table 1.

Data analysis techniques consist of a prerequisite test and hypothesis test. The prerequisite test consists of a normality test and a homogeneity test.

3 RESULT AND DISCUSSION

3.1 *Result*

Student learning motivation is obtained by using questionnaires. Critical thinking skills of students are obtained by using a description test instrument that has been tested for its validity and reliability. Data on critical thinking skills can be seen in the following table.

Table 1. 2×2 Factorial research design.

Motivation (B)	Learning model (A)	
	PBL-Flash (A_1)	PBL-Power Point (A_2)
High (B_1)	A_1B_1	A_2B_1
Low (B_2)	A_1B_2	A_2B_2

3.2 *Hypothesis testing*

After performing test requirements, analysis shows that the data is normally distributed and homogeneous. Then the next stage is testing the hypothesis. Here is a hypothesis to be tested: (1) Hypothesis 1 (main effect): students' critical thinking skills on ionic equilibrium in salt solution taught by PBL-Flash (A_1) is higher than students taught by PBL-PowerPoint (A_2). (2) Hypothesis 2 (interaction effect): there is an interaction effect between instructional media (A) and motivation (B) on students' critical thinking skills. (3) Hypothesis 3 (simple effect): students' critical thinking skills taught by PBL-Flash (A_1) is higher than students taught by PBL-PowerPoint (A_2) in the student group highly motivated. (4) Hypothesis 4 (simple effect): students' critical thinking skills taught by PBL-Flash (A_1) is lower than students taught by PBL-PowerPoint (A_2) in the student group motivated low.

Two-way ANOVA testing is used for interaction effect testing. If the interaction effect testing obtained H_o results rejected or H_1 accepted, then the test can be continued by testing the main effect hypothesis.

The summary of the test results using two-way ANOVA obtained data is as follows:

Test the main effect hypothesis between A_1 and A_2. Based on the results of the data processing obtained the value of F_h is 6.13. The F_t value is at the significance level (α) 0.05 of 4.06. Based on the results obtained, the value of $F_h > F_t$, then H_o is rejected. So it can be concluded that students' critical thinking skills with PBL-Flash are higher than with PBL-PowerPoint.

Hypothesis interaction effect between $A \times B$. Based on the results of the data processing, the F_h value is 68.56. The Ft value is at the significance level (α) 0.05 of 4.06. Based on the results obtained, the value of $F_h > F_t$, then H_o is rejected. Thus it can be concluded that there is an interaction between learning media (A) and learning motivation (B) on students' critical thinking skills. The influence of interaction between learning media and motivation can be seen in the following figure.

Test the simple effect hypothesis between groups A_1B_1 and A_2B_1. Based on the results of the data processing, the Q_h value is 9.98. The Q_t value at the significance level (α) 0.05 is 4.20. Thus the value of $Q_h > Q_t$, it can be concluded that students' critical thinking skills with PBL-Flash (A_1B_1) are higher than PBL-PowerPoint (A_2B_1) in a group of highly motivated students.

Test the simple effect hypothesis between groups A_1B_2 and A_2B_2. Based on the results of the data processing, the Q_h value is 5.03. While the Q_t value at the significance level (α) 0.05 is 4.20. So the value of $Q_h > Q_t$, so it can be concluded that students' critical thinking skills with PBL-Flash (A_1B_2) are lower than PBL-PowerPoint (A_2B_2) in the group of students with low motivation.

Table 2. Data of student's critical thinking skills.

Motivation (B)	Learning (A) PBL-Flash (A_1)		PBL-Power Point (A_2)		$\sum B$	
High (B_1)	n_{11}	12	n_{12}	12	n_{10}	24
	X_{11}	85.33	X_{12}	62.50	X_{10}	73.92
	$\sum X_{11}$	1024	$\sum X_{12}$	750	$\sum X_{10}$	1774
	$\sum X^2_{11}$	87600	$\sum X^2_{12}$	47740	$\sum X^2_{10}$	135340
Low (B_2)	n_{21}	12	n_{22}	12	n_{20}	24
	X_{21}	62.83	X_{22}	74.33	X_{20}	68.58
	$\sum X_{21}$	754	$\sum X_{22}$	892	$\sum X_{20}$	1646
	$\sum X^2_{21}$	48188	$\sum X^2_{22}$	67174	$\sum X^2_{20}$	115362
$\sum K$	n_{01}	24	n_{02}	24	n_{00}	48
	X_{01}	74.08	X_{02}	68.417	X_{00}	71.25
	$\sum X_{01}$	1778	$\sum X_{02}$	1642	$\sum X_{00}$	3420
	$\sum X^2_{01}$	135788	$\sum X^2_{02}$	114914	$\sum X^2_{00}$	250702

3.3 *Discussion*

Based on the results of testing the hypothesis, the discussion will focus more on 4-four hypotheses, namely:

– Hypothesis 1
  Critical thinking skills greatly influence the formation of students' conceptual systems. Critical thinking is an attempt to apply rational, high-thinking activities, which include analyzing, synthesizing, recognizing problems and solving them, concluding, and evaluating. Critical thinking skills of students are not obtained instantly but are obtained through processes in the classroom learning environment by emphasizing problem solving (Birgili, 2015). During the learning process using PBL, students are trained to develop critical thinking skills through problem solving given by teachers to students (Borhan, 2012). PBL encourages students to have deep knowledge (Jansson et al., 2015), improve their understanding of theory (Masek & Yamin 2011), and motivate them to continue learning. Learning groups in PBL are seen as a way for students to actively participate in the learning process, hone information seeking skills and hone collaboration and confidence. In addition, the use of ICT media during the learning process also stimulates students to further develop their critical thinking skills (Simbolon et al., 2017).

Table 3. The summary of test results using two-way ANOVA.

Source	db	JK	RJK	F_h	F_t
Between A_1 and A_2	1	385.33	385.33	6.13	4.06
Between B_1 and B_2	1	341.33	341.33	5.43	4.06
Interaction AxB	1	4307.00	4307	68.56	4.06
Between groups (A)	3	4263.00	1421.00		
In the group (D)	44	2764.00	62.82		
Total reduced (TR)	47	7027.00	149.51		
Average/Correction (R)	1	243675			
Total (T)	48	250702			

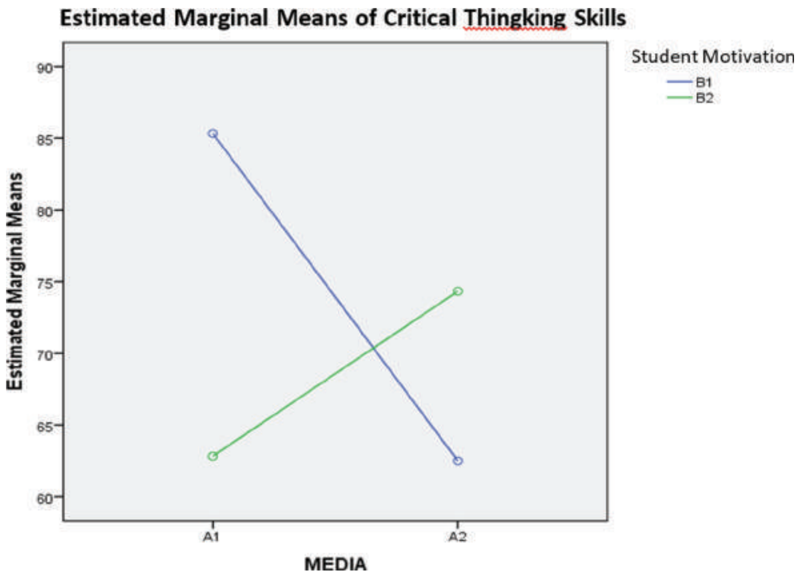

Figure 1. Graph of interactions between learning media (A) and student learning motivation on critical thinking skills.

Flash ICT media allows students to think more creatively in understanding material (Yusrizal et al., 2017) because the material displayed is in the form of animation that encourages students to be more active in interpreting subject matter (Simbolon et al., 2017). While in ICT Power Point media, teachers become more effective in providing further explanation to students.

– Hypothesis 2

The results of research on testing the second hypothesis show that there is an interaction between learning media and learning motivation on students' critical thinking skills. The existence of this interaction proves that the media used in learning will give different results if applied to students who have high motivation and low motivation.

Motivation is an internal factor in students that encourages them to continue learning. It is with this motivation that the learning process becomes more meaningful for students. Without motivation, it is very difficult for the learning process to go well. When students have a high motivation to learn, the goal of learning to improve students' critical thinking skills will be achieved. Therefore motivation is the key to success in problem-based learning (Harun et al. 2012).

In addition to learning motivation, the use of learning methods is also very instrumental in developing students' critical thinking skills. One of the learning methods that can stimulate students to think and be able to solve problems is the problem based learning (PBL) method. Problem based learning (PBL) is an instructional method that facilitates students to learn to solve problems. The problems given to students are contextual problems (Dirckinck-Holmfeld, 2009) which are often encountered by students in everyday life, so students feel that learning chemistry is an important lesson.

The use of learning methods will be maximized by using ICT media (Dwi et al., 2013). Combining PBL with ICT media will motivate students to learn because the problems given can be visualized so that it looks more attractive (Nicole, 2015).

– Hypothesis 3

The results of research on the third hypothesis show that students' critical thinking skills taught with PBL-Flash learning are higher than students taught with PBL-PowerPoint for groups of highly motivated students.

Students with high learning motivation have great interest and attraction in learning so they will be as strong as possible in achieving maximum results. This is what makes students with high motivation truly able to follow all the learning processes from beginning to end. In addition, they will be encouraged to learn new things through reading, discussing in groups and conducting experiments in the laboratory. Therefore, students with high learning motivation when given learning with PBL-Flash, will be very happy and follow all the learning processes well, so that in the end it can improve their high critical thinking skills.

In PBL learning using interactive flash media, the teacher acts as a facilitator. At the problem identification stage, the teacher provides learning the material in the form of flash media and students are given the freedom to study material in groups. Students with high learning motivation will be able to follow learning well, while students with low learning motivation will have difficulty in learning.

Based on the description above, students' critical thinking skills taught with PBL-Flash are higher than students who are taught with PBL-PowerPoint on the equilibrium material of ions in salt solution.

– Hypothesis 4

The results of the research on the fourth hypothesis show that students' critical thinking skills taught with PBL-Flash learning are lower than students taught with PBL-PowerPoint for groups of low motivated students.

Students with low learning motivation follow the learning process as is. So a well-structured learning goal is needed. The structure of the learning material will also be followed according to what is presented by the teacher (Fadliana et al., 2013). PBL-Power Point learning presents problem-based learning but still positions the teacher as the main learning source. Here the teacher's role is to explain in detail the material displayed in PowerPoint and the students are required to follow detailed explanations from the teacher. Learning models like this are preferred by students with low learning motivation because they get a more detailed explanation from the teacher.

Learning PBL with Power Point media still places the teacher as a source of information, even though PBL learning is student-centered. In PBL-PowerPoint learning, it tries to combine student-centered learning and the teacher. At the time of discussing problems, the learning is student-centered, while at the time of problem identification, the teacher and students discuss finding solutions to the problems. Here the teacher gives an explanation of learning material assisted with PowerPoint media. Students with low learning motivation will be helped by the explanations presented by the teacher.

Based on the description above, the critical thinking skills of students taught with PBL-Power Point are higher than students taught with PBL-Flash on the equilibrium material of ions in salt solution.

4 CONCLUSION

Based on data from research, analysis and testing of hypotheses, conclusions can be drawn, namely: (1) The critical thinking skills of students who are taught with PBL-Flash are higher than students who are taught to use PBL-Power Point on the equilibrium material of ions in a salt solution; (2) there is an influence of interaction between learning media and learning motivation on students' critical thinking skills on the equilibrium material of ions in salt solution; (3) critical thinking skills of students taught with PBL-Flash are higher than students taught with PBL-PowerPoint for groups of highly motivated students on the equilibrium material of ions in salt solutions; (4) critical thinking skills of students taught with PBL-Flash are lower than students taught with PBL-PowerPoint for groups of low motivated students on equilibrium materials of ions in salt solutions.

In general, learning with PBL can improve students' critical thinking skills. However PBL learning combined with macromedia flash media will improve higher thinking skills in groups of highly motivated students. Meanwhile, PBL, combined with PowerPoint media, is able to improve the thinking skills in a group of low-motivated students

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Identification of Technological Pedagogical Content Knowledge (TPACK) competency on self-efficacy of pre-service chemical teachers

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ABSTRACT: This research is aimed to identify the competencies of Technological Pedagogical Content Knowledge (TPACK) toward self-efficacy for pre-service chemical teachers. The research method used is the descriptive qualitative method. The sample consisted of 30 pre-service chemical teachers in semester 6. TPACK's measured competency consists of seven components, namely: (1) *Technological Knowledge* (TK); 2) *Pedagogical Knowledge* (PK); 3) *Content Knowledge* (CK); 4) *Technological Content Knowledge* (TCK); 5) *Pedagogical Content Knowledge* (PCK); 6) *Technological Pedagogical* Knowledge (TPK); 7) *Technological Pedagogical Content Knowledge* (TPCK). In addition, some aspects also will also be provided to measure the self-efficacy, such as Science Aspect (SA), Higher-Order Thinking (HOT), Laboratory Usage (LU), Everyday Application (EA), Science Communication (SCM) and Scientific Literacy (SL). Moreover, the writers use questionnaires based on the Likert scale as the instrument of the research. After collecting the data of the research, the data will be analyzed using descriptive qualitative. The result shows that the average percentage score of Technological Pedagogical Content Knowledge (TPACK) is about 76.1% (good) and the self-efficacy score is about 74.1% (good). Based on the result, it can be concluded that the TPACK ability of the pre-service chemical teachers is comparable to the self-efficacy.

1 INTRODUCTION

One of the important rights of the Indonesian citizens, which has been written in the 1945 Constitution, is obtaining a good quality of education (Bahriah, 2017). It focuses on developing an education system that can create a lot of competent graduated students who are able to compete with other people in the world. Furthermore, the quality of education can be determined by the teacher itself because education has a relationship with the interaction between teachers and learners. To be more specific, the teachers have an important role in the teaching and learning process although facing a lot of problems, such as lack of facilities or due to the insecure condition. The importance of qualified teachers can enhance the quality of education in the future life (Sukmadinata, 2011).

Based on the UU RI Number.14 Year 2005, which explains about teachers and lecturers, a professional teacher is a teacher who has an academic qualification, competences, certificate of teaching, is healthy in both physical and spiritual aspects as well as having the ability to achieve the objectives of the national education. The professional teacher should have a qualified competence, namely Pedagogical Content Knowledge (PCK). This competence becomes the basic knowledge for the teachers because they will face a lot of challenges in the classroom activities and will need to be able to find an appropriate way to solve the problems that happen. Besides, the teachers also should organize, arrange, implement, assess and evaluate the materials given to the students. (Shulman, 1986).

Additionally, the Department of National Education Republic of Indonesia also requires that teachers have standard competencies in teaching the materials such as, mastering the content, technology, pedagogy, culture, humanity, nationality and civilization (The Ministry of Education and Culture Republic of Indonesia, 2013). So, the government decided to conduct a teacher competency test, which is held once a year in order to examine the teachers' competencies in Indonesia. Moreover, 30% of pedagogic competency is included in the test and 70% is based on professional competency. Specifically, the pedagogic competency consists of questions about the teachers' understanding in pedagogic concepts and its implementation in the classroom activities. Meanwhile, the examiner provides some questions of a professional aspect that are related to the basic competencies based on the teachers' academic qualification. In fact, the teachers' competency result in the 337 regency shows a low average level of about 42.25 (Saga 2012; Bahriah, 2017).

Therefore, the education institutions and education personnel are responsible for preparing qualified, professional and competitive teachers. One of the strategic programs held by the education institutions and education personnel is a program focusing on pedagogical knowledge and content knowledge. Then, these two knowledges are collaborated into the professional teaching practice, particularly in the formal and informal school (Bahriah, 2017).

Consequently, the globalization has affected some changes in education and technology that can be a crucial challenge for the professional teachers. Nowadays, the students are influenced by the technology and it becomes an important point to them to increase their knowledge. Based on the research carried out by some experts, it indicated that the teachers' ability in using the technology is not better than the students (Belland, 2009; Yalin et al., 2007; Lim & Khine, 2006). It means that the technology should be integrated when implementing the pedagogic aspect (Ersanli, 2016).

According to Keengwe, Onchwari, and Onchwari (2009), teachers in all disciplines have to learn about how to design and develop the technologies in order of improve the students' objectives and build a modern learning environment. So, to achieve the objective of being a professional teacher some competencies must be upgraded. For instance, pedagogical content knowledge or, more commonly known as Technological Pedagogical Content Knowledge (TPACK). There are seven variables that influence TPACK competency such as (1) Technological Knowledge, (2) Pedagogical Knowledge, (3) Content Knowledge, (4) Technological Content Knowledge, (5) Pedagogical Content Knowledge, (6) Technological Pedagogical Knowledge and (7) Technological Pedagogical Content Knowledge (Cox & Graham, 2009, Mishra & Koehler, 2006; Shulman, 1986).

The technological knowledge is intended to operate the computers and relevant sources while the pedagogical knowledge can be specified as a learning management skill of the learners. The content knowledge discusses about the subject matter knowledge such as knowledge of language, mathematics, natural science and others. The technological content knowledge provides various knowledge about how technology can represent the content. Another competency is pedagogical content knowledge which used to represent and formulate the subject to be easier and comprehensible. On the other hand, the technological pedagogical knowledge is intended to explore how the technology can facilitate the pedagogic approach. Thus, the technological pedagogical content knowledge is focusing on how to facilitate the students learning activities by implementing the pedagogic approach and technology (Cox & Graham, 2009, Mishra & Koehler, 2006; Shulman, 1986).

Mastering the TPACK (Technological Pedagogical Content Knowledge) competencies for the teacher can influence their performance in the classroom activities. It reveals that the teachers should be able to transmit the content well and easy to be understood through the implementation of technology. So, this technique is believed to increase the confidence of the teachers themselves in the teaching and learning process (Lee & Tsai, 2010). When the teachers have believed that they have a powerful potential in creating innovative learning, it means that they are able to create and apply the learning activities effectively. According to Bandura, one of the influential factors of self-efficacy is enactive attainment, which is expressed from the experience (Alwisol, 2009). This case happens when the teachers have a previous achievement, such as being able to use the technology in transferring the knowledge, so their self-efficacy will improve (Abbitt, 2011).

Self-efficacy is a self-assessment, whether someone can do something well prepared or not, right or wrong, was able to work on something or not in accordance with the requirement (Bandura, 1997). Self-efficacy is different from aspiration because the aspiration only describes something ideal that should be achieved, while the self-efficacy explains the assessment of someone's ability (Alwisol, 2009).

According to Bandura (1986), there are three aspects of self-efficacy. For instance, (1) *Level* is the aspect related to the difficulty of the task; 2) *Generality* is the important aspects related to the broad field of the task or behavior; (3) *Strength* is the aspects relating to the level of strength or stability of a person against his conviction. Suprapto et al. (2017) classify the self-efficacy in six indicators, namely: science content (SC), higher-order thinking (HOT), laboratory usage (LU), everyday application (EA), science communication (SCM), and scientific literacy (SL).

Some research on TPACK and self-efficacy has been conducted by some experts. One of them is the research written by Aminah (2013) entitled "The analysis of the pedagogic abilities and self-confidence of mathematics teachers in facing the teaching training". The result showed that the pedagogic competence of the students is classified into a good category, while the self-confidence is relatively similar. Another research has been carried out by Ariani (2015) entitled "The relationship between technological pedagogical content knowledge and technology integration self-efficacy of mathematics teachers in the elementary school". It proved that the TPACK and TISE respondents are at the basic level. On the other hand, Tuqba, et al. (2015) proved that the use of TPACK can improve the education performance and extend a good effect for teachers and increase their confidence.

Based on the explanation above, the writers are interested in identifying the competence of TPACK (Technological Pedagogical Content Knowledge) toward the self-efficacy of pre-service chemical teachers.

2 METHOD

The writers conducted this research using a descriptive qualitative method. Compared with another type of research, it emphasized the researchers to describe the facts systematically and explain the characteristic of an object correctly (Sukardi, 2007). In addition, a descriptive research was not focused on examining a hypothesis, but it was only specified to describe the real condition and the variable itself during the research (Arikunto, 2005). This research was carried out for about three months from March to May 2018 at the Department of Chemistry Education. The writers also involved thirty students in chemistry education who were studying at the sixth semester as the sample of this research. The sixth semester students were chosen because they had received chemistry content and pedagogic courses.

Table 1. Questionnaires' framework for *Technological Pedagogical Content Knowledge* (TPACK).

	Indicator	Description
1	Technological Knowledge (TK)	Knowledge of technology tools
2	*Pedagogical Knowledge (PK)*	Knowledge of teaching methods.
3	*Content Knowledge (CK)*	Knowledge of subject matter.
4	*Technological Pedagogical Knowledge (TPK)*	Knowledge of using technology to implement teaching methods.
5	*Technological Content Knowledge (TCK)*	Knowledge of subject matter representation with technology
6	*Pedagogical Content Knowledge (PCK)*	Knowledge of teaching methods with respect to subject matter content.
7	*Technological Pedagogical Content Knowledge (TPACK)*	Knowledge of using technology to implement constructivist teaching methods for different types of subject matter content.

Table 2. Questionnaires' framework for self-efficacy.

	Indicator	Description
1	Science Content (SC)	Assessing the confidence of chemistry teachers in implementing the basic cognitive ability such as the concept of chemistry, law or the theory.
2	Higher-Order Thinking (HOT)	Assessing the confidence of chemistry teachers in implementing their modern cognitive skills such as problem solving, critical thinking, or scientific investigation in chemistry domain.
3	Laboratory Usage (LU)	Assessing the confidence of chemistry teachers in exploring their abilities through various experiment activities in laboratories.
4	Everyday Application (EA)	Assessing the confidence of chemistry teachers in implementing a lot of chemistry concepts and those skills in their daily life.
5	Science Communication (SCM)	Assessing the confidence of chemistry teachers in communicating and discussing a related content of chemistry subject to their friends.
6	Scientific Literacy (SL)	Assessing the confidence of chemistry teachers in analyzing, interpreting data and reporting them in laboratory activities.

Moreover, the writers used questionnaires to collect the data consisting of a questionnaire on TPACK and a questionnaire on self-efficacy. The questionnaires have been validated by two experts. The TPACK questionnaire was required to investigate the competencies of Technological Pedagogical Content Knowledge, particularly for the pre-service chemical teacher. Specifically, the writers adapted the instruments from Chai et al. (2013). The questionnaires consisted of thirty questions and measured by a Likert scale (4-3-2-1) through various categorizations, such as very good, good, enough and lack.

On the other hand, the writers implemented the questionnaires of self-efficacy by adapting the instrument from Suprapto et al. (2017). Furthermore, the instrument of self-efficacy could be explained in the table below.

After collecting the data from the questionnaires, the data would be calculated on the percentage and analyzed by descriptive technique. Then, the writers conducted an in-depth analysis through the SPSS program determining a variety of categorizations, such as very good (80–100), good (66–79), enough (56–65), lack (40–55), very lack (0–39) (Arikunto, 2006).

3 RESULT AND DISCUSSION

3.1 *Result*

The Technological Pedagogical Content Knowledge (TPACK) competencies and self-efficacy for the pre-service chemical teachers can be seen from the following table.

Based on Table 3 above, the average score of Technological Pedagogical Content Knowledge (TPACK) was about 76.1%. Additionally, the highest score gained was 92.5%, whereas the lowest score attained was 68.3%. Another aspect was also calculated to know the self-efficacy of the pre-service chemical teachers. It showed that 74.1% was established as the average score with 87.5% as highest score and 61.7% as the lowest score. Therefore, it indicated that the competencies of TPACK and self-efficacy were categorized as good.

Besides analyzing the questionnaire results of the TPACK competencies comprehensively, the writers also examined and analyzed each indicator in the TPACK competencies. It could be used to assess which indicator indicated the highest score and the lowest score. The result for each indicator is presented in Figure 1 below.

Table 3. The competencies of TPACK and self-efficacy for the pre-service chemical teachers.

Data	TPACK	Self-efficacy
Max	92.5	87.5
Min	68.3	61.7
Average	76.1	74.1

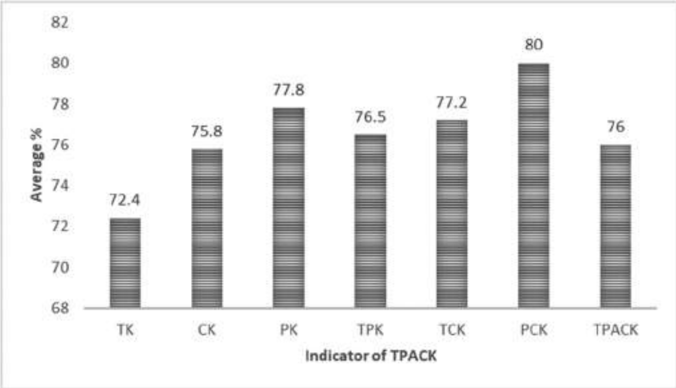

Figure 1. TPACK competencies in each indicator.
Note: TK: *Technological Knowledge,* PK: *Pedagogical Knowledge,* CK: *Content Knowledge,*TPK: *Technological Pedagogical Knowledge,* TCK: *Technological Content Knowledge,* PCK: *Pedagogical Content Knowledge,* TPACK: *Technological Pedagogical Content Knowledge.*

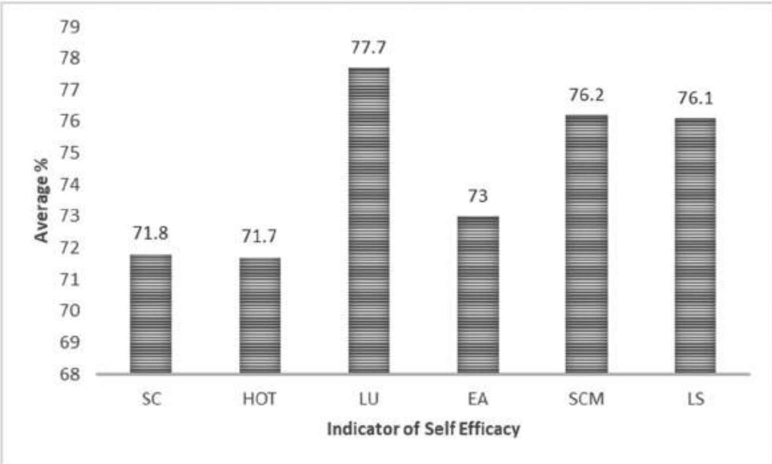

Figure 2. Data of self-efficacy of the pre-service chemical teachers.
Note: CS: Content of Science, HOT: Higher-order thinking, LU: Laboratory Usage, EA: Everyday Application, SCM: Science Communication, SL: Science Literacy.

Based on the graph in Figure 1 above, it could be seen that the average percentage of TPACK competencies was achieved by the Pedagogical Content Knowledge aspect, which gained a score of 80 (very good), which was the highest score. In contrast, the lowest score was showed by the Technological Knowledge, which descended to 72.4 (good). Furthermore, the self-efficacy of the pre-service chemical teachers could be identified through the graph in Figure 2 below.

Based on the information in the graph, it proved that the average percentage of self-efficacy competencies of the pre-service chemical teachers was obtained by Pedagogical Content Knowledge at about 77.7 (good) as the highest score. However, the lowest score was indicated by Technological Knowledge aspect at about 71.7 (good).

3.2 *Discussion*

A qualified educator can be defined as a professional teacher who has a good academic qualification, teaching competency, certificate of professional teacher, is healthy in physical and spiritual aspects, as well as having the ability to achieve the objectives of national education (Permen Number 74 Year 2008 Section 2). One of the indicators to determine the teachers' professional competencies is Technological Pedagogical Content Knowledge (TPACK).

The competencies of TPACK are a combination of the three domains of knowledge (content, pedagogy and technology) which emphasizes the relationship between technology, curriculum content and the pedagogy approach. It is aimed to develop a basic knowledge of when a teacher learns a new knowledge and to try to understand how a technology can enhance the students' learning opportunities and increase their experience. It can be a good way for the teachers to improve their teaching methodology and the content itself (Ariani, 2015; Harris, Mishra, Koehler &, 2009).

Furthermore, TPACK becomes the basic concept for being a good teacher by using technology. Also, it needs an understanding about the concept of a representation concept through technology. Besides, the teachers should have various techniques to teach the students and elaborate the classroom activities by using technology. In addition, the teachers should master the teaching materials, find an easy concept to solve some problems faced by the students and develop a new epistemology or strengthen the old one (Kocoglu, 2009). Consequently, the teachers must be able to integrate the technology into the teaching and learning process. It needs an appropriate approach to integrate what teachers know and how they implement the materials in the classroom. Based on the research finding, it reveals that there are plenty of techniques that can be applied in the teaching and learning process. Also, the efforts to integrate the technology should be designed with creativity and be more structured for certain subjects (Koehler et al., 2006; Lestari, 2015).

Therefore, this research is aimed to identify the TPACK competencies and the self-efficacy of the pre-service chemical teachers. The writers used a questionnaire to assess the TPACK competencies by adapting the questionnaire from Chai et al. (2013). On the other hand, a questionnaire of self-efficacy has been taken from Suprapto et al. (2017).

Based on the result, the average percentage of the TPACK score for the pre-service chemical teachers showed 76.1%, which meant it was in the good position (Arikunto, 2006). To be more specific, the lowest score of the TPACK competencies was about 68.3, which categorized it in the good position, while the highest score was about 92.5, which identified it in a very good position.

These results had been proved by the average percentage of each competence of TPACK. For instance, Technological Knowledge aspect (72.4), Pedagogical Knowledge aspect (75.8), Content Knowledge aspect (77.8), Technological Pedagogical Knowledge aspect (76.5), Technological Content Knowledge aspect (77.2), Pedagogical Content Knowledge aspect (80), Technological Pedagogical Content Knowledge aspect (76).

In addition, the lowest percentage of the average percentage was stated in the aspect of Technological Knowledge that acquired 72.4 (good). The important thing to be assessed on aspects of Technological Knowledge is the ability of teachers on technological knowledge particularly in operating computers and relevant software Chai et al., 2013. This is because teachers are not familiar and have less available media use of ICT in the learning process, as well as assessment. As a consequent, the teachers feel not quite ready for the use of ICT in learning (Brush & Saye, 2009; Kramarski & Michalski, 2010; Chai et al., 2013).

The level of TPCK competencies can be determined from the self-efficacy of the pre-service chemical teachers. A self-efficacy can be defined as their confidence in the ability of themselves (Bandura, 1997) Based on the results, a self-efficacy score of the pre-service chemical teachers obtained amounted to 74.1 (good) with the lowest average value of 61.67 (good) and the highest of 87.5 (excellent). This is because the self-efficacy of each individual varies. According to Bandura (2011), the increased knowledge of the pre-service chemical teachers will upgrade their beliefs of self-efficacy.

Moreover, the aspect of self-efficacy examined in this study consists of six indicators. For instance, science content, high-order thinking skills, the laboratory usage, applications in the daily life, communications and Science literacy (Suprapto et al., 2017). Based on the results of a self-efficacy questionnaire, it the average percentage obtained for the Content of Science was 71.8 (good), high-order thinking skills (HOT) amounted to 71.7 (good), aspects of the use of the laboratory amounted to 77.7 (good), the aspects of applications in daily life amounted to 73 (good), the aspect of communications amounted to 76.2 (good) and the aspect of literacy and Science amounted to76.1 (good).

The lowest average score was found in the aspects of high-order thinking skills (HOTS), and the highest average score was obtained on aspects of the laboratory usage. Furthermore, the high-order thinking aspect still became the crucial problem because the teachers were not accustomed to implement this aspect in the teaching and learning process. Therefore, the students faced some difficulties in solving the problems and also answering the questions in national examination, particularly in 2018. The main point to be assessed in the high order thinking aspect is about the teachers' belief in their abilities to explore the cognitive skill, problem solving, critical thinking and science investigation in the chemistry domain (Suprapto et al., 2017).

The relationship between TPACK competencies of the pre-service chemical teachers toward the self-efficacy has been analyzed using a statistic correlation called product moment Pearson. Based on the result, the significance value 0.000 is higher than 0.05, which means that a significant relationship is shown between 30 of pre-service chemical teachers and the self-efficacy. Furthermore, this result is calculated by Person correlation, which points out to 0.885. Therefore, it can be concluded that the correlation between TPACK and self-efficacy of pre-service chemical teachers is included in the category. This is in line with Guzey & Roehrig (2009) who stated that there is a positive relationship between technology, pedagogy and content knowledge in science learning (Ariani, 2015; Aminah, 2013; Tuqba, 2015).

4 CONCLUSION

This research has proved that the average percentage score of Technological Pedagogical Content Knowledge (TPACK) is 76.1, which classified as a good position, and the self-efficacy raises to 74.1, which is also categorized as a good position. Therefore, it can be concluded that the ability of Technological Pedagogical Content Knowledge (TPACK) is proportional to self-efficacy.

The contributions of this study are: (1) For the pre-service teachers; it can be used as a benchmark for improving self-quality by attending training, workshop, and others. (2) For authorized institutions; it can be used as recommendations to prepare professional and competent educators and education staff. (3) For the researchers; to get information about the relationship between Technological Pedagogical Content Knowledge (TPCK) and self-efficacy of pre-service chemical teachers.

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The effect of mobile learning and motivation for students' High Order Thinking Skills (HOTS) in electrolyte and nonelectrolyte solutions learning

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ABSTRACT: This study aimed to determine the effects of mobile learning on Higher Order Thinking Skills (HOTS) of students associated with students' learning motivation. The research was conducted on students in the 10th grade at a public high school in Bogor, West Java in the 2017/2018 academic year. The research method used was quasi-experimental with a two-way ANOVA design (treatment by level 2×2). The samples included 36 students who were selected using the simple random sampling technique. In the experimental group, the learning process was conducted using mobile learning, which was validated by experts and tested by teachers and students, while in the control group the learning process was conducted using PowerPoint media. This research concluded that mobile learning had positive effects on the higher order thinking skills of students when it was applied to students with high learning motivation; for students with low learning motivation, mobile learning did not have any effects of higher order thinking skills; there was an interaction between mobile learning and motivation on higher order thinking skills of students.

1 INTRODUCTION

Nowadays, students require 21st century skills in order to have higher order thinking skills so that they can be competitive in facing global problems. Indonesia was ranked 69 out of 76 countries in PISA 2015 (OECD 2015). The results of TIMMS IPA for the 8th grade in 2011 showed that more than 95% of Indonesian students were only able to think at a middle level or master science at the level of application thinking (TIMSS 2011). These results showed that Indonesian students could not do critical thinking in the problem-solving of high levels of thinking. The low level of students' thinking skills can be seen from the level of problems in exam questions that were still limited to lower order thinking skills (LOTS). The government made an effort to introduce 21st-century skills by developing the new curricula of 2013. This curriculum incorporated 21st century learning skills that were integrated with the content and learning process so that students had the competitive ability of higher-order thinking in resolving any problems that were complex. However, in the context of the study, it was found that teaching methods were mostly conducted by a teacher-centered method, which lead to students' passive learning. The school teachers become the main source for students to acquire knowledge.

HOTS will be achieved if students are given the stimulus in the learning process that can improve their thinking processes. According to Bloom's taxonomy, high order thinking skills (HOTS) is called critical thinking, creative thinking, problem-solving, making decisions and metacognitive in nature (Yen & Halili, 2015). Heong et al., (2011) explained that the ability of high order thinking is the widespread usage of the mind to find new challenges. This high-level thinking capability requires a person to apply new information or prior knowledge and manipulate information to reach possible answers in new situations. Bookhart (2010) states that providing a stimulus can make students able to think in the form of introductory texts, visuals, scenarios, or various kinds of problems so that proactive learning occurs. Ealy (2015) concluded that HOTS could be stimulated by using visual media. Simon (2015) developed and fostered students' thinking skills and HOTS of students by using simulation software and virtual experiments in a laboratory environment. According to Li et al., (2016), teaching with e-schoolbags applications such as virtual simulation, cognitive tools, instant feedback, and portfolio learning, can foster HOTS of students, especially analytical and evaluation skills.

Learning media will provide a stimulus to improve students' thinking skills. The learning motivation possessed by students can influence students' thinking processes in learning towards a more complex direction. Torkoguz (2012), explained that the process of learning chemistry would be better if using media or technology that could visualize the chemicals used. Furthermore, based on previous research learning, using mobile learning has a positive effect on chemistry learning outcomes (Cahyana et al., 2017). The main purpose of science education is to help students improve HOTS, thus helping them to face challenges in everyday life by enhancing cognitive skills such as critical thinking, reflective thinking, and individual process skills (Zachariades et al., 2013). Mobile learning media will provide a stimulus in the form of audio and visuals, games, and quizzes that can be used by students to learn anywhere and anytime (Traxler, 2009). Then Miller's research (2017), concluded that students were more confident in learning when they use mobile devices, showing a greater change in interest and learning motivation than learning through textbooks. According to McQuiggan et al., (2015), mobile learning has many advantages: (1) it enables students to learn anywhere without being limited by place and time; (2) it is more economical, so it can reach students and schools that lack facilities; (3) the features of mobile learning media are able to increase HOTS of students; (4) provides alternative learning environments for students; (5) cultivates students' knowledge and makes it easier to track the difficulties that each student faced; and (6) fosters students' learning motivation. According to Ciampa (2013), motivation can be enhanced through the challenge, curiosity, control, recognition, competition, and cooperation. This study aimed to determine the effect of mobile learning on higher order thinking skills (HOTS) of students associated with students' learning motivation.

2 METHODOLOGY

This research was conducted at a state high school in Bogor, West Java in the even semester of the 2017/2018 academic year. The method used in this research was a quasi-experimental method with a two-way ANOVA research design (treatment by level 2×2). The experimental research design by factorial level can be seen in Table 1.

Samples in this research consisted of 36 students in 10th grade selected by the simple random sampling technique. Mobile learning with the topic of electrolyte and nonelectrolyte solutions used in the experimental group has been validated by experts and tested by teachers and students. Students in the control group used PowerPoint media. Data was collected using validated tests and questionnaires. Tests for measuring students' HOTS consisted of 16 questions, and a questionnaire to measure learning motivation that consisted of 38 questions. The calculation of an instrument's validity used the Karl Pearson's product moment correlation and the calculation of reliability used the Cronbach's alpha formula.

Table 1. Research design two-way ANOVA (treatment by level 2×2).

	Learning media (A)	
Motivation (B)	Mobile learning (A_1)	PowerPoint media (A_2)
High Learning Motivation (B_1)	A_1B_1	A_2B_1
Low Learning Motivation (B_2)	A_1B_2	A_2B_2

Before analyzing the data, the students' score was tested for normality using the Liliefors test and homogeneity using the Fisher and Bartlett test. There were four hypotheses in this research. The first (main effect) and second hypotheses (interaction effect) were tested by two-way analysis of variance technique (ANOVA), then the third and fourth hypotheses (simple effects) were tested using the Tukey test.

3 RESULTS AND DISCUSSION

This research determined the effect of mobile learning on HOTS of students associated with learning motivation.

3.1 *The effect of mobile learning on HOTS of students*

Based on the results of hypotheses testing (Table 2), the Fcount was 8,78, while the Ftable value at the significance level (α) = 0.05 is 4,15. Because the value of Fcount > Ftable, then H0 is rejected, so it can be concluded that HOTS of students who are using mobile learning is higher than students who use PowerPoint media. It is because mobile learning has more advantages, such as the ability to access information and subject materials anywhere and anytime from a device that students carried everywhere (Traxler, 2009). Mobile devices are considered as a leading factor in the learning process (Huang et al., 2010; Gedik et al., 2012; Navaridas et al., 2013). Mobile learning can combine learning with lots of time and diverse learning, it can also foster students' learning motivation (McQuiggan et al., 2015). Furthermore, Miller (2017) explains that students are more confident when learning to use mobile devices; their interest and motivation to learn is greater than learning through textbooks. Cavusa & Uzunboylub (2009), explained that learning with mobiles has a positive impact on students' attitudes and creativity, and increases their critical thinking skills, unlike the students who are taught using PowerPoint media. Generally, PowerPoint media is in the form of impressions combined with the lecture method. PowerPoint media is more teacher-centered; it makes students less active in the classroom, learning becomes monotonous because students only receive the information from teachers theoretically, so their thinking is only memorizing, which is a low level of thinking. This condition can decrease students' learning motivation.

So the use of mobile learning has a positive influence in improving students' high-level thinking skills (HOTS). Students can access material or information wherever and whenever, and are not bound by space and time. Learning material contained in mobile learning is equipped with games, animations, quiz questions and learning videos so that it can increase learning motivation and provide stimulus in learning, so students can be trained to think at a higher level.

3.2 *Interaction between Mobile Learning (A) and Motivation (B) toward HOTS of students*

Based on the hypothesis testing results (Table 2), the obtained value of Fcount is equal to 62,15. Whereas, the Ftable value at the significance level (α) = 0.05 is 4,15. As the Fcount >

Table 2. Hypothesis testing results using two-way ANOVA.

Variance	Db	JK	RJK	F count	F table	Conclusion
Between A_1 & A_2	1	289,00	289,00	8,78	4,15	Ho Rejected
Interaction A X B	1	2045,05	2045,049	62,15	4,15	Ho Rejected
In group	32	1052,94	32,90	–	–	
Total (T)	36	222608,44	–	–	–	

Ftable, then H0 is rejected, so it can be concluded that there is an interaction between learning media and learning motivation toward the HOTS of students. The interaction shows that each learning media has a different influence on HOTS of students when used by groups of students who have different learning motivation. The results showed that mobile learning is more effective when it is used by students who have high learning motivation. The interaction between learning media and learning motivation can be seen in Figure 1.

Based on Ealy's research (2015), high order thinking skills can be stimulated by using visual media. Furthermore, Simon's research (2015) explained it could develop and foster students' critical thinking skills by using simulation software and virtual experiments in a laboratory environment. This is in line with the study of Li et al. (2016), which explained that teaching with e-schoolbags applications such as virtual simulation, feedback, and portfolio learning can foster high order thinking skills, especially analytical and evaluation skills.

So the use of learning media will provide a stimulus to improve students' thinking skills. The learning motivation possessed by students influences students' thinking processes in learning, so that with learning media and higher learning motivation, students will influence thinking skills toward more complex ones. Based on the description above, it can be concluded that there is an interaction between learning media and learning motivation toward HOTS of students.

3.3 *The HOTS of students' differences between A_1B_1 and A_2B_1*

Based on the results of hypothesis testing (Table 3), the Qcount was 10,85. The value of Qtable at the level of significance (α) = 0,05 is 4,41. Therefore, the value of Qcount > Qtable, then H0 is rejected, so it can be concluded that HOTS of students who were taught by using mobile learning is higher than students taught by using PowerPoint media with students who have high learning motivation. The results also show that mobile learning is more effective than PowerPoint media if used with students who have high learning motivation.

The principles of Keller's motivation (2008) consists of 4 (four) categories, namely attention, relevance, confidence, and satisfaction. Students who have a higher motivation to learn

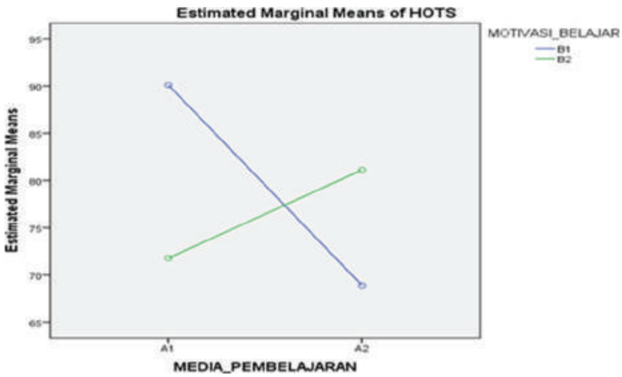

Figure 1. Graph of the interaction between learning media and learning motivation toward HOTS of students.

Table 3. Hypothesis testing results using Tukey test.

Group	N	Q count	Q table	Conclusion
A_1B_1	9	10,85	4,41	Ho Rejected
A_2B_1	9			
A_1B_2	9	4,92	4,41	Ho Rejected
A_2B_2	9			

have a higher interest or curiosity when studying a thing or material, and assume that the subject material will benefit their lives.

3.4 *The HOTS of students differences between A_1B_2 and A_2B_2*

Based on the results of hypothesis testing (Table 3), the Qcount was 4,92. The value of Qtable at the level of significance (α) = 0.05 is 4,41. For the value of Qcount > Qtable, H0 is rejected, so it can be concluded that HOTS of students who were taught by using mobile learning is lower than students taught by using PowerPoint media with students who have low learning motivation.

Students who have low learning motivation tend to follow the learning process as it is and accept the structure of the material that has been determined by the teacher so that learning planning is systematically arranged. The learning process with PowerPoint media is more beneficial for students who have low learning motivation, in other words mobile learning is not suitable for students who have low learning motivation because it requires students to have high learning independence so students will be motivated in learning. This is consistent with the research of Cahyana et al., (2017) in that mobile learning has a positive effect on the learning outcomes of chemistry in groups of students who have high independence.

3.5 *The HOTS of students differences between A_1B_2 and A_2B_2*

Based on the results of hypothesis testing (Table 3), the Qcount was 4,92. The value of Qtable at the level of significance (α) = 0.05 is 4,41. For the value of Qcount > Qtable, H0 is rejected, so it can be concluded that HOTS of students who were taught by using mobile learning is lower than students taught by using PowerPoint media with students who have low learning motivation.

Students who have low learning motivation tend to follow the learning process as it is and accept the structure of the material that has been determined by the teacher so that learning planning is systematically arranged. The learning process with PowerPoint media is more beneficial for students who have low learning motivation, in other words mobile learning is not suitable for students who have low learning motivation because it requires students to have high learning independence so students will be motivated in learning. This is consistent with the research of Cahyana et al., (2017) in that mobile learning has a positive effect on the learning outcomes of chemistry in groups of students who have high independence.

Based on the analysis, instructional media has helped to convey information or lessons with the aim of stimulating students to learn. Learning media can overcome the limitations of space and time in learning, they can also motivate students to learn. In addition, mobile learning as a visual media has encouraged students' high-level thinking skills, and, as stated by Ealy (2015), that higher-order thinking skills can be stimulated by using visual media. So, the use of learning media will provide stimulus to improve students' thinking skills. In addition, student learning motivation influences students' thinking processes in learning, so that with learning media and learning motivation students will influence their thinking skills towards more complex ones (HOTS). The results also shows that higher order thinking skills of students who use mobile learning are higher than students who use PowerPoint media. This is relevant to Miller (2017) in that students are more confident in their learning because the use of mobile devices has increased their interest and motivation compared to learning from textbooks. PowerPoint media used in classrooms is more teacher-centered, which causes students to be passive in learning. Students only receive sources of information from teachers, which causes students to lack motivation and excitement. Therefore, in this study, students feel more excited and motivated to learn when using mobile devices. The study also found that mobile learning is suitable for students who have high learning motivation. This is because mobile learning provides an advantage to be used anytime and anywhere so that students can gain knowledge in a more in-depth and comprehensive manner, and it can also improve student learning motivation. Learning motivation has the potential to influence what, when and how to learn, and increase the likelihood of being involved in activities that will help students to learn and achieve better performance, and consequently will result in higher level thinking skills. This is relevant to the study by Ciampa (2013), which shows that motivation can be improved through challenges, curiosity, control, recognition, competition and co-operation. Therefore, mobile learning can greatly help to increase student motivation. Students with low learning motivation tend to be passive learners and follow the learning process as the teacher says, so students who have this attitude may find it easier to master the lesson. The learning material delivered by the teacher must be structured and systematic. So the learning process with PowerPoint media seems more profitable for students who have low learning motivation. This study has limitations that only use learning media and the study of learning motivation for students' high-level thinking skills. This can be further developed based on the focus of various levels of motivation.

4 CONCLUSION

The use of mobile learning has a positive effect on improving students' higher order thinking skills (HOTS). Students can access material or information wherever and whenever as they are not bound by space and time. Learning materials contained in mobile learning is interesting because it is equipped with games, animations, quiz questions, and learning videos, so that it can increase learning motivation and provide a stimulus to students in learning so that students could be trained to think at higher levels.

Based on the results obtained, the use of mobile learning has a positive effect when applied to a group of students who have high learning motivation. For example, in groups of students who have low learning motivation, when using mobile learning, there is no effect on their HOTS. Thus the use of mobile learning in chemistry learning will provide positive results when applied to groups of students who have high learning motivation. The condition is also supported by research findings, that there is an interaction between mobile learning and learning motivation toward HOTS of students.

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Analyze students' scientific literacy based on environmental cognitive using nature of science learning method

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ABSTRACT: This research aimed to analyze students' scientific literacy based on environmental cognitive using Nature of Science learning method. This research involved 33 students at the 2nd grade in high school. The research methodology was qualitative, which using several instruments such as questionnaire, observation and scientific literacy test. Nature of science learning method used to develop science knowledges and science skills especially to solve problems that relevant in daily life. The research show that 21% students had higher scientific literacy, 57% students with medium scientific literacy skill and 21% students had lower scientific literacy skill. Based on the result, that students' in the classroom had medium scientific literacy skill. The Nature of Science learning method show the positive result to help students' understanding about science knowledge based on environmental cognitive.

1 INTRODUCTION

The education process is expected to be able to form students who are literate in science (scientific literacy) and technology. According to Shwartz (2006) at the present time, the achievement of students scientific literacy is one of the main goals in science education. One character that needs to be developed in students is the caring attitude towards the environment. Environmental-based science literacy is the ability of students to apply scientific concepts, especially the chemical concepts they learn, to solve problems that occur in the environment. Nowadays, environment problems seems to be more difficult and complex, but human ability to overcome environmental problems does not increase and develop significantly with increasing and complex environmental problem themselves (Purwanto, 2012). In order to achieve this expectation, it is necessary for students who have high scientific literacy and creativity. Science literacy is increasingly needed to live in the midst of modern society (New Zealand Curriculum Guides, 2013). In connection with the ability of students to solve environmental problems in the learning process, it is necessary to create a learning atmosphere that is able to encourage students to think creatively and are rooted in factual problems in daily life (Purwanto, 2012).

Gilbert and Treagust (2009), claim that many aspects of scientific literacy have direct applications in daily life, enabling one to understand chemistry and chemical products, and to overcome various environmental issues in daily life. Based on the objectives of science education above, it appears that the nature of science (NOS) is an epistemological part of scientific literacy and important component of scientific literacy. NOS is an epistemology of science, means science as a way to find out or refer to the values and beliefs inherent in science (scientific knowledge) and its development (Abd-El-Khalick, Bell & Lederman, 2000). According to Lederman and Schwart (2008), there are seven elements of NOS (1) tentative (2) the role of creativity (3) Science subjectivity (4) based on experience (empirical) (5) social culture (6) differences between theory and law (7) the nature of observations and conclusions. Lederman (2007) states that NOS typically refers to epistemology and sociology from science, science as a way to know, or values and beliefs that are the nature of scientific knowledge and its development. NOS-oriented learning results in students understanding the process of inquiry and knowing that science is a blend of logic and imagination, explaining and predicting facts, but not authoritarian. They will understand that science is a complex social activity (Wenning, 2006).

2 METHOD

The research methodology used is a qualitative method. The data were collected based on the results of students' environmental-based scientific literacy tests, observation results, student worksheets, and students' reflective notes. The study begins with analyzing the basic competencies of acid base material and achievement indicators that are in accordance with this study. As well as determining the appropriate learning model to measure students environmental-based scientific literacy skills.

The learning process is carried out using the Nature of Science learning model, which is complemented by practical activities in the laboratory. This research was carried out with qualitative methods with interpretative paradigms that were carried out to examine the meaning of a behavior, symbol and phenomena that occurred. The interpretive paradigm in this study can be used to understand and analyze students' environmental-based scientific literacy skills observed during learning process in classroom and student activities in the laboratory.

Students' scientific literacy skills can be observed through student science literacy tests and student worksheets that are carried out individually or in groups. In addition, student environment-based scientific literacy can also be observed when students conduct experiments, such as experiments using natural indicators, determining the pH of waste and the impact of acid base on the environment.

3 RESULT AND DISCUSSION

Based on the results of the environmental-based scientific literacy tests obtained, it can be concluded that the application of the Nature of Science learning model on acid and base material, can generate students' environmental-based scientific literacy abilities. As many as 21% or 7 students have high sciencetic literacy based on student's environmental cognitive, as many as 61% or 20 students have moderate scientific literacy skills, and as many as 18% or 6 students have low student literacy skills, as shown in Table 1 below:

In addition, the researchers also grouped students' scientific literacy categories based on the scores of their answers on the students' worksheet given by the teacher. Domains measured from scientific literacy are the processes of science, content of science and the context of science.

3.1 *Results of student science process domains*

This science process domain is measured based on the results of student experiment worksheets, "natural indicators of acids and bases" subject matter, determining the strength of acid base and application of acid base in the environment. The following is the result of each aspect of the students' science process for each group as shown in Table 2 below:

Table 1. Category of scientific literacy based on environmental cognitive.

Terms	Amount	Result (%)	Category
Students' grade > 91,23	7 persons	21	High
7369 ≤ students' grade ≤ 91,23	20 persons	61	Medium
Students' grade ≤ 73,69	6 persons	18	Low

Table 2. Percentage of students` science process aspect.

		Score of science process aspect		
No	Group	I	II	III
1	1	91	89	87
2	2	90	90	91
3	3	92	89	88
4	4	94	86	82
5	5	93	92	83
6	6	90	90	90
Amount		550	536	521
% per aspect		92	89	87

Based on the domain of scientific literacy, the aspects of the scientific process that will be measured include:

3.2 *Aspects of identifying scientific questions (I)*

In this aspect, the percentage obtained is equal to 92%. The measured criteria include the accuracy of students in writing observations and experiments, which in this aspect train students' ability to identify facts based on the findings of the experiment. Based on Table 2, most students have been able to identify and write down the results of the observed experiments.

3.3 *Aspects of explaining scientific phenomena (II)*

In this aspect, the percentage obtained is 89%. The criteria measured in this aspect include accuracy in interpreting answers based on questions in the worksheet. This aspect measures the extent to which students understand the concept of a material, able to apply it in daily life and make it a meaningful learning. In accordance with Ausubels' opinion (Grove & Bretz, 2012), state that meaningful learning is a process of developing new information on concepts contained in cognitive structures, so that students will understand that science are in their lives. Based on Table 2, there are 3 groups that are not appropriate in describing the answers to each question contained in the students' worksheet, while the other three groups have given the right answers.

3.4 *Aspects using scientific evidence (III)*

In this aspect, the percentage obtained is equal to 87%, where the criteria measured in this aspect include in the accuracy of students in analyzing the results and writing conclusions. Based on Table 2, there are 2 groups that are still not right to analyze the results of the experiment and write down the conclusions of each experiment. For an example, in the experiment of natural indicators of acids and bases using a turmeric indicator, students concluded that an acidic solution would turn yellow to brown when pressed with turmeric extract. This is in accordance with the results of the trial that has been done by the teacher, the acidic solution should change color to yellow to pale yellow, as shown in Figures 1 and 2 the changes of color in base using turmeric indicator below.

3.5 *Results of content domains and students' scientific context*

In the final stage of the learning process, students are given a tests. From the results of this test, the highest score obtained by students is 97 and the lowest score obtained by students is 71 of the maximum score of 100. The following is a percentage of the results of the answers of 33 students for each item shown in the following Table 3.

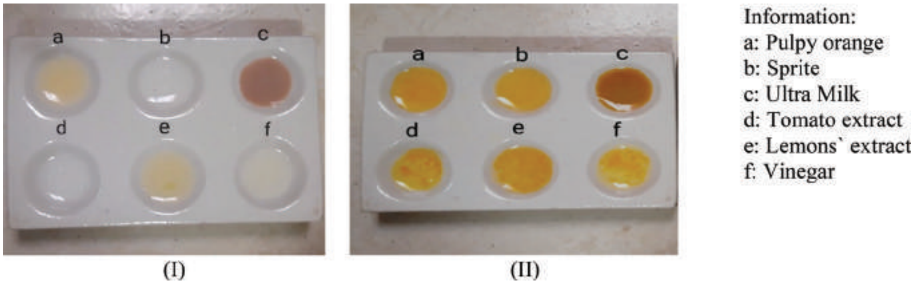

Figure 1. Color change of acid solution using turmeric indicator, I (before adding turmeric indicator) & II (after adding the turmeric indicator).

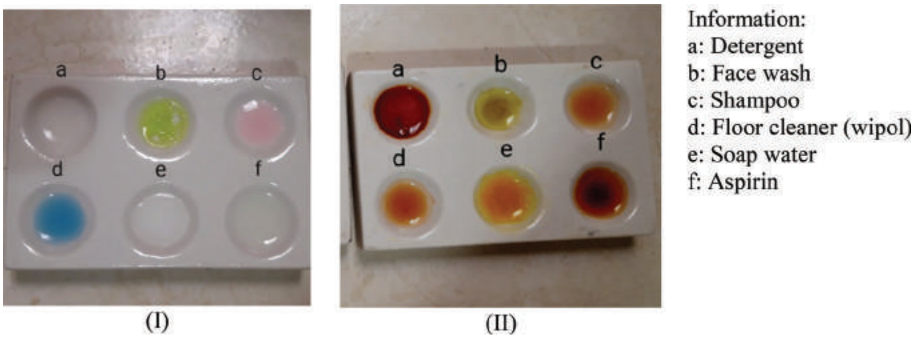

Figure 2. Color change of base solution using turmeric indicator, I (before adding turmeric indicator) & II (after adding the turmeric indicator).

Table 3. The result percentage of the 33 students answer.

No	Score	Students' maximal score	Students' score	Result (%)
1	8	264	261	99
2	6	198	138	70
3	6	198	136	69
4	8	264	216	82
5	6	198	154	78
6	6	198	129	65

Based on Table 3, show that the sub-material questions about the acid base indicator with the highest percentage of student achievement is 99%. In this problem, most students can mention what plants can be used as natural indicators to find out the nature of acids and bases, and can specify the criteria for plants that can be used as natural indicators. This illustrates that students have understood the science content of acid base indicator material. The lowest percentage of student answers is 65% in the sub-material pH of the water. This indicates that some people have not been able to connect the concept of pH and its relation to water that is suitable for consumption. In this problem students are also asked to determine the nature of the four water samples given and determine which water is suitable for consumption. All students in this question did not answer the questions correctly, the answers given by students only stated that the pH of the water must be different without mentioning the pH criteria for water that is suitable for consumption. This happened because some students gift the reason that they had never conducted an experiment using universal indicators, so they could not estimate the pH of some of the water. Based on the explanation above, it can be seen that the student science context domain is still low.

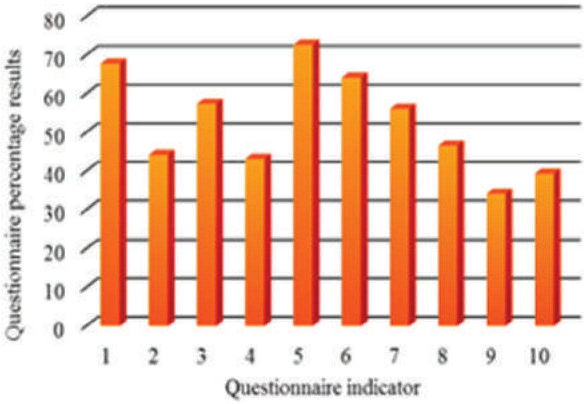

Figure 3. Results questionnaire diagram of responses to learning models.

After carrying out the learning process using the NOS model, students were asked to fill out a questionnaire regarding students' responses to the NOS learning model. Based on the calculation using a Likert scale, the calculation results are shown in the Figure 3.

In Figure 3 above the diagram shows that the NOS learning model gets a very positive response, because it has a very high and high interpretation which shows that students like the NOS learning model. The statement "I understand the application of the concept of acid base solutions in everyday environments after studying chemistry through the Nature of Science learning model" has the highest percentage of 85% with the category of very high student interest.

4 CONCLUSION

Based on the results of qualitative research, it can be concluded that the application of the Nature of Science learning model to acidic and alkaline material can generate students' environmental-based scientific literacy abilities. As many as 21% or 7 students have high environmental science-based literacy skills, as many as 61% or 20 students have moderate scientific literacy skills, and as many as 18% or 6 students have low student literacy skills. In addition, the researchers also categorized students' scientific literacy categories based on the domain of scientific literacy, namely the science process that has a high percentage in each aspect, namely 92% identifying aspects of scientific questions, 89% explaining aspects of the phenomenon and 87% using scientific evidence. Whereas in the domain of science content and science context which is calculated based on sub-material in scientific literacy test questions, it shows that the highest percentage is in the sub-material acid base indicator and the lowest percentage is in the sub-material pH of water.

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Development and evaluation of a project-based STEM learning module on the scientific creativity of gred five Students in Malaysia

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ABSTRACT: Transformation in education warrants the integration of STEM into project-based learning for promoting creativity among students. This study aimed to determine the validity and reliability of an integrated project-based STEM teaching and learning module (Pro-STEM) and evalute idts effects on the scientific creativity of grade five students. The modul was developed using the ADDIE instructional design model which consisted of six lessons and six project activities regarding life science, physical science and material science. Evaluation was conducted to determine the realibility, content validity and students perception of the learning module, which involved seven subject matter experts and 30 gred five students. Data were captured through students responces to two five-point Likert scale questionnaires, open-ended questios and a self-developed scientific creativity test. Finally, a pre-test and post-test non-equivalent control group quasi experiment design was employed to determine the effects of the Pro-STEM module. A total of 60 fifth graders from two primary schools were randomly assigned to the Pro-STEM group (n = 30) and control group (n = 30). The results of the module evaluation indicated good content validity and an acceptable realibility with a Cronbach's alpha value of 0.65 to 0.87. The majority of students had moderately high positive perception (m = 4.37) that the activities in the Pro-STEM module enabeled them to: a) generate many ideas, b) generate unique ideas, c) expand ideas, d) think of a special topic and e) use information from multiple sources to complement sketches. The results of the paired sample t-test and indipendent t-test established the effects of the Pro-STEM module in all trait dimensions of scientific creativity. These findings show that the Pro-STEM module would represent a reliable, valid and effective learning module for fostering scientific creativity of fith graders.

1 INTRODUCTION

The implementation of the twenty-first century learning that has become popular in the decades of the world education system is also demanding a transformation in Teaching and Learning (TaL) methods. In order to create creative and innovative generations, the integrated of Project-Based Learning (PBL) and STEM in science subjects is a strategy to unleash scientific creativity among students. Creativity is one of the key skills needed in order to drive the development of a nation, especially in an increasingly complex social environment (Hennessey and Amabile 2010; Molly, 2015). Creativity is also one of the key components for the development of science and technology (Robinson, 2006). In this regard, the role of teachers as the agents of knowledge should be wise in implementing TaL strategies to ensure the disseminated knowledge reaches its goal. However, the lack of reference materials and teacher guides to implement the PBL and STEM approach is often an issue. Recognizing these difficulties, the researchers have developed a Pro-STEM learning module to assist teachers in preparing TaL plans aimed at enhancing scientific creativity through the design and making of science toys among year five students. Therefore, this paper will examine the integration of PBL and STEM (Pro-STEM) in science subjects to enhance students scientific creativity. The effects of using the Pro-STEM TaL module developed by the researcher will be evaluated through the achievement of the year five students at the pre-test and post-test scientific creativity test. Students' views on Pro-STEM activities a also analyzed to evaluate the validity and usability of the Pro-STEM learning module before its application in the actual study.

2 METHOD

2.1 *Respondents*

This study involved 30 grade five students at one of the primary schools in the Tawau district. Chua (2011) states that a number of 30 respondents is sufficient to determine the aspect of consistency in a measuring instrument. The study was conducted for 15 weeks at the beginning of the first semester of 2017. Table 1 shows the study procedures conducted for 15 weeks to determine the face validity of the Pro-STEM module.

2.2 *Instruments*

The instruments used in this study are an open-ended questionnaire, two five-point Likert scale questionnaires and a self-developed scientific creativity test (Norjanah & Siew, 2017). Open-ended questions gave respondents the freedom to point out their views on the activities undertaken while learning using the Pro-STEM module. Each activity in the Pro-STEM module covered five dimensions of scientific creativity trait among pupils namely fluency, originality, elaboration, title abstraction and resistance to premature closure.

2.3 *Procedures*

The content validity of the Pro-STEM module was assessed by a team of seven experts from different fields. Experts were required to make a remark on the module evaluation form whether they agreed on the proposed assessment criteria and to make comments. Experts were also required to evaluate items in the open questionnaire adapted from Ozia Othman (2015) regarding the activities in the developed Pro-STEM learning modules. The validity of the lan-

Table 1. Study procedures.

Day/Week	Activity
Week 1	– Administering scientific creativity pre-test to 30 grade five students at a city-level primary school. – Students are divided into six small groups – Briefing to the students
Week 2–3	First intervention – Project 1: Animal of my imagination
Week 4–5	Second intervention – Project 2: Bird cage
Week 6–7	Third intervention – Project 3: Floating seeds
Week 8–9	The fourth intervention – Project 4: Balloon-powered cars
Week 10–11	The fifth intervention – Project 5: Friendly light home
Week 12–13	The sixth intervention – Project 6: Mini ice box
Week 14–15	– Administering scientific creativity post-test – Administering questionnaires.

Table 2. Pro-STEM module content legislation panel.

No.	Name	Representatives	Position	Expertise
1	Expert A	IPTA	Professor	Scientific creativity
2	Expert B	IPTA	Senior lecturer (Dr)	Creativity/STEM
3	Expert C	Education Institute	Lecturer (Dr)	Project-based learning/ science pedagogy
4	Expert D	Secondary school teacher	Hall lecturer	Malay language
5	Expert E	Primary Science teacher	Excellent teacher	Science pedagogy
6	Expert F	Primary school teacher	Science head panel	Science pedagogy
7	Expert G	Primary school teacher	Year 5 science teacher	Science pedagogy

guage was assessed by a teacher from the Language and Literature Board. Table 2 shows a list of experts involved in determining the content validity of the Pro-STEM module.

3 RESULTS AND DISCUSSION

3.1 *Content validity*

Table 3 shows the content validity fimdings based on the Pro-STEM module evaluation criteria. The validity of the language content indicates that the language used is appropriate with only a few improvements. Among the improved criteria are spelling and writing style.

Comments and feedback for improvements are listed in Table 4.

The reliability of the Pro-STEM module was assessed to determine if the students can successfully master the objectives and follow the steps of each activity in the module. Table 5 shows that the Cronbach's alpha value for all project activities in the module ranged from 0.65 to 0.87 with the an overall Cronbach's alpha value of 0.90. Most researchers suggest that an alpha value of 0.8 and greater is typical of a high level of reliability (Cohen et al. 2000; Bogden & Milken 2003; Sekaran & Bougie 2010). However, according to Mohd Najib (1999) and Mohd Majid (2000), a Cronbach's alpha-value of 0.6 is also sufficient for instruments developed in the social science field of education. This shows that the developed Pro-STEM module has a good degree of consistency (Babbie, 2001).

A questionnaire was administered to ditermine students' perception of the Pro-STEM activities. The results in Table 6 show the students had an overall mean of 4.37 regarding Pro-STEM activities. From the results, the mean scores ranged from 4.03 to 4.60 indicating that the grade five students agreed that the module was acceptable to be used to foster scientific creativity in primary school. According to Inas, Harry, Yugo, and Andika (2015), criteria with a mean level equal to or greater than 3.50 are acceptable, while below 3.50 are considered as unsatisfactory, indicating that changes should be made in the module.

3.2 *Effects of the Pro-STEM module*

The purpose of the developed Pro-STEM learning module was to foster the scientific creativity of grade five students by integrating PBL with the elements of STEM. The scientific creativity test was used to measure the five trait dimensions of scientific creativity: fluency, originality, elaboration, title abstractness and resistance to premature closure scores.

Table 7 shows the paired sample correlations between pre-test and post-test for each trait dimension. The findings show that there is a strong significant correlation for fluency ($r = 0.603$), originality ($r = 0.815$), elaboration ($r = 0.980$), title abstraction ($r = 0.901$) and resistance to premature closure ($r = 0.967$).

A paired sample t-test was performed to determine if there was a significant difference between the pre-test and post-test mean scores in the Pro-STEM group in the five trait dimensions of scientific creativity. The result of this analysis (Table 8) indicates that the post-test mean score of fluency ($M = 12.03$, $SD = 2.141$), originality ($M = 11.87$, $SD = 2.515$),

Table 3. Content validity of the Pro-STEM module.

	Criteria	Percent (%) agreement							
		Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Summary
1	Daily lesson plan	100	100	100	100	100	100	100	Overall are good and satisfactory with few improvements
2	Learning standard	100	100	100	100	100	100	100	
3	Project activities	100	100	100	100	100	100	100	
4	TaL activities	100	100	100	100	100	100	100	
5	Scientific creativity skill	100	100	100	100	100	100	100	

Table 4. Module feedback from expertsand improvements made.

Aspects	Review/improvement
Daily Lesson Plan (DLP)	DLP was clearly designed and detailed (P1) The writing of the DLP followed KSSR format
Learning standard	All learning standards were in line with Year five DSKP Learning outcomes were clearly explained
Project activity	The explanation for activity 5 needs to be explained in parallel with learning standard 1.3.1 and 1.3.2 It is suggested that the project title five changed to Friendly-light house All project activities were able to stimulate pupils' minds to solve non-routine problems
Teaching and learning activity:	Able to be implemented by teachers and pupils and suitable to the level of grade five pupils TaL activity might be time-consuming. Not all groups are able to present their sketch/model
Scientific creativity:	All activities can stimulate pupils' minds to think more creatively, plan ideas/prototypes, make a project which solve problems
Cooperative learning:	Teamwork is implemented through activities. Small groups (four pupils) makea 'compulsion' for each member to do their part. So, there is no 'sleeping partner'

Table 5. Cronbach alpha value of the Pro-STEM module (N = 30).

Project	Title of activities in the module	Cronbach's alpha	Item number
1	Animal of my imagination	0.66	5
2	Bird cage	0.70	5
3	Floating seeds	0.65	5
4	Balloon-powered cars	0.79	5
5	Friendly-light home	0.85	5
6	Mini ice box	0.87	5
	Total: 0.90		**30**

elaboration (M = 24.00, SD = 4.511), title abstraction (M = 20.67, SD = 5.738), and resistance to premature closure (M = 14.00, SD = 3.184) are significantly higher (t (29) = –6.608, $p < 0.05$; t (29) = –10.433, $p < 0.05$; t (29) = –19.078, $p < 0.05$; t (29) = –7.067, $p < 0.05$; t (29) = –21.650,

Table 6. Ranked means of students' perceptions regarding the Pro-STEM activities.

Item	1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree	Mean
f (%)						
I feel good throughout the activities.	0(0)	1(3)	0(0)	5(17)	24(80)	4.73
My knowledge of STEM grows after theactivities.	0(0)	1(3)	5(17)	14(47)	10(33)	4.10
Theactivitiesare able to foster collaboration among group members	0(0)	2(7)	5(17)	16(53)	7(23)	4.53
The activities stimulate my mind to generate many ideas.	0(0)	3(10)	5(17)	2(7)	20(67)	4.23
The activities stimulate my mind to produce original and special ideas	0(0)	2(7)	1(3)	13(43)	14(47)	4.30
The activities stimulate my mind to develop diverse ideas.	0(0)	1(3)	3(10)	15(50)	11(37)	4.50
The activities stimulate my mind to provide a special title for each sketch.	0(0)	0(0)	6(20)	15(50)	9(30)	4.03
The activities stimulate my mind to use information and ideas from multiple sources to complement sketches and projects.	0(0)	0(0)	5(17)	15(50)	10(33)	4.26
The activities enhances the quality of the designs producedthrough cooperative learning.	0(0)	2(7)	5(17)	6(20)	17(57)	4.40
I am more interested in following this kind of learning activity in the future.	0(0)	1(3)	2(7)	5(17)	22(73)	4.60
Overall	0(0)	11(4.3)	35(12.5)	88(35.2)	126(48)	4.37

Table 7. Paired sample correlations **(n = 30).**

		Correlation	Sig.
Pair 1	Pre-fluency & post fluency	0.603	0.000
Pair 2	Pre-originality & post originality	0.815	0.000
Pair 3	Pre-elaboration & post elaboration	0.980	0.000
Pair 4	Pre-abstractness & post abstractness	0.901	0.000
Pair 5	Pre-resistance & post resistance	0.976	0.000

Table 8. Paired sample t-test.

Variables	Pre-test	Post-test	Difference	t	df	p
	Mean (SD)w					
Fluency	9.80 (2.007)	12.03 (2.141)	−2.233 (1.851)	−6.608	29	$P < 0.05$
Originality	9.03 (2.356)	11.87 (2.515)	−2.833 (1.487)	−10.433	29	$P < 0.05$
Elaboration	20.87 (4.337)	24.00 (4.511)	−3.133 (0.900)	−19.078	29	$P < 0.05$
Title abstraction	17.40 (4.731)	20.67 (5.738)	−3.267 (2.532)	−7.067	29	$P < 0.05$
Resistance to premature closure	11.27 (3.107)	14.00 (3.184)	−2.733 (0.691)	−21.650	29	$P < 0.05$

$p < 0.05$ respectively) than pre-test mean score of fluency (M = 9.80, SD = 2.007), originality (M = 9.03, SD = 2.356), elaboration (M = 20.87, SD = 4.337), title Abstraction (M = 17.40, SD = 4.731) and resistance to premature closure (M = 11.27, SD = 3.107). These results indicated that the Pro-STEM group performed significantly better on the post-test compared to the pre-test in all trait dimensions of scientific creativity.

3.3 *Open questions*

Open questions were given to pupils after the intervention was conducted. A total of 30 respondents were asked to express their opinions on activities that were carried out using the Pro-STEM module. Answers provided by respondents are explanatory. Therefore, the method of analysis involved was to transcribe the results of open questions first, then the findings were separated by sections and themes. Analysisof the results were shown in the form of tables, the number of frequencies and percentages. Then the table was discussed and interpreted to make a conclusion. This transcript was manually analyzed by careful repeated reading to see the broader context of the content. Through this process, the researcher was able to see every student's view of the activities carried out in the module. According to Chua (2012), through domain analysis, the theme and codes were developed from the own survey data rather than predetermined before the analysis was done and the coding process was known as inductive coding.

3.3.1 *Student assessment of the Pro-STEM learning activities*

Item 1

What are your feelings throughout the project-based STEM learning activities?

Joy and fun

For the six project activities carried out, the pupils expressed their joy and fun in performing activities involving hands-on activities.

> *"I feel joy…" (S1, S2, S5)*
> *"The activities that the teacher told us to do are the bestone" (S4)*
> *"I am happy because we make various activities" (S3)*
> *"it is fun while following through STEM activities" (S8)*

Feel excited

The students also expressed excitement and eagerness to carry out the project and test the built prototype.

> *"I like the testing of the prototype most.... amazing" (S3)*
> *"Everyone is eager to know what activities our numbers will do" (M6)*
> *"Mostmeaningful if a project is ready…let's test it" (S11)*
> *"I am looking forward to science class next week, what STEM project will the teacher tell us to do" (S8)*

Feeling bored

For students who are less creative and do not like sketching, they demonstrate boredom. Normally, they try to avoid engaging in activities while engaging in other activities. However, they are bound by the number of tasks given during cooperative learning to put their heads together. If the specific task given during the week is not their favorite, then the pupil will show a sense of boredom and less cheerful. Apparently, most pupils prefer "hands on" activities rather than sketching activities. Only a few people dare to present themselves confidently and smoothly. Most students are passive, shy and stiff during the group's presentation session. This can lead to a boredom. Similarly, if the material to make the project is in adequate, boredom will arise because good ideas and sketches cannot be completed due to lack of material. Although basically, the teacher provides certain equipment, in order to find a difference, students need to prepare their own materials so that their prototype produced is more unique and creative.

> *"I'm tired of being told that my paintings are bad" (S5)*
> *"Boring if asked to be involved in the stretching activity" (S7)*
> *"Bored if there is no more material to do the project" (S9)*

Experience positive competition

Although the Pro-STEM learning objectives were not for competition, each group strove to produce the best design and creation. Additionally, teachers would reward the group that produced unique, fast and completed designs. This also enhanced motivation and healthy competition in discovering the student's scientific creativity.

"Often we are the most awesome group" (S1, S16)
"Our project's is the best among all, we are not going to lose" (S25)
"We are targeting to beat other groups in their creations" (S29)

The feeling of dissatisfaction

There is no doubt that feelings of discontent arise due to a lack of positive attitude and cooperation by each member of the group. The attitude of the monopolies and a lack of responsibility shown by each member of the group can cause this problem.

"I do not like group activities because friends like to scramble, I'm fine doing it myself" (S7, S15)
"Some friends do not work ... I have to do a lot of work" (S30)
"Friends do not want to help, lazy to work" (S14)

However, teachers emphasized the role of ' putting head together ' so that each group member performs tasks by referring to the numbers and tasks they should follow. This indirectly trains discipline among students.

Item 2

Briefly describe your most enjoyable experience in the Pro-STEMlearning sessions.

Get tested for prototypes/demonstrations

It is a natural fit for children who like to play. Hence, the testing activity of the project prototype of each group was the most anticipated time. Additionally, the designs were built in the form of science-based game tools. Each prototype of the group had its own design and uniqueness.

"I like most testing of the project ' floating seed '" (S8)
"We use the water in the school fish pond to float the seeds…best" (S4)
"I like to play the balloon-powered car…but balloon was too big then we release the balloon, eventually the car will move" (S22)

Having a chance to build a model

Creative students will be eager to develop models according to their sketches. The collaboration shown by each team member was also a main factor in producing a good project.

"I like to do project activities because I can buildsomething new" (S17)
"The best time is doing the project ... we're working together" (S2)
"Making the mini fridge is the most fun…our juices slowly become liquid" (S3)

Having a chance to make a presentation

Discouraged students and talk-makers are passionate about presentation. However there are also students who like the activity because it is a good time to pose friends in other groups with various questions and criticisms during the question and answer session. This activity actually trained students to communicate well and wisely in explaining during presentation sessions.

"The first time, I was afraid, but after a few strides I was ok" (S18)
"It is not hard work because we just explain what' s done" (S7)
"I like presentation because other groups deliberately want to see our solution" (S30)

Awareness of the elements in STEM

The integration of STEM elements in the Pro-STEM activity indirectly opened the mind of students to think more creatively and divergently. Students were increasingly aware that the Pro-STEM learning also enabled them to master the concepts of mathematics, science and technology. However, students were still weak in mastering engineering skills.

> *"All activities are for sketches, there are ways to calculate the cost of creating a project. There must be an explanation of science and technology with the unique design" (S1)*
> *"the activity is good, because I learn science, math, technology and others" (S19)*
> *"I like to calculate, ..the cost we used to make the project, just a small amount" (S6)*

Item 3

What do you find in this Pro-STEM learning session?

Generate many ideas fluency

Generally, the students acknowledged that the activities train them to generate more ideas.

> *"Many ideas can be shared with friends" (S16)*

Expands original idea (elaboration)

The activities carried out also stimulated the minds of the students to think outside the box. However, sometimes pupils needed to be stimulated by giving examples, situations or explanations before showing their ideas.

> *"Yes, my ideas are expanding" (S5)*
> *"I can think more than what teachers gave" (S17)*
> *"First of all, it is hard to think, but later more and more ideas I get" (S18)*

Generate a special/unique Idea (originality)

Students aware that the activities carried out in the Pro-STEM module could sharpen their minds to generate creative and unique ideas. Although the basic materials used were the same, each group would find uniquenessin every design.

> *"Yes, my ideas are always unique and special" (S1)*
> *"My idea is not the same as anyone else" (S25)*
> *"Yes, my idea is better than anyone else" (S12)*

i. Do you think you can give a special title to the sketch?

Thinking of a special title (title abstraction)

Almost 50% of students cannot give a title to the illustrated sketches.

> *"It' s hard to write a title for all the sketches I've made" (S14, S18, S25)*
> *"I do not know what title is appropriate for each title I am going to give" (S15)*

However, another 50% of students can give a special title.

> *"All the titles I give in my design are unique and special" (S25)*
> *"We've got it first, just love to give it a headline" (S16)*
> *"We feel happy to find a special title" (S30)*

ii. Do you think you can use information from various aspects to complete sketches?

Obtaining information from various aspects (Resistance to premature closure)

Students get information on various aspects to find solutions.

> *"Yes, I use information from various sources to produce good and interesting inventions" (S23)*
> *"My own idea was based on my daily life experiences" (S15)*

"Information gained is through reading, experience and what has been taught by my parents and teachers" (S20)

Item 4

Do you think the Pro-STEM project can improve all the skills in item No. 3 above? Explain why you are.

Mastering multiple skills

Respondents agreed that the activities carried out helped them to master a variety of skills.

"Yes, through Pro-STEM learning and projects, we all make, paint, calculate project costs, inventions, games, stretches and many more" (S30)
"Pro-STEM learning not only trains us to think but makes us more creative and courageous to create something versatile" (S28)

Increased confidence to share ideas

The activities carried out also provide a bit of coaching for students to boldly show themselves, to express their ideas, respond to the issues raised, and give a glimpse of their creativity.

"I used to be afraid to express my ideas, but now it is ok" (S17)
"I' m not shy anymore about doing a presentation" (S16)
"I' m not afraid to be wrong because the teacher will correct me" (S14)

Nurturing teamwork

Pro-STEM activities through 'putting head together' also trains students to always practice teamwork. Although each member has a role, however, a good product requires cooperation among members.

"We are working together in all of our activities" (S23)
"There are also our lazy members, but we forced them to do work" (S4)
"If all the members work together, all the work will be ready" (S19)
"More ideas are collected to produce good projects" (S15)

Be wise in calculating costs

Pro-STEM learning not only trained students to learn about science and technology but also familiarize them with smart calculations taking into account the cost aspect of carrying out a project. The details of the cost of each project indirectly improve motivation towards mathematics among students.

"In every project we make, there is an approximate budget" (S19))
"The cost estimation is important so that the project does not require much spending" (S3)
"All the projects we made were using recycled materials. So we do not need to use a lot of cost, more saving" (S11)
"This activity trains us to be smart in designing the activity but the outcome is very good" (S4)

Item 5

Do you think that the activity of sketching can uncover all the skills in item No. 3 above? Explain.

Growing the idea

Pro-STEM learning and projects successfully train students to produce more designs but timeconstraint reduce the quality of sketch produced.

"Yes, we can do if we have enough time" (S1)
"Of course, we share ideas to do what we want" (S19)
"Every member contributes their ideas, ideas are so many" (S4)

Think creatively

Pupils were more creative as each sketch would be followed by prototype development.

> *"Although the materials provided by the teachers are all the same, we have managed to produce unique sketches and others from other groups" (S30)*

Rational thinking

The pupils develop their own justification which can be explained in more detail through the presentation of the sketches.

> *"Although our sketches are strange, we have the reason why we did so" (S16)*
> *"All our designs have their own functions" (S5)*

Item 6

Why are you interested in following Pro-STEM learning activities in future?

Application in everyday life

Every activity learned in this module can be applied in the daily life of the student because the activity is simple and does not involve much cost, in addition to responding to the '3R' campaign.

> *"Yes, I ' ll do it again, at home I can do with my brother's brother" (S6)*
> *"Of course, now I understand how to make a project" (S2)*

Toward prototype development

Pupils are more creative as each sketch will be followed by prototype development.

> *"What we are going to expect is similar to the results of the projects we build" (S24)*
> *"Although our paintings are weird, we can transform it in the form of a product" (S19)*

Item 7

Do you think collaboration within the group can improve the quality of the model?

Quality sharing of ideas

Students have also been aware of the importance of group work to produce a good and skinny model. Furthermore, group activities can foster a loyal spirit of friends striving to help one another.

> *"I feel very happy that the activities are appropriately organized in groups, many better ideas as a result of sharing ideas. We're good at it until everyone is satisfied" (S15)*

Item 8

Is building a toy model developing your skills ?

Be able to produce various designs (smoothness)

Designing and making activities through the project within the group were seen as developing their skills. Students recognized that many model building activities were carried out, indirectly training them to create more designs.

> *"Yes, the more models are created, the more inventive skills we master" (S7)*

Expanding ideas outside of school

Pupils were aware that design and making activities can not only be carried out at school but can be made anywhere in the home. Armed with the existing experience and knowledge, while pursuing learning in school, the idea will be developed and applied by the students according to the suitability and the material in the environment.

"At home, we can make various models" (S6)

4 CONCLUSION

This paper highlights the development and evaluation of the Pro-STEM module in fostering scientific creativity through content validity and reliability analysis. The feedback from the module's expert panel is positive and some improvements need to be made before the Pro-STEM module is used in an actual study. The result of the questionnaires shows that the Cronbach's alpha value is 0.90, so the developed Pro-STEM module has a good degree of consistency. The result of the paired sample t-test indicated that grade five students taught in Pro-STEM performed significantly better in the five trait dimensions of scientific creativity in the post-test compared to the pre-test. The majority of the students are of the opinion that the activities in the Pro-STEM module generate excitement as they have the opportunity to build and test the prototypes and do the presentation to justify each design. This indirectly creates positive competition between groups. In each activity, students have the opportunity to generate many and unique ideas applying the elements of STEM. Despite efforts to create a prototype, there is sometimes a feeling of dissatisfaction and boredom among a small group of members. However, thanks to teamwork, they have finally succeeded in producing creative products. Not only that, the activities carried out turned out to be a platform for: a) generating many ideas; b) generating unique/ideas; c) expanding ideas; and d) thinking of a special topic. Activities that were conducted also enabled students to obtain information from various aspects while making them more confident to share ideas, foster teamwork, intelligently calculate cost, think creatively and rationally in every action. In short, students think that all activities in the module are applicable to everyday life. Therefore, it can be concluded that STEM-based learning activities can generate learning environments that nurture students' scientific creativity. This convinces the researcher to test the Pro-STEM module in a real study involving a larger sample.

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Development of students' creative thinking skills in chemistry using Mobile Game-Based Learning (M-GBL) with integrated creative problem-solving

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ABSTRACT: This study explored the development of creative thinking skills by using a Mobile Game-Based Learning (M-GBL) media chemistry using the topic of ion equilibrium in salt solution. The M-GBL media used in this research has been validated regarding chemistry content by educational experts, while the pilot study has been validated by experts, students and teachers. The research was conducted in three chemistry classrooms of three secondary schools. Data were collected through participant observation using interviews, observation, a reflective journal and a questionnaire. The research quality standards included prolonged engagement, persistent observation, progressive subjectivity and member checking. The interview results show that the students developed their creative thinking skills in flexibility to find ideas in different ways, original ideas, fluency in generating ideas and elaborative thinking. The results concluded that in learning chemistry, especially in the topic of ion equilibrium in salt solution, M-GBL had a positive effect and can also develop students' creativity.

1 INTRODUCTION

Mobile technology is very popular among today's users, including students. The advent of mobile technology is changing students' learning, including mobile game-based learning. This is because mobile game-based learning is a unique way that can be used by learners anywhere and at any time (Ally, 2009). Mobile technology can improve communication significantly and can be used in learning (Imran, 2007), as it has roles in attracting and motivating students toward learning and engagement (Scott et al., 2015). Teachers can develop mobile game-based learning assessments, considering the factors affecting students, including motivation (Shin & Han, 2016). Based on studies, there is a statistical difference between teaching with a mobile game-based approach and traditional media (Nouri et al., 2014). Learning using mobile game-based learning media can improve student learning outcomes and independence (Cahyana et al., 2017). Additionally, the education system based on student's needs is easily adopted and very promising in improving student learning outcomes and independence (Hwang et al., 2013).

Mobile and web-based learning have a positive influence on creative thinking ability (Lin, 2014). Learning, based on mobile approaches, also has a significant effect on students' attitudes and other soft skills such as creative thinking skills, group work collaboration and sharing information in group activities (Cavus & Uzunboylu, 2009). Students who receive creative thinking teaching through mobile game-based learning reveal higher performance in their creativity than those receiving conventional teaching (Lin & Wu, 2016).

Students' problem-solving and creative thinking skills can be developed by designing a learning environment integrated the mobile game-based and the creative problem-solving the model. Based on a Global Creativity Index study in 2015, Indonesia has a low creativity index (0.202), ranked 115 of 139. The results of the creativity index were based on three indicators (technology, talent and tolerance). Therefore, teaching using mobile game-based learning with integrated creative problem-solving models can develop students' creative thinking skills in the chemistry topic of ion equilibrium in salt solution.

2 METHOD

This research was conducted in three schools in Indonesia during the 2017/2018 academic year. There were 36 students from class XI using the Mobile Game-Based Learning (M-GBL) media that had been validated by experts and tested by students and teachers. Data were collected through observation, interviews, a reflective journal and a creative thinking skill questionnaire. The research quality standards included prolonged engagement, persistent observation, progressive subjectivity and member checking. The analysis will explore how M-GBL helps students to think creatively, covering each aspect of creativity (flexibility, fluency, originality and elaboration).

3 RESULTS AND DISCUSSION

3.1 *The analysis of students' creative thinking skill of flexible thinking aspect*

Creative thinking skill in the aspect flexible thinking means that students are able to produce many ideas and have different ways of thinking, that be seen when the students given by a problem so they can thinking many kind of way to solve the problems. In this research, the effort is to use the M-GBL media, so the analysis concerns the effect of using M-GBL media on students' creativity in the aspect of flexibility.

From Table 1 and Table 2, it can be said that the students have positive answers in relation to the use of M-GBL media as their way to get some ideas, both in learning and solving problems. This indicates that the students' creative thinking skill in flexible thinking aspect is caused by learning using M-GBL as an alternative way that helps them produce ideas. Students' spirit can make them produce many ideas and participate actively during learning. It is due that they are given the opportunity to convey and provide ideas in their own way, besides the material is considered easy for students, learning activity is not monotonous, they can provide ideas different ways, and learning resources that not only use the book. The features contained in M-GBL also attracts the attention of students so that they are more enthusiastic in participating in learning chemistry. This result is in accordance with Chiang, Yang, and Hwang research in 2014 which found that the use of M-GBL improves students' motivation in the dimension of attention and satisfaction. This is because of the ease of using the media

Table 1. Results of questionnaire for flexible thinking aspect.

		Results (%)			
No	Statements	Strongly agree	Agree	Seldom	Never
1	I use the M-GBL media to solve problems on ion equilibrium in salt solution matter	16	61	22	0
2	When the teacher explains about ion equilibrium in salt solution, I find out more about it using the M-GBL media	25	58	16	0
3	When the teacher gave a problem, I can't think of any solution nor the way to convey the solution idea	8	13	52	25
4	The use of M-GBL media makes me complete my own assigned tasks	30	50	11	8

Table 2. Results of the reflective journal, observation and interview for flexible thinking aspects.

Reflective journal	Yes, I get the solution through discussion and use the application
Observation	During class discussions, students can provide many ideas in their group discussion from different perspectives to solve the problems
Interview	Using the application makes easier in discussions and to answer the questions because besides to the book and Internet, the application is also complete enough, there's even a video of it as well
Interview	The learning was exciting, I attempted to be active; moreover, to solve the problems, we don't have to always read a book, because there is a complete formula and exercises in the application

Figure 1. View of game page.

Figure 2. View of animation videos.

and its interesting appearance, as well as the additional features such as games and animation. The existence of game features also attracts students to learn more deeply. Various types of games, which are contained in this media, provide many choices for students. In the quiz section, there are several levels that can test the level of student understanding, along with the discussion which will allow students to better understand the question answers. The animation feature, which contains experimental videos, also increases students' understanding of self-learning using the media.

Based on this aspect result, which shows that the use of M-GBL media is an effective way to produce ideas, students participate in giving ideas and provide concepts in different ways. These results are supported by Cavus and Uzunboylu's (2009) study, which suggests that learning with M-GBL has a significant effect on students' attitudes and other soft skills such as positively influencing student creativity, developing a collaborative attitude in work and sharing information in group activities.

3.2 *The analysis of students' creative thinking skill of original thinking aspect*

Creative thinking skill in the aspect original thinking means giving unusual answers, different from others or answers rarely given by most people. Student behavior, in the aspect of originality, is seen when students are able to think about problems or things that others never think of.

Table 3 and Table 4 show a good result for their creative thinking skill in the originality aspect, which indicates that students made a good effort to create new ideas and were capable of thinking in different ways than others. From the overall data above, some students were

Table 3. Results of questionnaire on original thinking aspect.

No	Statements	Results (%)			
		Strongly agree	Agree	Seldom	Never
1	While doing a task, I was able to think of ways that no one else had thought of	16	58	19	5
2	I have a different way of thinking than others	19	52	25	2
3	I never try to give a new idea after reading or hearing ideas which have existed	2	8	58	30

Table 4. Results of the reflective journal, observation and interview for original thinking aspect.

Reflective journal	With using books and the application, I can think of alternative solutions, even my friends could not think of
Interview	I like when the teacher gave freedom in answering, from a lot of learning sources including the application, so I can think of new ideas because of many learning facilities provided
Interview	The teacher commands to think of alternatives from any point of view, and find different original solutions from our own minds
Observation	Many students are trying to find an alternative. Students use books, mobile learning applications and the Internet

shown to be able to produce new ideas. Problem-based learning, contained in the games on mobile devices, uses various ways to help students understand concepts and resolve various issues. Some researchers believe that the teaching materials and techniques are not as good as having children learn via games by having fun and being happy (Norman, 1981). Games are easily accepted and used by students (Kafai, 1995). Furthermore, games can help students develop problem-solving skills (Seonju, 2002; Chuang & Chen, 2009; Lee & Chen, 2009; Blumberg et al., 2008; Shih et al., 2010). M-GBL is presented as an alternative to help students understand chemistry by using games on mobile devices, which can help students to produce new ideas, demonstrating the originality aspect in creativity.

3.3 *The analysis of students' creative thinking skill of fluent thinking aspect*

Aspects of fluent thinking refer to the number of ideas produced in an appropriate response. Student behavior, in this aspect, can be seen from students' ability in answering a number of questions fluently and expressing their ideas independently.

Table 5 and Table 6 show a good result for their creative thinking skill in the fluency aspect, which appears because students are not ignoring the learning and they attempt to provide many arguments in the discussion. The use of M-GBL media in this aspect allows students to provide many ideas and answer questions, because of their bravery in providing many arguments in solving the problems. Students' fluency in answering a number of questions and their bravery in providing many arguments in solving the problems, make them more independent in learning.

From the overall data above, the students are capable of producing and providing their ideas independently and answering questions fluently. This result is accordance with Zan's (2015) research that suggests that the use of mobile media in chemistry learning can build students' positive attitude and make the learning process easier then another learning methods. The study shows that students who receive creative thinking teaching in a mobile based approach reveal a higher performance in the creativity of fluency, flexibility, uniqueness and elaboration than conventional teaching. It proves that mobile and web-based creative thinking teaching could stimulate students' creation potential (Lin & Wu, 2016).

Table 5. Results of the questionnaire for the fluency aspect.

		Results (%)			
No	Statements	Strongly agree	Agree	Seldom	Never
1	If any part of the lessons aren't obvious, I just ignore them	0	22	52	25
2	I attempt to provide many arguments in the discussion	19	58	16	5
3	I was able to do my task even though it wasn't guided by the teacher	2	77	19	0

Table 6. Results of the reflective journal, observation and interview for fluency aspect.

Reflective journal	At first it was difficult, but after group discussion, reading the book and using the application, I finally understand
Reflective journal	Yes, I can answer the question fluently. Because I can look for the solution by reading books, discussion groups and the application
Observation	Students have no difficulties, it is easy to find solutions from books and mobile learning media that are given by teacher
Interview	Easy to find solutions, moreover the class discussion is very active, the application is also very helpful

Table 7. Results of the questionnaire on the elaborative aspect.

		Results (%)			
No	Statements	Strongly agree	Agree	Seldom	Never
1	If I am not satisfied with the teachers' explanation, then I try to find information at the next lesson	19	55	19	2
2	If any part of the lessons aren't obvious, I ask directly	25	36	38	0
3	I never make any steps that I can easily remember to work on the task	5	16	66	11
4	I like to think and try practical new ways that I found by myself to accomplish a task	11	50	38	0
5	The M-GBL media allows me to think of other ways to accomplish tasks	30	38	30	0
6	I try to always do the task, as well as respond to friends' questions	19	61	16	2
7	I'm not glad if I have not responded to a teacher's or friend's questions	5	25	61	8

3.4 *The analysis of students' creative thinking skill in the elaborative aspect*

Aspects of elaborative thinking refers to students' ability to develop, add and detail an idea. Detailing in this case is that they can explain details about an object or idea so that it is more interesting. Students' behavior in this aspect can be seen from their ability to develop or enrich other people's ideas and add or specify an idea.

Based on the data, it can be assumed that the use of M-GBL media makes students capable of adding to and detailing an idea. This is marked by the behavior of students who think of other ways by using learning resources including the M-GBL media and who are capable of taking steps to complete the task. Students' elaboration ability can also be seen from their ability in developing or enriching the idea of others. Developing or enriching other people's ideas can be done with high student participation in learning, where students frequently ask

Table 8. Results of the reflective journal, observation and interview on the elaborative aspect.

Interview	Yes, by using the application, I can make the steps to complete the task, because in the quiz there is a complete discussion, in the material there is an example of salt pH calculation with the formula
Interview	I was asking a lot, because surely lack of understanding, anyway it allowed to directly ask if we didn't understand
Observation	Students were asked to find a way to calculate the pH based on prior knowledge of acid–base to find the salt pH. Students are seen using books and mobile learning media
Reflective journal	I am active in learning. I always ask friends or the teacher when there is something I don't understand

opinions or questions and also respond to questions. It can be seen by the students' behavior, who are working on their tasks, by thinking of other ways of using learning resources including the M-GBL media and are capable of taking steps in accomplishing tasks and being active in learning, as well as brave in asking and answering questions. This result is in accordance with Cavus and Uzunboylu (2009), who suggest that learning based on mobile approaches also has a significant effect on students' attitudes and other soft skills such as creative thinking skills, group work collaboration and sharing information in group activities. Lin and Wu (2016) suggest that mobile and web-based creative thinking teaching could stimulate students' creation potential. Students who receive creative thinking teaching using mobile based approaches reveal higher performance in creative fluency, flexibility, uniqueness and elaboration than conventional teaching.

4 CONCLUSION

In the process of learning chemistry, the use of M-GBL media has a positive effect in improving student creativity. Students are not bound by time and space. They can learn, not only in the classroom but they can also study outside the classroom, depending on the student's individual conditions. The learning material contained in M-GBL is interesting as it comes with games, animations and learning videos. The students' creative thinking ability in the flexibility aspect showed good results, in that the use of the M-GBL media is an effective way to produce ideas, and can make students participate in providing ideas and presenting concepts in different ways. The aspect of originality shows that students are able to provide new ideas. For the fluency aspect, it shows a good result in that by using the M-GBL media, students are able to produce and express their ideas independently and answer questions fluently. For the elaboration aspect, it is shown that by using the M-GBL media, students are able to add and detail their own ideas as well as others. It can be seen by the students' behavior who can solve the problems on other ways using many learning resources including the M-GBL media, capable to make steps in accomplishing tasks, being active in discussion, and also brave in asking and answering the questions.

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Molecular engineering activity for chemistry teacher education: An interactive simulation on cellulose dissolution in ionic liquids

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ABSTRACT: The research was conducted to reconstruct molecular engineering activity for chemistry teacher education through interactive simulations on cellulose dissolution in ionic liquids as "designer" solvents. This activity is aimed to enhance the View of Nature of Science and Technology (VNOST) of the pre-service chemistry teacher. This study refers to the Model of Educational Reconstruction (MER) with stages: (1) analysis of content structure, (2) research in learning and (3) development of learning design. The instruments used were text analysis form, validation form, interview guidelines, VNOST questionnaire, expert assessment form and the test items available in the interactive simulation program. The questionnaire and interview were conducted to 20 pre-service teachers from the third year. According to the scientific perspective and the results of the validation of learning outcomes, the chemical concepts related to the topic of ionic liquids as cellulose solvents are ionic bonds, forces between particles and polymers. The results of the interviews as preconception data indicated that the topic of ionic liquids as cellulose solvents is new to students but some students can relate them to the related chemical concepts after analyzing illustration pictures and animation. The initial understanding of VNOST students is generally in the category of Has Merit and Naïve. All data obtained is used as the basis for the reconstruction of interactive simulations. The results of a small-scale trial of the simulation which involved 10 pre-service teachers showed an increase in the number of the pre-service teachers with Realist category of their VNOST. This shows that the interactive simulation that has been reconstructed is feasible to be implemented in learning to build pre-service teachers' VNOST.

1 INTRODUCTION

21st-century competency demands require students to have good scientific literacy skills (OECD, 2016). Related to this, the organization for economic cooperation and development (OECD) conducted an international study through the Program for International Student Assessment (PISA) to determine the level of scientific literacy skills of students. Based on the PISA results, it is known that Indonesian students still have low scientific literacy skills. This is evidenced by the score achieved by Indonesian students is below the average international achievement. As an example in the 2015 PISA results, the score achieved by Indonesian students is 403 of the 493 international achievement average score and Indonesia is ranked 62 of the 70 countries involved in the PISA study (WEF, 2015). The low level of scientific literacy of Indonesian students, as revealed in the 2015 PISA study, needs to be seen as a serious mistake and a solution to the problem well and comprehensively.

Vesterinen (2012) revealed that what is an important element of scientific literacy is the nature of science (NOS) (Vesterinen, 2012). Nature of science describes what science is, how it works, how scientists work, and the interaction between science and society. Science teachers who do not understand NOS will have difficulty teaching and helping students to gain a good understanding of scientific concepts (Hodson, 1988). However, according to Tala (2013), an increase in NOS can be done if aspects of technology are noticed because NOS cannot be understood correctly without the technological role (Nature of Technology/NOT) (Tala, 2013).

Developing an adequate understanding of the nature of science and technology (NOST) and its interaction with the community is basically an important matter in science education (Tairab, 2001). To understand NOST a science teacher needs to have an understanding of the five main aspects related to the relationship between science and technology, namely (1) the characteristics of science and technology, (2) the purpose of science and scientific investigation, (3) the characteristics of scientific knowledge and scientific theory, (4) ways obtain scientific knowledge and scientific theory, and (5) the relationship between science and technology (Tairab, 2001; Rubba & Harkness, 1993; Chamizo, 2013b). An understanding of the nature of science and technology can also be done through technoscience (Tala, 2013).

Techno-chemistry (technoscience in chemistry) is one way to combine aspects of science and technology from contemporary scientific activities (Chamizo, 2013b). In this study, the selected techno-chemistry was ionic liquid on cellulose dissolution. The selection of ionic liquids is motivated by several reasons, namely (1) scientific explanations related to science and technology based on ionic liquids can be used to strengthen the context of chemistry learning, and have great potential as a medium to develop thinking skills (processes/competencies) demanded by PISA, (2) modern science and technology based on ionic liquid materials can also be used as discourses to strengthen students' scientific attitudes, and (3) ionic liquids are a new generation of green solvents, reliable electrolyte and fluid techniques that are safe and friendly for various purposes (Brennecke & Maginn, 2001). The use of ionic liquids as cellulose solvents is based on the nature of cellulose which is difficult to dissolve in water and conventional organic solvents (Mudzakir et al, 2009).

In techno-chemistry education, models and modeling play an important role in the integration of scientific concepts (Chamizo, 2011a). The model is a representation based on an analogy built to conceptualize certain parts of the world with specific objectives (Coll & Taylor, 2005). According to Oh and Oh (2011), the model serves as a bridge that connects theory and phenomena. Besides that, the model also plays a role to describe, explain and predict natural phenomena and communicate scientific ideas (Oh & Oh, 2011). One example of a model is a simulation.

Simulation is dynamic multiple models to illustrate a complex process such as natural phenomena (Harrison & Treagust, 2000). Simulations that can support chemistry learning are interactive simulations because they can provide opportunities for learners to interact with the dynamic visualization, enabling focused ecological investigation; involved in fast feedback cycles and can make causal relationships easily visible (Moore et al, 2013). Based on this background, the purpose of this study was to reconstruct molecular engineering activities for chemistry teacher education through interactive simulations on the dissolution of cellulose in ionic liquids as a "designer" solvent to improve the View of Nature of Science and Technology (VNOST) of the pre-service chemistry teacher.

2 METHOD

This study uses the Model of Educational Reconstruction (MER) (Duit et al, 2012) as a research design, which consists of three components, namely; 1) clarification and analysis of science content, through the analysis of material structure and learning outcomes; 2) research on the teaching and learning process, through empirical studies of preconceptions and early VNOST of students; and 3) design and evaluation of learning, through the reconstruction of interactive simulations and small-scale trials of interactive simulation products. The subjects in this study were students of pre-service chemistry teacher (third-year students in the department of chemistry education, Pattimura University) which were divided into two groups, namely 20 students for taking VNOST and preconception data, and 10 students for conducting trials small scale of interactive simulation products. These ten students are part of students who have done VNOST and preconception tests. The research data was collected using text analysis form, validation form, interview guidelines, VNOST questionnaire, expert assessment form and test items in interactive simulation media.

3 RESULT AND DISCUSSION

3.1 *Scientist perspectives on ionic liquids as cellulose solvents*

3.1.1 *Ionic liquids*

Ionic liquids are salts that are liquid at lower temperatures (<100°C) (Pinkert et al, 2009). In general, ionic liquids consist of organic cations and inorganic or organic anions. As ionic species (cations and anions), ionic liquids do not contain molecules or neutral species and have a relatively low melting point, generally at room temperature. Some examples of cations from ionic cases are imidazolium, pyridinium, ammonium, phosphonium, and piperidinium. While examples of anions are Cl^-, BF_4, and Br^-. The ions in ionic liquids are large and asymmetrical with delocalized charges so that they remain liquid at temperatures below 100°C. In contrast to kitchen salts (such as NaCl) which have symmetrical crystal structures, high melting, and viscosity points and are solid at room temperature (Gupta & Jiang, 2015).

3.1.2 *Properties of ionic liquids*

Ionic liquids have a variety of physical properties that make them attractive for widespread application. One application is as a solvent. The prominent characteristic that distinguishes ionic liquids from conventional solvents is that they have a wide range of fluids (–40 to 400°C), high thermal stability (above 400°C), very small vapor pressure, very low symmetry, non-flammability, high conductivity and range-wide electrochemical potential (–4 to 4V) (Gupta & Jiang, 2015).

The physical and chemical properties of ionic liquids can be adjusted by changing cations and anions, which is almost impossible in conventional solvents. Therefore, ionic liquids have been considered as good solvents of conventional volatile solvents and are classified as "green" solvents for wider applications in industrial and laboratory scale. The solubility of ionic liquids is influenced by the types of cations, anions and alkyl chain lengths in the cation. The interaction of strong anions and cations with dissolved substances (e.g. cellulose) will increase their solubility. The longer the alkyl chain will reduce the solubility of ionic liquids (Gupta & Jiang, 2015; Yuan & Cheng, 2015).

3.1.3 *Application of ionic liquids as cellulose solvents*

The first experiment using ionic liquids to dissolve cellulose began in 1934 by Graenacher, who used N-ethylpyridinium chloride in the presence of a base containing N. At that time, however, the practical importance of ionic liquids was not realized. Only in 2002, Swatloski et al. found that 1-n-butyl-3-methylimidazolium chloride [C_4 mim] [Cl] can dissolve cellulose up to 25% by microwave heating (Swatloski et al, 2002).

The dissolution of cellulose in ionic liquids is influenced by many factors, such as the type of anion, cation and side chain length in the cation. The proposed dissolution mechanism of cellulose in ionic liquids (Pinkert et al, 2009) is as follows:

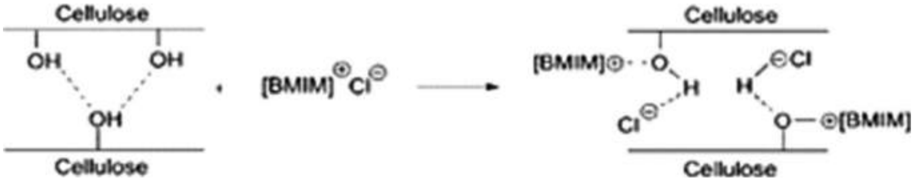

Figure 1. Mechanisms of Cellulose Dissolution in Ionic Liquids (Pinkert, 2009).

Oxygen and hydrogen atoms from cellulose form electron donor-acceptor electron (EDA) complexes with a type of ionic liquid charge. This occurs between the C-6 and C-3 hydroxy groups of neighboring cellulose chains. This interaction results in the separation of hydroxyl groups from different cellulose chains which causes cellulose dissolution in ionic liquids (Pinkert et al, 2009). Dissolution of cellulose in ionic liquids involves breaking up of hydrogen bonds (Gupta & Jiang, 2015).

3.1.4 *Chemical concepts related to ionic liquids as cellulose solvents*

Some chemical concepts of ionic liquids as cellulose solvents are ionic bonds, forces between particles and polymers. Ionic bonding is the electrostatic force that occurs between ions (positive and negative ions) in an ionic compound. The bond is formed between two atoms when one or more electrons are transferred from the valence shell of one atom to another. Atoms that lose electrons become cations (positive ions), and atoms which obtain electrons become anions (negative ions) (Jesperson & Brady, 2012).

Intermolecular force is the force of attraction between molecules, and intra-molecular force is the force between atoms in a molecule. Intramolecular forces affect the chemical properties of a substance, while intermolecular forces affect the physical properties of a substance. In general, intermolecular forces are weaker than intramolecular forces. The types of intermolecular forces are Van der Waals forces, ion-dipole forces, and hydrogen bonds (Jesperson & Brady, 2012; Chang & Overby, 2011).

Polymers are molecular compounds that are distinguished by high molar masses and consist of many repeating units. One type of natural polymer is cellulose (Nelson & Cox, 2012). Cellulose is a polysaccharide consisting of linear chains, which are connected by β (1→4) D-glucose bonds (glycosidic bonds). The size of the cellulose chain depends on the level of polymerization, which is the number of repeated units of glucose (Gupta & Jiang, 2015).

3.2 *Student conceptions about ionic liquids as cellulose solvents and early perspectives of students concerning nature of science and technology*

3.2.1 *Student concepts about ionic liquids as cellulose solvents*

Students' conceptions were obtained through interviews with 20 pre-service chemistry teachers. Based on the results of the interviews it is known that: (1) all students have studied about the concept of cellulose but have not fully understood the concept, especially with regard to structure, hydrogen bonds and cellulose properties; (2) students do not recognize ionic liquids (salts that can be liquid at room temperature); and (3) students generally have an overview of ionic liquids as ionic solvents in the cellulose dissolution process after paying attention to animations, tables, and images when interviewing.

3.3 *Student perspectives on Nature of Science and Technology (NOST)*

To find out the views of students about the Nature of Science and Technology, the VNOST questionnaire instrument was adopted from Tairab (2001) and Devi (2018) (Tairab, 2001; Chamizo, 2013b). This questionnaire covers five aspects of VNOST, namely: 1) the characteristics of science and technology, (2) the purpose of science and scientific investigation, (3) the characteristics of scientific knowledge and scientific theory, (4) ways obtain scientific knowledge and scientific theory, and (5) the relationship between science and technology. Every view of the VNOST aspect is grouped based on three categories that have been determined by Rubba (1993), namely (1) Realist (R), which is a group of statements that show the actual conditions and in accordance with the general view of science and in accordance with the concepts and theories science; (2) Has Merit (HM), is a group of statements that show conditions that are not completely true but there are parts of statements that are still in accordance with the general view of science and in accordance with the concepts and theories of science; and (3) Naïve (N), is a view that is not at all related to the concepts and theories of science (Rubba & Harkness, 1993).

Table 1. Student conception data on nature of science and technology.

No	VNOST Aspects	Questions	Category (%) R	HM	N
1	Characteristics of Science and Technology	(1) Definition of science	20	80	0
		(2) Characteristics of science	25	50	25
		(6) scientific theory	35	45	20
2	Science and research objectives Scientific	(3) Science objectives	50	35	15
		(7) Definition of technology	40	55	5
3	Characteristics of scientific knowledge and scientific theory	(5) Definition of scientific knowledge	90	10	–
		(4) Definition of scientific research	50	25	25
4	How to obtain scientific knowledge and scientific theory	(9) How to obtain scientific knowledge	5	95	–
5	The relationship between science and technology	(8) The relationship between science, technology, and society	40	50	10

Table 2. Results of understanding VNOST students before and when using interactive simulation.

			Interactive simulation usage					
			Before (%)			Current (%)		
No	VNOST Aspects	Questions	R	HM	N	R	HM	N
1	Characteristics of Science and Technology	Characteristics of Science	30	70	0	50	50	0
2	Science and Scientific Research Objectives	Science goal	40	30	30	70	20	10
		Understanding technology	30	70	0	40	60	0
3	Scientific and Scientific Theory Knowledge Characteristics	Scientific knowledge	90	10	0	100	0	0
		Scientific research	40	20	40	30	60	10
4	How to get scientific knowledge and scientific theory	How to get scientific knowledge and scientific theory	10	90	0	60	40	0
5	The relationship in Science and Technology	The relationship in Science and Technology	40	40	20	80	20	0

The results of the student's perspective on Nature of Science and Technology can be seen in Table 1. Based on Table 1, it is known that students' views on the nature of science and technology are generally in the category of Has Merit and Naïve.

3.3.1 *Potential of interactive simulation in building view of nature of science and technology capability*

Interactive simulations that have been assessed by experts and declared feasible, then conducted a small-scale trial to 10 students to find out the potential for simulation in building VNOST students' abilities. VNOST understanding of students is tested directly when students do learning using interactive simulations. VNOST student data can be seen in Table 2. The results of students' understanding of VNOST, while conducting learning using interactive simulations, have largely increased to realist.

4 CONCLUSION

Based on the results of the study, it can be concluded that the interactive simulation of cellulose dissolution in ionic liquids that have been reconstructed has the potential to build

VNOST abilities of the pre-service chemistry teacher, thus this interactive simulation can be used in chemistry learning.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Development of an electronic module with a discovery learning model to improve Higher-Order Thinking Skills (HOTS) learning outcomes in a senior high school study of harmonic oscillation

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ABSTRACT: The aim of this research is to develop electronic modules with discovery learning models that contain learning stages, such as stimulation, problem identification, data collecting, data processing, verification and generalization. This electronic module is proposed as a media and learning resource to improve Higher-Order Thinking Skills (HOTS) of students. The improvement can be done by students, while evaluating themselves in an evaluation section on the electronic module, which contains HOTS problems. Analyzing, synthesis and evaluation are aspects of HOTS problems. The research method used is Research and Development (R&D) with Analysis, Design, Development, Implementation and evaluation (ADDIE) models. Seen in terms of module characteristics, the percentage of achievement from experts is 89.63% for self-instruction, 97.14% for self-contained, 91% for stand alone, 95.6% for adaptive and 93.3% for user friendliness, with an average percentage of module characteristics reaching 92.73%. The results show that the control class N-gain test was 0.357413 and the experimental class was 0.449905. Two classes were tested using a t-test with a test result of 4.02. The conclusion is that the development of electronic modules with a discovery learning model is feasible for use as media and sources of independent learning and can have a positive influence on improving HOTS of students in harmonic oscillation material.

1 INTRODUCTION

Education is essential for the progress of a nation. The discussion about education is never separated from the learning process and learning media in schools and other educational institutions. According to needs analysis on students of SMAN (senior high school) 75 Jakarta, it is said that 74,3% of students has problems on physics due to lack of illustration on their physics textbook. In another hand, learning media has a role as an educational tool that can make the learning process go smoothly (Suparman, 2014). Although there are a lot of development in physics learning, it is still found that physics learning is a teacher centered learning where students do a lot assignment, writing some notes, and more listening teacher explanation. So, it is very hard to create student centered in physics learning. Therefore, learning media are needed, such as electronic modules that can display many videos and illustrations, especially in a material with abstract concepts such as harmonic vibration, such as when describing the quantities possessed by harmonic vibrations, to help students' individual learning without the maximum help from the teacher.

In obtaining optimal achievement, it is necessary to have an atmosphere and learning environment that supports the implementation of a reasonable and appropriate learning model that involves students actively and independently in the learning process, where they are responsible and demonstrate initiative to recognize their learning needs, find information sources and build knowledge, namely the discovery learning model (Hosnan, 2014). The discovery learning model is the application of one of the learning models of the 2013 curriculum (Depdiknas, 2008). Discovery learning models can encourage students to ask questions and draw conclusions from general principles based on experience and practical activities (Alex, 2013). Students are not only required to learn about the material but also learn how to think critically to solve problems that are interrelated with each other (Brookhart, 2010). At present, many teaching materials present material by inviting students to active learning, systematic conceptual presentation, but often end in the existence of evaluation questions that lack training in Higher-Order Thinking Skills (HOTS) of students. This finding is based on the results of a questionnaire stating that 94% of the books used daily have not practiced HOTS, although high-level thinking ability is an important aspect that can be applied to the learning process, including physics learning (Gulistan, 2015). Students' thinking skills can be trained through activities where they are given a problem and in this study, the problem is presented in the form of a variety of questions (Widana, 2017). By giving a variety of question, it is expected that HOTS ability of Indonesia student can be better. With the application of HOTS questions, students will be accustomed to analyzing, reasoning and being creative in solving problems found in their lives (Apiano, 2017). Based on the description above, it is necessary to have learning media in the form of an electronic module with discovery learning models equipped to improve HOTS in the topic of harmonic oscillation.

2 METHOD

2.1 *Research method*

The research was conducted in SMAN 72 Jakarta in class X MIA (science program) 1 and MIA 3. The research method used involved Research and Development (R&D) with analysis, design, development and evaluation (ADDIE) models. The models consist of five stages including analysis, design, development, implementation and evaluation.

A needs analysis was conducted to determine the problems in learning activities, the type of teaching media to be developed and the achievement competence expected. The design stage was conducted to determine the specification of the media to be developed, the content to be loaded and the assessment strategy. The development stage contains the process of making electronic modules with discovery learning models, a validation test, review and revision. A validation test was used to determine the feasibility of electronic modules with the discovery learning models that have been developed. Validation tests were performed by a material expert, media expert and learning expert. The implementation stage was conducted by testing electronic modules with discovery learning models in experimental and control classes. The evaluation stage was conducted to determine the students' learning outcomes before and after using the electronic modules.

2.2 *Description of product development results*

The media produced through this development research are electronic modules and harmonious vibrations. Electronic modules were developed with a total of 128 pages, which consist of a preface, table of contents, module content, initial knowledge test, two learning activities (each learning activity consists of an introduction, material studies, sample questions, formative tests and summaries), final test of learning activities, feedback, answer key, glossary and bibliography. The images, simulations, and videos displayed in this electronic module are sourced from researchers' documentation, YouTube sites and several educational websites, including the source at the bottom of the video.

There are additional background and motivational words in several pages so the electronic module produced is more exciting. The main characteristics of the electronic modules developed are arranged based on discovery learning model stages with stimulation stages, problem identification, data collection, data processing, verification, formulating conclusions and equipped with student worksheets to facilitate students in learning to use electronic modules with a discovery learning model.

Student worksheets, as a complement to the electronic module, are prepared as a medium that supports students to be active in learning activities. The resulting student worksheet is

Figure 1. Cover of the electronic module.

Figure 2. Display of the electronic module.

Figure 3. Display of the student worksheets.

available in an electronic module so that students can learn directly. This electronic module can be accessed via electronic devices such as computers and laptops via flash disk or CD.

3 RESULTS AND DISCUSSION

3.1 *Feasibility test*

After developing the product, it continued to be evaluated by some experts. Here, the result gained by the product

The electronic module developed was temporarily tested for feasibility based on three aspects, namely material, media and learning. Provisional feasibility test results for electronic modules developed by the material expert are 98% with the interpretation 'good', 98.8% with the interpretation 'very good' and the learning expert by 72% with the interpretation 'good'.

Based on the results of the feasibility test by the material expert, the average achievement obtained was 98% of the maximum percentage of 100%. According to the interpretation of the Likert scale table (Sukardi, 2009), the electronic module meets the criteria very well, and according to the percentage table of Likert scale interpretation criteria (Riduwan, 2013), electronic modules with 98% assessment percentage are considered very feasible for use as physics learning media.

Based on the results of the feasibility test by the learning expert, the average achievement obtained was 72% of the maximum percentage of 100%. According to the interpretation of the Likert scale table (Sukardi, 2009), the electronic module meets the criteria well, and according to the percentage table of Likert scale interpretation (Riduwan, 2013), electronic modules with 72.2% assessment percentage are considered feasible for use as physics learning media.

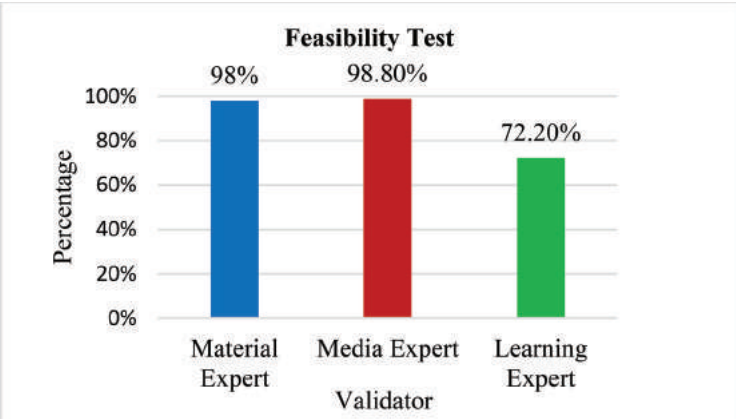

Figure 4. Graph of feasibility test.

Table 1. Pretest and post-test data of the experimental and control classes.

	Pretest		Post-test	
Statistic	Control class	Experimental class	Control class	Experimental class
n (number of students)	30	30	30	30
Minimum value	7	13	40	53
Maximum value	47	53	67	73
Range	40	40	27	20
Average	29.4	30.1333	54.633	61.56667

Table 2. The result of gain value.

Class	$\bar{x}$ Pretest	$\bar{x}$ Post-test	Gain value	Criteria
Experimental	30.133	61.56667	0.458405	Medium
Control	29.4	54.6333	0.357413	Medium

3.2 *Data description*

The data obtained in this study concern student learning outcomes in cognitive abilities obtained from 60 students divided into two groups of 30 students, both in the control class and the experimental class.

Pretest and post-test instruments consist of 15 multiple-choice questions that are at the cognitive level C4, C5 and C6, which have gone through different stages of validity, reliability, difficulty and power. Judging from the results of the post-test obtained, the post-test mean value of the experimental class was 61.5667 with a minimum value of 40 and a maximum value of 67. While the control class was 54.633 with a minimum value of 53 and a maximum value of 73. In this case, it shows an increase in the average value in both classes and ranges generated from both classes are now different. The control class has a range of 27, and the experimental class has a range of 20. This is because, as students begin to train in HOTS, they begin to understand and can answer the post-test questions given.

Based on the calculation of the N-gain test for the two classes, the value of the N-gain test in the control class was 0.357413 in the medium criteria, and the experimental class was 0.449905 in the medium criteria. However, the differences include: (1) the average value of the experimental class was higher than the control class; (2) the maximum value of the experimental class post-test was higher than the highest value in the control class.

The t-test was conducted to determine the significance effect of using an electronic module with discovery learning models on the HOTS of students. The hypothesis of this test was Ha = there are significant effects of using an electronic module with discovery learning models to improve the HOTS of students, Ho = there are no significant effects of using an electronic module with discovery learning models to improve the HOTS of students. The result of the calculation of the t-test was 4.02 and from the t-test table with $\alpha = 0.05$ (N = 30) that is 1.6973, so that $t_{count} >$ t table which indicates rejection of Ho and acceptance of Ha. This means that there are significant effects of using an electronic module with discovery learning models to improve the HOTS of students. This is because the electronic module with discovery learning models guides students to read graphs, summarize experimental data, link the material to one another as evidenced by the experimental class post-test results being more significant than the control class.

4 CONCLUSION

Based on the feasibility test by the three experts, namely a material expert, media expert and learning expert, and the results of field trials, it can be concluded that electronic modules with discovery learning models deserve to be used as learning media in physics and influence the improvement of learning outcomes of HOTS questions for class X high school students.

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A chemistry learning module based on a scientific approach for developing problem-solving ability

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ABSTRACT: This study aims to develop an e-learning module for a high school class XI in chemistry on solubility and solubility product results with a scientific approach and determine its effectiveness in terms of student problem-solving abilities. The development of this module adapts Borg and Gall's (1983) research and development stages consisting of a preliminary analysis stage and requirements, planning, product development, expert validation and revision, small-scale and revised trial, large-scale trial and final revision, and implementation of teaching and learning activities. The main application used in developing the e-module products is 3D PageFlip Professional. The e-module assessment by experts, teachers and students as a whole had a good interpretation. This module is complemented by examples and problem exercises that are completed based on the stages of problem-solving, namely understanding the problem, planning completion, implementing the plan and checking the results. By using this module, the problem-solving abilities of students will be trained. In the implementation phase, research was conducted to determine the influence of the use of an e-module that has been developed comparing the problem-solving ability of the students with the class that use the book. The results show that there were significant differences between students using e-modules and package books. Therefore, it can be concluded that e-modules can be used as a learning resource for students.

1 INTRODUCTION

The 4.0 industrial revolution was marked by the emergence of supercomputers, smart robots, driverless vehicles, genetic editing and the development of neurotechnology which enabled humans to further optimize brain function (Mourzist et al., 2018). Only qualified and highly educated people can control technology in this era (Benesova & Tupa, 2017). The challenge of education in the future is how to prepare human resources that have competencies that will not be replaced by machines. Jobs that are still unable to be taken over by machines and robots are jobs that require the ability to analyze, make decisions or collaborate. One of the competencies needed in preparing for the industrial era 4.0 is the ability to solve problems. These abilities can be trained by applying learning that integrates problems that must be solved by students. Polya (1985) describe the following problem-solving steps: 1) understanding the problem; 2) devising a plan; 3) carrying out the plan; 4) looking back.

Based on research, the use of scientific approaches has contributed to the improvement of students' problem-solving abilities (Dahlia et al., 2015). Higher mathematical problem-solving skills are taught through a scientific approach rather than the problem-solving skills taught by realistic mathematical approaches (Nuralam & Eliyana, 2017). The scientific approach contains learning steps that allow students to be able to solve a problem scientifically, logically and analytically, then communicate the results of their thoughts to other students (Nugraha & Suhendi, 2017). The scientific approach is a learning approach that helps students play an active role in the learning process, as well as in constructing their knowledge and skills. Besides, the scientific approach encourages students to conduct investigations to find facts about a phenomenon or event. The important thing that affects the implementation of learning with the scientific approach is the availability of adequate facilities and learning resources.

In chemistry learning, one aspect that requires a problem-solving approach is solubility and solubility results. Macroscopically, students study precipitates formed in a solution that is saturated. Microscopically, students must understand the ions that are still dissolved and not saturated. Studies (Doymus et al., 2010) show that animation and simulation using information and communication technology can help students to visualize, so that they can improve their understanding of learning chemical topics that are abstract. One of the learning resources that can train students' independence in learning is the electronic module (e-module). Chong, J. (2005) stated that 85.4% of respondents thought that an e-module had helped them in learning and was in accordance with student requirements. Novitasari (2017) developed a chemistry learning module on reaction rates and concluded that an e-module is suitable for use as a learning resource. Lee and Osman (2012) further stated that students had a higher score in the post-test and had gained a higher level of motivation after learning with interactive multimedia modules. The research conducted by Cahyaningrum, R. (2017) entitled 'Development of a chemistry learning module based on POGIL (Process Oriented Guided Inquiry Learning) on oxidation-reduction reaction material' concluded that the modules developed were very good and were suitable for use in the learning process and could be used as a source of students' independent learning. This study aims to develop a chemistry learning e-module on solubility material and solubility results with a scientific approach and its application to improve problem-solving abilities.

2 METHODOLOGY

This research was conducted at Senior High School 11 South Tangerang in the 2017/2018 academic year. The research method utilized refers to the method of research and development of Borg and Gall (1983) comprised of the following stages: 1) preliminary and physical analysis; 2) planning; 3) development of e-module; 4) expert validation; 5) revision; 6) small-scale trials; 7) initial revisions; 8) large-scale trials; 9) final revisions; 10) implementation and dissemination. E-modules that have been developed are then implemented in the learning process with the aim of determining the effect of using e-modules on students' problem-solving abilities. One class was randomly selected as an experimental class, which was treated using the e-module with a scientific approach, and one parallel class as a control class, which was treated with scientific learning by using a textbook. The research design can be described as follows:

3 RESULTS AND DISCUSSION

3.1 *Preliminary analysis of needs*

A preliminary analysis of the needs of students was carried out by distributing questionnaires on December 6–12, 2017. There were a total of 70 respondents in South Tangerang 11 State High School and Jakarta Don Bosco High School. This questionnaire was given to class XII students who have studied solubility and solubility results. As many as 83% of students consider the concept of solubility and solubility results as material that is difficult to understand. Overall, 66% of students have difficulty understanding the textbook. Eighty percent of students need learning resources other than textbooks. All students agreed with

Table 1. Research design.

Class	Treatment	Test
Experiment	Learning using e-module	Problem-solving ability
Control	Learning using book	Problem-solving ability

the concept of e-solubility modules and solubility results with an attractive appearance and easy to understand material. This is supported by the availability of computer laboratories in schools and 77% of students have laptops as a means of supporting independent learning.

Based on the distribution of questionnaires to teachers, as many as 75% of teachers stated that students had difficulty in learning the concepts of solubility and solubility results. Fifty percent of teachers stated that students had difficulty understanding the textbook. All of the teachers know the e-module and agree that an e-module will be developed to improve students' understanding. The e-module is expected, by the teacher, to have an attractive appearance with pictures (animation), short and solid material so that it is easy to understand for students.

3.2 *Planning*

The next step is to plan the development of the module by analyzing the subject matter and determining the application used. Based on the analysis of the chemical syllabus for class XI in senior high school, the solubility and solubility results consist of three concepts, namely: the concept of solubility; the effect of namesake ions on solubility; and the deposition of precipitates. The main application used in developing the e-modules is a 3D PageFlip Professional.

3.3 *Developing the e-module*

This step is carried out to produce e-modules that are suitable to be used as learning resources for students and teachers. There are three learning activities in the e-module, namely: 1) the concept of solubility and solubility results; 2) the effect of namesake ions on solubility; and 3) predicting the occurrence of precipitation. Each learning activity is equipped with a scientific learning step, which includes observing, asking, experimenting, associating and communicating. The e-module is also completed with sample questions and exercises with problem-solving steps, namely understanding the problem, planning completion, implementing the plan and checking the results. By using this module, the problem-solving abilities of students will be trained. The development of the e-module can be seen in the following figure:

3.4 *Expert validation*

3.4.1 *Media experts*

This validation was carried out by media experts consisting of two Information and Communication Technology (ICT) lecturers, Jakarta State University Information and Communication Technology Center expert staff and ICT teachers. Validation by these media

Figure 1. The process of developing the e-module with the 3D PageFlip Professional application.

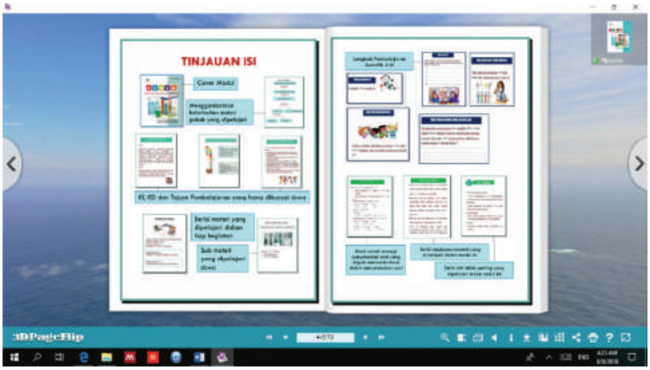

Figure 2. Display of the contents of the e-module.

experts aims to improve the appearance of the e-module. The expert validation results are as follows:

Table 2. Media expert validation results.

Indicator	% Average expert answer	Interpretation
Cover design	78.4	Good
Cover typography	85.8	Good
Content design	78.0	Good
Content typography	87.4	Good

Based on these data, the module developed has a good and appropriate interpretation to be used as a learning resource.

3.4.2 *Material and language experts*

This validation aims to improve the e-module in terms of presenting the material in order to be more qualified and provide students with an understanding of solubility and solubility times, as well as an e-module that suits the needs of students and teachers. This validation was carried out by material and language experts consisting of two chemistry lecturers and three chemistry teachers from South Tangerang High School and the results are as follows:

Table 3. Material and language expert validation results.

Indicator	% Range expert answer	Interpretation
Material coverage	63.3–80.0	Good
Accuracy of material	80.0–85.0	Good
Skill	65.0–80.0	Good
Comunicative	80.0–85.0	Good
Motivating	75.0–80.0	Good
Flow of thought	80.0	Good
Suitability of language rules	80.0–85.0	Good
Use of chemical symbols	85.0–90.0	Good–Very Good

Based on these data, the module developed has a good and appropriate interpretation to be used as a learning resource.

3.5 *Small-scale trial*

This trial aims to determine the feasibility, obtain opinions and suggestions from students so that the resulting e-module can be used as a source of learning for students on solubility and solubility results. As many as 30 students and three teachers filled out the assessment of the e-module by completing the questionnaire. The results of the small-scale trial are as follows:

Table 4. Percentage of student and teacher answers on the small-scale trial.

	Student		Teacher	
Indicator	% Average	Interpretation	% Average	Interpretation
Conformity with curriculum	82.22	Good	80	Good
Content clarity	80.50	Good	81	Good
Questions as evaluation tools	78.33	Good	80	Good
Language	81.67	Good	80	Good
Display design	82.47	Good	80	Good

3.6 *Large-scale trial*

After the small-scale trial and improvements to the e-module, the next process is to conduct a large-scale trial with the aim of determining the feasibility and opinions of students and teachers on a large scale regarding the e-module that has been developed. As many as 70 students and five teachers assessed the e-module and the results are as follows:

Table 5. Percentage of student and teacher answers on the large-scale trial.

	Student		Teacher	
Indicator	% Average	Interpretation	% Average	Interpretation
Conformity with curriculum	85	Good	87.6	Good
Content clarity	83	Good	87.2	Good
Questions as evaluation tools	80	Good	86.6	Good
Language	90	Good	89.6	Good
Display design	90	Good	87.2	Good

3.7 *Implementation*

From the results of the validation carried out by the experts, it can be said that the e-module learning developed is suitable for use as a learning resource. Then, the implementation is carried out into learning with the aim of knowing the effect of using an e-module on students' problem-solving abilities.

The data taken are data on problem-solving ability by giving a test related to solubility material and solubility results. Tests are conducted on students in the form of a pretest and post-test in the control and experiment classes to determine the extent to which the development products tested can improve students' problem-solving abilities. The problem-solving ability test results can be seen in the following table:

Table 6. Average test scores of students' problem-solving abilities.

Class	Pretest	Post-test
Experiment	14.53	84.01
Control	13.59	49.43

After testing the analysis prerequisites, namely normality and homogeneity tests, it is known that the two sample classes are normally distributed and homogeneous. Therefore, the research hypothesis testing uses a parametric test, namely a t-test to determine the effect of using an e-module on the problem-solving ability of class XI students on solubility and solubility product.

Based on the results of calculations to compare the value of the post-test of the experimental class and the control class a count of 1.9147 was obtained, while the t-table was 1.2972 for dk = 78 at $\alpha = 0.05$. The calculation results are in the rejection area H0. Therefore, H0 is rejected, meaning that there is a significant difference between the value of the post-test of the experimental class and the control class. It can be concluded that there is a significant difference between the value of problem-solving abilities of students treated with learning using an e-module compared with students who use textbooks.

There is an increase in the average problem-solving ability of students who use the e-module as a learning resource. This is in line with observations made by researchers that students become trained to use problem-solving steps to solve problems. Groups that use e-modules in pretests and post-tests have an increase in problem-solving abilities. This result is in accordance with Hwang, G., Chen, C., Tsai, P. & Tsai, C. (2011) who state that the novel approach based on IT is able to provide accurate and constructive suggestions to students in improving their problem-solving abilities.

4 CONCLUSION

Based on the results of the research, it can be concluded that the e-module in chemistry learning on the solubility and the solubility product developed produces a good interpretation and is suitable for use in the 2013 Curriculum learning at the high school level and has been developed according to the needs of teachers and students. The use of multimedia creates an environment where students could visualize the abstract chemical processes via animations and videos at macroscopic, microscopic and symbolic levels (Bowen, 1998)

The module developed is equipped with examples and practice questions that train students' problem-solving ability. In the experimental class, students who use the e-module have higher problem-solving ability than the class that uses books as a control class. Therefore, it can be concluded that the use of an e-module with the scientific approach developed, can improve students' problem-solving abilities.

In developing the e-module, researchers realize there are strengths and weaknesses of the products. The strength of the e-module developed is an attractive display that motivates students to learn, can help visualize abstract concepts and is easy to operate (user friendly), so that it can be studied independently by students. Additionally, it is equipped with scientific learning so that it can train students' problem-solving ability. There are weaknesses of the e-module developed so it must be refined.

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Effect of instructional materials on academic performance in the heat transfer concept among secondary school physics students in the Fagge Educational Zone, Kano State, Nigeria

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ABSTRACT: This study investigated the effects of instructional materials on academic achievement in the concept of heat transfer in physics among senior secondary school students in the Fagge Educational Zone, Kano State, Nigeria. The population consisted of Senior Secondary School II (SSII) students from ten public schools. Of these, 87 students were randomly selected from which 24 males and 22 females formed the experimental group, with 41 students as the control group. A quasi-experiential design with a pretest and post-test for both groups was adopted. Two research questions and null hypotheses guided the conduct of the study. The experimental group was exposed to teaching using instructional materials, while the control group was taught using the normal lecture mode. The Heat Transfer Achievement Test (HTAT) was used for data collection. This instrument has been validated by experts in the science education field. A Pearson Product Moment Correlation (PPMC) was used to determine the reliability coefficient, which was found to be $r = 0.83$. The research questions were answered using descriptive statistics while the hypotheses were tested at a $p \leq 0.05$ level of significance using a t-test. The results obtained from the data analysis showed that students in the experimental group performed significantly better than those in the control group and that there was no significant difference in the academic performance between male and female students in the experimental group. Based on the findings of this study, it is recommended that physics teachers should receive regular training on the importance of using instructional materials whether ready-made or improved in their teaching.

1 INTRODUCTION

Science, as a subject, occupies a very important position in the school curriculum. Therefore, there is much emphasis on science and science related subjects in both primary, secondary and tertiary levels of education and on the need for the introduction of more practical components in order to improve scientific thinking and application among the students (Bello, 2012).

Physics, which studies matter, energy and their interactions, is an international enterprise which plays a key role in the future progress of human kind. The support of physics education and research in all countries is important because it is an exciting intellectual adventure that inspires young people and expands the frontiers of knowledge about nature ("C14: Mandate | IUPAP: The International Union of Pure and Applied Physics," 2018). It extends and enhances understanding of other disciplines.

The teaching of physics in schools has not been encouraged due to the abstract nature of the subject, which is why the use of instructional materials is needed to facilitate students' leaning. Oladejo et al. (2011) stressed that mastery of physics concepts cannot be fully achieved without the use of instructional materials. Looking at the nature of science, we should not read science, but we should do science. This can only be done by the effective use of instructional materials. Therefore, the effects of instructional materials on academic achievement among senior secondary school physics students is worth investigating.

Instructional materials are used by teachers to facilitate effective teaching and better quality of learning by students. While some students learn and retain information that is fed to them through lectures, others learn better by reading and others absorb information with the aid of visual cues in addition to the lectures and reading. The use of instructional materials assures and provides students with different learning and helps them retain the information given to them (Atadoga, 2006).

1.1 *Statement of the problem*

Physics is one of the science subjects that remains one of the most difficult subjects in the school curriculum according to Aina and Akintunde (2013). They add that students usually perform very poorly in physics in all levels of education. In a contribution by Abimbola (1999) to ways of improving students' understanding in physics, he stressed that teachers as well as curriculum developers must emphasize the use of instructional materials during lessons. Many researchers have equally supported the view that students perform poorly in physics (Aiyelabegan, 2003; Akanbi, 2003).

Van (2010) stated that the guidelines for the use of instructional materials emphasized that they should be based on the fundamental concepts and principles of the specific subject or courses that are taught. The purpose of this is to align students' understanding of the topic with current knowledge. It also teaches them to control and monitor their thinking processes to facilitate learning and subsequently, performance in physics can be improved.

1.2 *Objectives of the study*

The objectives of this study are:

1. To determine the effect of instructional materials on physics students' academic performance in the heat transfer concept.
2. To determine the gender difference in academic performance when taught using instructional materials.

1.3 *Research questions*

1. What is the difference between the mean scores of students taught using instructional materials and those taught using a lecture method?
2. What is the difference between the mean scores of male and female students taught using instructional materials?

1.4 *Null hypotheses*

The following hypotheses were formulated and tested at a $p < 0.05$ level of significance:

$H0_1$: There is no significant difference between the mean scores of students taught using instructional materials and those taught using a lecture method.

$H0_2$: There is no significant difference between the mean scores of male and female students when taught using instructional materials.

1.5 *Significance of the study*

The study is of great importance to both the students of the various secondary schools as well as the teachers teaching in various secondary schools. The study will positively contribute toward improving the knowledge of the students by relating theory lessons taught in the class with concrete reality. By implication, it will serve as a source of motivation for learning.

Physics teachers will find this research very useful by creating awareness of the state of availability of physics instructional materials in their possession. They will be made aware of the need of sourcing instructional materials and integrating them into teaching students each physics concept.

Other researchers may develop an interest in investigating the effect of instructional materials on academic achievement of students in other concepts of physics or in other science subjects in general. This will also serve as a literature review in related fields.

1.6 *Scope*

The scope of the study will be limited to SS2 students of two senior secondary schools in the Fagge Educational Zone of Kano State on the topic of 'heat transfer'.

2 METHOD

The research design adopted a pretest, post-test quasi-experimental control group design as proposed by (Kerlinger, 1973). The study concerned two groups consisting of both male and female students.

A pretest was administered to both the experimental and control groups before treatment. The pretest was administered to determine the general knowledge of entry behavior of the subjects on the selected topics before treatment and the post-test was administered to determine the effectiveness of the treatment. The design for the study is represented as follows:

$$\begin{array}{lll} EG \longrightarrow & O_1 \longrightarrow X_1 \longrightarrow O_2 \\ CG \longrightarrow & O_1 \longrightarrow X_0 \longrightarrow O_2 \end{array}$$

Figure 1. Research design adopted from Kerlinger (1973).

Key: EG → Experimental Group,
CG → Control Group,
X_1 → Treatment (use of instructional materials),
X_0 → No Treatment (Lecture method),
O_1 → Pretest,
O_2 → Post-test.

2.1 *Study population*

The study population comprised all SSII physics students in ten public schools in the Fagge Education Zone of Kano State as indicated in Table 1.

2.2 *Sample and sampling procedure*

A simple random sampling technique was utilized in order to select two schools out of the ten in the population. The choice of 87 students as a sample was appropriate for the study and is in conformity with the central limit theorem where Tuckman (1972) proposed 30 as a minimum sample size for an experimental study of this nature. The sample statistics are shown in Table 2.

The instrument used to collect data for the study was a 40 item Heat Transfer Achievement Test (HTAT). The test items were based on the senior secondary physics curriculum. The instrument was developed by the researcher and validated by experts in the science education field. HTAT was used for both the pretest and post-test. The instrument was pilot tested on a different set of students who were not involved in the study. A test–retest method was used to determine the reliability of the instrument. The result of the test was correlated using the Pearson Product Moment Coefficient (PPMC) and was found to be 0.83, which indicated that the instrument could reliably be used to carry out the research. Table 3 carries the specification for HTAT.

Table 1. The study population.

S/N	Name of school	Type of school	Male	Female	Total
1.	Govt. College Kano (KTC)	Male	58	–	58
2.	Govt. Girls Sec. School Aisha Shehu	Female	–	55	55
3.	Govt. Sec. School Danwaire	Mixed	24	22	46
4.	Govt. Sec. School Stadium	Male	45	–	45
5.	Govt. Sec. School Nomans Land	Mixed	30	26	56
6.	Govt. Girls Sec. School Dabo	Female	–	45	45
7.	Govt. Sec. School Zawa'i	Mixed	22	19	41
8.	Govt. Day Sec. School Bukavu	Mixed	33	20	53
9.	Govt. Girls Sec. School Maryam Abacha	Female	–	50	50
10.	Govt. Sec. School Kwakwaci	Male	48	–	48
		Total	**260**	**237**	**497**

Table 2. Sample of the study.

S/N	Schools	Male	Female	Total	Group
1.	G.S.S Danwaire	24	22	46	Experimental
2.	G.S.S Zawa'i	22	19	41	Control
	Total	**46**	**41**	**87**	

Table 3. Table of specification based on Bloom's Taxonomy in the cognitive domain.

S/N	Content	Weight %	Knowl. 40%	Compr. 20%	Appl. 20%	Analy. 0%	Syn. 10%	Eval. 10%	Total
1.	Types of medium	25	4	2	2	–	1	1	10
2.	Conduction	25	4	2	2	–	1	1	10
3.	Convection	25	4	2	2	–	1	1	10
4.	Radiation	25	4	2	2	–	1	1	10
	Total	**100**	**16**	**8**	**8**	**–**	**4**	**4**	**40**

Source: Adapted from Obeka (2012).

Both the control and the experimental groups were pretested using test items that reflected the concept of heat transfer. This is to assess the level of knowledge of these groups before a treatment is given. Having taught the students in the control group using lecture methods and the experimental group using the instructional materials for the desired period, the post-test was then administered to both groups using the same HTAT used in pretest. After marking, the scores recorded were statistically analyzed to answer the research questions and test the null hypotheses. The research questions were answered using descriptive statistics of mean and standard deviation, while the two null hypotheses stated, were statistically tested at a 0.05 level of significance.

3 RESULTS AND DISCUSSION

3.1 *Research question one*

What is the difference between the mean scores of physics students taught using instructional materials and those taught using a lecture method?

To provide an answer to the above question, the mean and standard deviation scores of the students where used in Table 4.

Table 4. Post-test mean scores of the experimental and control groups based on performance.

Group	N	Mean	Std. deviation	Mean difference
Experimental	46	57.65	15.00	11.16
Control	41	46.49	16.00	

Table 5. Post-test *t*-test of the experimental and control groups based on academic performance.

Group	N	Mean	Std. deviation	Std. error mean	df	t_{calc}	t_{crit}	p-value
Experimental	46	57.65	15.00	2.24	85	3.34	1.98	0.00062
Control	41	46.49	16.00	2.50				

* Significant at $p < 0.05$ level.

Table 6. Post-test mean scores of the experimental and control groups based on performance.

Gender	N	Mean	Std. deviation	Mean difference
Male	24	57.96	15.17	0.64
Female	22	57.32	20.12	

From Table 4, it is clear that the mean score of the experimental group of students taught using instructional materials is higher than the mean score of the students in the control group taught using the conventional lecture method and the mean difference is recorded as 11.16. With this difference, it can be deduced that the use of instructional material in teaching the experimental group had a positive impact on the learning of the selected physics concept over their counterparts. To find out how significant the difference is, *t*-test statistics were used.

3.2 *Null hypothesis one*

$H0_1$: There is no significant difference between the mean scores of students taught using instructional materials and those taught using a lecture method.

To test this hypothesis, the mean scores of students in the experimental group and those of students in the control group were analyzed using *t*-test statistics. The analysis is shown in Table 5.

The analysis in Table 5 shows that t_{calc} of 3.34 is higher than the observed t_{crit} of 1.98 and the *p*-value observed was 0.00062 at the degree of freedom of 83 and 0.05 level of significance. From what is shown, it is conspicuous that, the observed p-value of 0.00062 is less than the alpha value of 0.05, which justifies that there is a significant difference in the performance of students taught a physics concept using instructional materials and those taught without it. The experimental group mean score is clearly higher than that of the control group and this implies that the students in the experimental group have performed relatively better than those in the control group.

3.3 *Research question two*

What is the difference between the mean scores of male and female students taught using instructional materials? The data recorded for the purpose of answering research question two were analyzed using descriptive statistics in the form of mean and standard deviation as indicated in Table 6.

From Table 6, there exists a relatively small difference of 0.64 between the mean of the males and that of the females, which indicates that the males have achieved higher scores. However, to find out if this difference is significant, *t*-test statistics were applied.

Table 7. Post-test *t*-test analysis of the performance of male and female students in the experimental group.

Group	N	Mean	Std. deviation	Std. error mean	df	t_{calc}	t_{crit}	p-value
Male	24	57.96	15.17	3.10	44	0.12	2.00	0.45
Female	22	57.32	20.12	4.28				

Not significant at $p > 0.05$ level.

3.4 *Null hypothesis two*

$H0_2$: There is no significant difference between the mean scores of male and female students when taught using instructional materials.

To test the second hypothesis, the post-test mean scores of male and female students in the experimental group were analyzed using *t*-test statistics. The results of the *t*-test analysis are displayed in Table 7.

From Table 7, the calculated *t*-value of 0.12 is less than the observed critical value of 2.00 at $p < 0.5$ level of significance and 44 as the degree of freedom. Also, the obtained *p*-value of 0.45 is greater than the 0.05 significance level. With these, it can be deduced that, there is no significant difference in the performance of male and female students when taught using instructional materials. From the fact that they show a marginal difference in performance, it can be concluded that they have a relatively equal performance. The null hypothesis is therefore retained.

3.5 *Discussion of results*

The findings of this study have revealed that the result from research question and hypothesis one indicated that the experimental group have benefited from learning about the concept of heat transfer in physics using the instructional material. This is evident from their performance in the post-test, which is higher than that of the control group.

Furthermore, from the findings, considering the research question and hypothesis two, the performance of male and female students in the experimental group was almost similar in their post-test results. In this respect, Yakubu (2011) stated that teaching and learning processes under the same conditions have to do with mental and intellectual ability and not gender. This author also observed that the degree of academic success measured by achievement outcome is higher for students who benefited from instructional materials in supporting learning than those who did not.

4 CONCLUSION

Based on the findings of this study, it can be concluded that the use of instructional materials like prints, audios, visuals and audiovisual materials in the teaching of a physics concept has a significant effect on students' academic achievement because they support learning by creating an atmosphere for interaction and provide repetition.

5 RECOMMENDATIONS

The following recommendations are made:

1. Physics teachers should develop a positive attitude toward the use of instructional materials in their possession for their students in order to encourage the development of proficiency.

2. It is pertinent for curriculum planners and textbook publishers to put more emphasis on the use of instructional materials in science teaching, particularly in physics.
3. Federal government, through its agencies like NERDC, NTI, FIE and so on, should pay more attention to the provision of instructional materials and compel its usage in schools and the same should apply to states.
4. Physics teachers under teachers' boards in the states should be trained on the importance of using instructional materials in teaching physics whether ready-made or improvised.

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Integration of the green chemistry approach in essential oil extraction practice to develop students' critical thinking skills

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ABSTRACT: The purpose of this study was to develop students' critical thinking skills through the integration of a green chemistry approach in laboratory teaching of essential oil extraction and nanoscale Zero-Valent Iron (nZVI) synthesis materials. The research employed a qualitative approach with multiple methods including interviews, reflective journal, student observation and a critical thinking skills test. The study involved 33 secondary school students of the 2017/2018 academic year. The results show that students' critical thinking was analyzed in the dimensions of identifying questions about issues, conceptual understanding, connected assumption and inference with the criteria of competence. In addition to critical thinking test shows 21.21% students show very good criteria, 18.18% students show good criteria, 39.39% students show enough criteria, 9.09% students show less criteria, meanwhile 12.12% students have very less criteria of thinking skills. The green chemistry approach allowed students to engage with critical reflective thinking process and envision for environment sustainability. The chemistry learning has become a more engaging and meaningful experience.

1 INTRODUCTION

Chemical learning emphasizes how students gain knowledge (learning to know), concepts and theories through practical experience by conducting observations or experiments (learning to do) and skill objectives so that they act as scientists (Boss & Krauss, 2007). Chemical learning today is focused on thinking about the influence of chemical compound production on the environment. Many chemical products that were once considered environmentally friendly were later restricted because they are harmful to the environment and health; green chemistry began in the 1980s and relates to the application of 12 principles aimed at reducing industrial activity and impact chemicals and products to human health and environmental conditions (Anastas & Warner, 1998). In this study, the green chemistry principle used was limited to six principles, including the third principle (non-hazardous chemical synthesis), fifth (safer solvent use), sixth (energy efficiency design) and the twelfth (safer chemicals to prevent accidents).

The synthesis of a green nanoproduct has its own policy. Klausmeier (2016), reveals that simple concepts, cheaper synthesis costs and more environmentally friendly processes will reduce the risk of pollution caused by nanoscale products. Green nano policy is also directed at producing experts in the field of nanotechnology who can develop themselves in methodologies as well as experts who understand potential nanomaterials. Critical thinking is one of the important products that can be generated through contextual learning of chemistry. Critical thinking skills have become an absolute necessity for learners in this technology era (Fisher, 2014).

This is done to improve critical thinking skills, so learning is directed at the application of the principles of green chemistry. This green chemistry principle can be used to conduct laboratory activities by utilizing the environment as the main source. Schools can keep doing practicum activities by using materials that are environmentally friendly and available in nature. In addition, laboratory activities can be performed not only indoors but also at home or in the neighborhood (Hjeresen et al., 2000).

2 METHOD

This research has a specific purpose, which is to conduct 'Integration Of The Green Chemistry Approach In Essential Oil Extraction Practice To Develop Students' Critical Thinking Skills'. This research is a qualitative research providing a detailed description of the learning process using a green chemistry approach. Data collection is based on observations made during the study, a reflective student journal and interviews.

3 RESULTS AND DISCUSSION

The integration of green chemistry into the chemistry curriculum provides students with motivation and opportunities to overcome, explore and enjoy science from the beginning. This curriculum provides a broad understanding of the impact of science, bridging the gap between the global class and environment and most importantly, helps to prepare chemists who are concerned about health and the environment in the future. Green chemistry is a pillar for sustainable development (Singh & Ravichandran, 2014). The green chemistry approach in this study aims to prevent pollution due to chemicals that can damage the environment and health. It is necessary to think about how to apply green chemistry concepts and ideas in chemistry learning in schools; thus, educators or teachers in chemistry need to have adequate knowledge.

3.1 *Research implementation*

3.1.1 *Learning process with the green chemistry approach*

In the approach to green chemistry in the laboratory, students are given a learning experience to examine each of the practicum steps to be undertaken, to examine chemical reactions, the properties of the chemicals used such as solvents including toxic and hazardous substances or that materials used are environmentally friendly. Therefore, students, in doing practicum, not just follow the procedures that already exist, but are invited to develop the ability to think critically in solving environmental problems.

3.1.2 *Practicum implementation*

The green chemistry learning approach is a chemical learning approach developed by linking directly to real objects or phenomena around students' lives about environmental sustainability to prevent pollution, so that in addition to educating, a green chemistry approach also allows students to learn the process of processing a material into a useful product, making the chemistry lesson more interesting, fun and more meaningful.

3.1.3 *Extraction of polyphenols from Citronella Wangi*

Laboratory experiments conducted by students were extracting essential oils (polyphenol compounds) in citronella with a green chemistry approach integrated nanotechnology. The steps taken in the practicum, including the citronella extraction process are carried out using the Soxhlet method.

The application of the green chemistry principle in this practicum involves the use of environmentally friendly solvents (green solvent) to extract polyphenol compounds contained in fragrant lemongrass essential oil. The solvent used in the practicum is ethanol (C_2H_5OH).

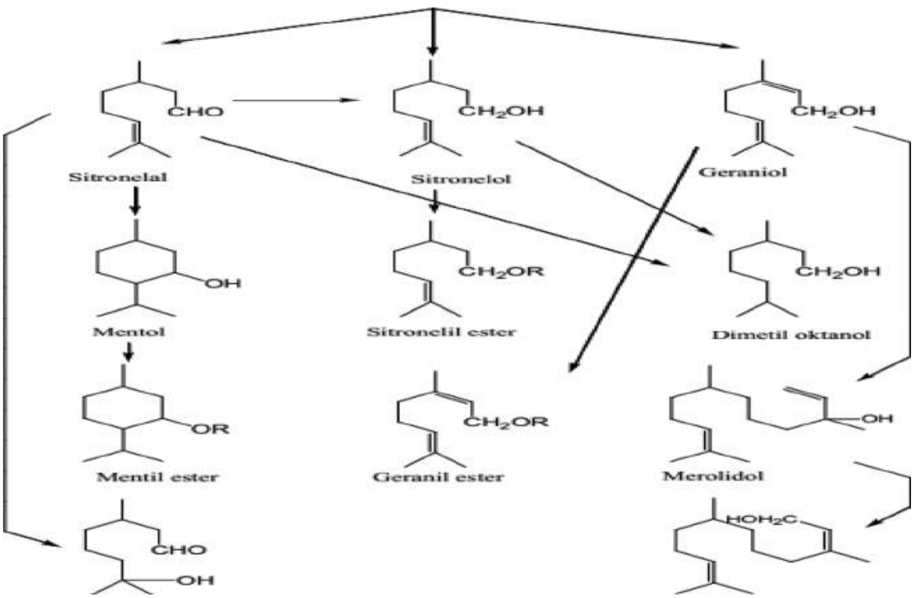

Figure 1. Components of fragrant essential oil.

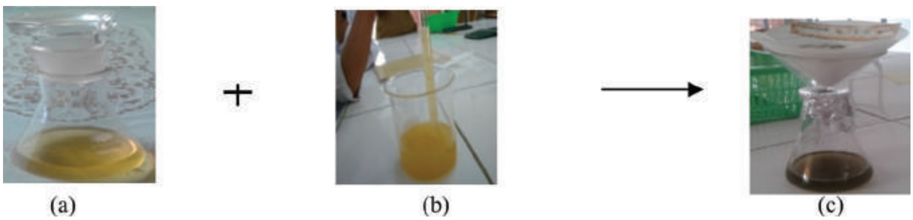

Figure 2. Polyphenols: (a) $FeSO_4.7H_2O$ 0.1 M; (b) before the reaction; (c) nZVI produced.

This is because, ethanol solvents are cheap, have a low boiling point (65ºC), making a suitable solvent to extract fragrant lemongrass essential oil. Here, the compounds contained in the essential oil of citronella are outlined:

3.1.4 *Synthesis of nZVI from $FeSO_4$ using polyphenols*

Nanoscale zero-valent iron (nZVI) or zero-valent iron nanoparticles are nanoparticles that have Fe (0) nuclei, and Fe (II) and Fe (III) layers on the outside due to Fe (0) oxidation by air (Li et al., 2006). The nZVI synthesis process is carried out by reacting a 0.1 M $FeSO_4.7H_2O$ solution with polyphenol directly with a ratio of 1:1 composition; 3:2 and 4:1 (Budi et al., 2019).

The nZVI synthesis of polyphenol in clear brown and yellow $FeSO_4.7H_2O$ 0.1 M produces nZVI in a black solution. During the course of the practice, questions were asked of the teacher by the students:

Student 6: 'Miss, why is the solution so black?'
Teacher: 'The color change of this blackish solution indicates the formation of iron nanoparticles'.

Based on conversations similar to the above, the students' critical thinking skills arise, when there are things that have just been discovered or come up with more curiosity about the processes that occur during the lab. Teachers provide answers that are accompanied by references to such matters in journals or scientific books.

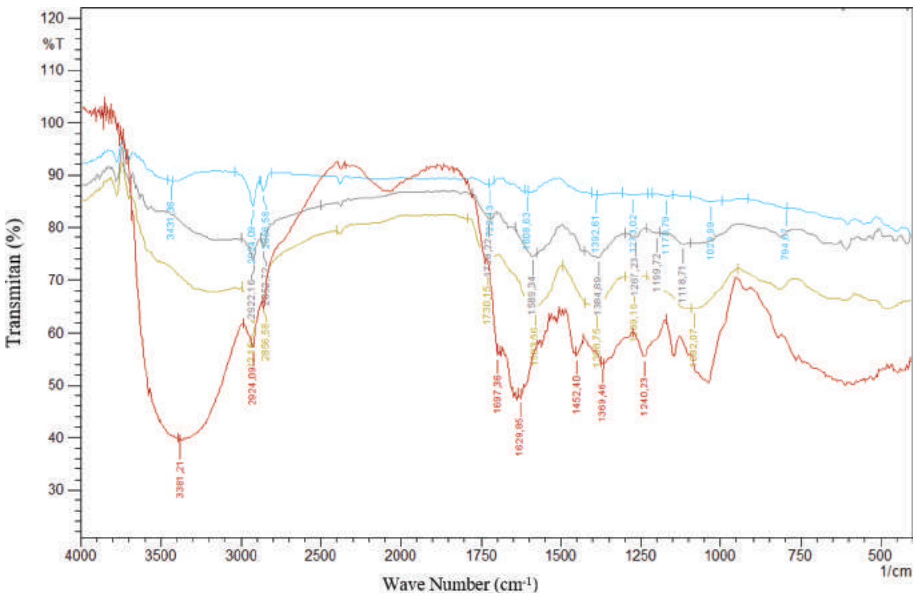

Figure 3. Spectrum IR polyphenols are fragrant sereh (▬), polyphenols: $FeSO_4.7H_2O$ (1:1) (▬), polyphenols: $FeSO_4.7H_2O$ (3:2) (▬) and polyphenols: $FeSO_4.7H_2O$ (4:1) (▬).

The analysis using Fourier-Transform Infrared (FTIR) spectroscopy aims to identify the functional groups contained in nZVI synthesis. Previously, synthesis of nZVI was carried out by reacting polyphenols and $FeSO_4$ 0.10 M using an optimum composition ratio, which is 4:1 with a reaction time of one hour. The suspected compound nZVI is then analyzed using FTIR to see the change of functional group. Figure 3 shows the spectrum of FTIR nZVI synthesis with a ratio of 4:1 composition.

Based on the spectrum in Figure 3, there are several different peaks when compared with the FTIR spectrum of polyphenols. This difference indicates a change in functional group structure from polyphenols to nZVI. At wave number 3390.86 cm^{-1}, there is a peak that shows stretching O-H. The peak at 1604.77 cm^{-1} is the aromatic C = C functional group uptake, then the peak at wave number 1093.64 cm^{-1} indicates the presence of the $SO_4$2– (Nakamoto, 2009) inorganic group derived from $FeSO_4$ used in the synthesis of nZVI, while wave numbers 443.63 cm^{-1}, 511.14 cm^{-1} and 619.5 cm^{-1} indicate the presence of Fe-O bonds from Fe_2O_3, Fe_3O_4 and γ-Fe_2O_3. This result is consistent with the study reported by Zhang et al. (2011) where, in the wave number, there is stretching of Fe-O from the tetrahedral and octahedral sides of the structure. The formation of Fe-O is because the synthesized nZVI has been oxidized to iron oxide which then envelops nZVI around the core (shell-shell).

3.2 *Results of student critical thinking skills test*

This question is useful for strengthening students in understanding the concept and developing critical thinking skills after conducting learning and extraction of citronella essential oil with a green chemistry approach integrated nanotechnology. Completing the concept comprehension questions is undertaken after the practicum is carried out. The results will be categorized as very good with values ($80 < \chi \leq 100$), good ($70 < \chi \leq 79$), sufficient ($60 < \chi \leq 69$), less than ($55 < \chi \leq 59$) and considerably less ($54 < \chi \leq 0$), using the school assessment system.

Each student is grouped according to a very good group of seven students, a good group of six students, a sufficient group of 13 students, a less than group of three students and a considerably less than group of four students based on the value of critical thinking tests. Based on the data, the average score of students' critical thinking skills for the very good group is 83.30; good group is 75.00; sufficient group is 64.80; less than group is 55.83; and the considerably less than group is 33.50. Data from the assessment of students' critical thinking skills were analyzed qualitatively. The bar diagram of the assessment of students' critical thinking skills is presented in Figure 4.

Based on Figure 4, it is seen that students' critical thinking skills are said to be in the category of 'considerably less than' ($0 < \chi \leq 54$) at least if compared with other categories, that is only four students or 12.12%, while the critical thinking ability of the most category 'sufficient' ($60 < \chi \leq 69$), is as many as 13 students or 39.39%. Students who have critical thinking skills in the category of 'very good' ($80 < \chi \leq 100$) are seven students or 21.21%. Students who have critical thinking skills in the 'good' ($70 < \chi \leq 79$) category are six students or 18.18%. Students who have critical thinking skills in the categories 'less than' ($55 < \chi \leq 59$) are three students or 9.09%, so the average score of students' critical thinking ability is 64.8 which is in the 'sufficient' category. The interpretation of the final score of the final ability to think critically can be seen in Figure 5.

Based on the average score of critical thinking skills of class XII students in the academic year 2017/2018, students' critical thinking ability is in the 'sufficient' category. The first indicator, namely identify the question at issue, appears at the stage of the practicum implementation where students are expected to identify a phenomenon which is a problem given by the teacher, then they answer questions based on what they understand. Based on the essay test analysis, students are able to explain the findings and formulate the problem based on the phenomenon that has been understood by the percentage as a whole, which is in the very good category. Students already have the ability to focus the question on the given problem of getting appropriate and directed answers, which will not raise the question back from the written answer.

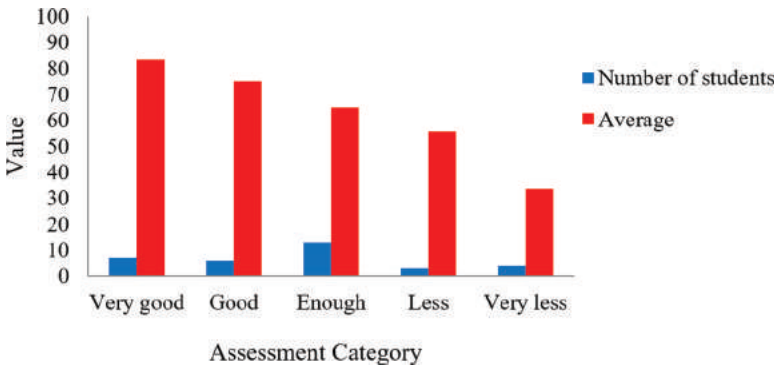

Figure 4. Bar chart test results of critical thinking skills.

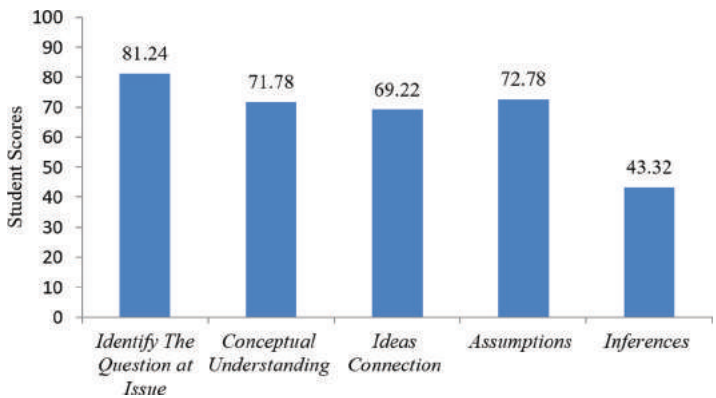

Figure 5. The average value bar diagram is a critical thinking indicator.

The second indicator, in Bloom's taxonomy, understanding ability, is higher than remembering. Based on the results of critical thinking tests obtained in the category of 'good', it can be said that students have enough concept to answer the given problem. There is a linear relationship between the understanding of concepts possessed by students with critical thinking abilities that can be seen in the test results. However, a few students have difficulty in learning the concept of essential oil extraction and nZVI synthesis with a green chemistry approach, which affects the test results of critical thinking ability. The third indicator, connection ideas, some students respond appropriately, in which students are able to distinguish which relevant arguments and which arguments are irrelevant. However, there are also students who have not been able to differentiate between relevant and irrelevant arguments. Regarding the fourth indicator, assumptions, some students responded appropriately, in that they were able to assess the allegations or presuppositions given. This assumption must be demonstrated through a procedure to produce an answer, whether the assumption is right or wrong. However, there are still students who have not been able to work, so it cannot determine whether the assumptions given are true or false. The fifth indicator, namely inferences, some students answer correctly, where students are able to apply skills in identifying and searching for things that are needed in order to draw conclusions, namely information, then consider the information and conclude the consequences of data provided.

4 CONCLU SION

Based on the results of the study, learning with a green chemistry approach can improve students' critical thinking skills. The synthesis of nanoparticles with a green chemistry approach adds to students' insight into making environmentally friendly synthesis products. The essence of the synthesis of these products can be used as the latest information and widely applied, as well as in depth to improve the quality of learning in SMK.

It is suggested that the green chemistry approach is not only done on practicum matter of extraction of essential oil of cross link nZVI. In order for teachers to review and revise the experiments that have been carried out, they should look for alternatives and choose practical materials and develop, design and conduct new experiments oriented toward green chemistry.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Development of mobile learning media based on Education for Sustainable Development (ESD) in a chemical equilibrium topic

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ABSTRACT: This study aimed to develop and test the feasibility of mobile learning media based on Education for Sustainable Development (ESD) in a chemical equilibrium topic. The study was conducted in a chemistry learning laboratory, Universitas Negeri Jakarta (UNJ) and the trial was conducted at one of senior high school in Jakarta, Indonesia in the 2017–2018 school year. This study used the research and development method of Gall, Gall and Borg which is modified with the stages of needs analysis, development, feasibility tests and product trials. The feasibility test by a media expert obtained an average score of 95.5% with a value of $r = 0.77$ and the feasibility test by the subject material expert obtained an average score of 94.6% with a value of $r = 0.85$. The mobile learning media developed is suitable for use as learning media with very good criteria in terms of media and subject matter. The results in the small-scale trial stage obtained an average score of 89.5%, trial by the chemistry teacher obtained an average score of 92.6% and the large-scale trial obtained an average score of 88.2%. Overall the trials achieved very good criteria. Based on the results of all of these stages, it can be concluded that ESD-based mobile learning media in a chemical equilibrium topic is suitable for use as learning media and in accordance with needs.

1 INTRODUCTION

Education for Sustainable Development (ESD) is a program from United Nation Educational, Scientific and Cultural Organization (UNESCO) that is currently being carried out intensively considering that ongoing development has not taken into account the impact on the environment. ESD has a primary focus of equipping the community, especially the younger generation, to be ready to face the challenges of the globalization era in the twenty-first century. In Indonesia, ESD programs are carried out by mobilizing a number of Non-Governmental Organizations (NGOs) that have partnerships with local governments such as teachers, principals, city offices or district education, Environmental Agency or other NGOs to realize their programs. One of the main applications is in schools, but the results are not yet apparent because there is still a lack of activities that support the implementation of the ESD program.

Based on observations in one of the high schools in Jakarta, 94% of respondents did not know the ESD program. This shows that the majority of respondents, who are the younger generation, have not been provided with ESD insight. Teachers, as facilitators during the learning process, can actually link ESD to learning. A lot of learning material and limited face-to-face time are obstacles in implementing ESD in learning. If the ESD program can be applied by the younger generation in their daily lives, it will provide benefits in economic, ethical and social aspects.

Chemistry is one of the learning materials that plays an important role in ESD programs. There are many aspects of everyday life related to chemistry. Based on observations, students who are less interested in chemistry, especially the topic of chemical equilibrium, because the delivery of the topic is less interesting. One of the reasons for the lack of interest of respondents is due to limited face-to-face time in class when the learning process takes place. Therefore, in the learning process, teachers must be able to create alternative learning resources in accordance with the demands of twenty-first century competencies/skills.

One technology approach that is growing rapidly at this time is mobile phone devices. Based on observations, it was noted that 100% of respondents had mobile phone devices. This can be an opportunity for teachers to utilize technology to develop a learning medium as a solution to attract students' interest in learning chemistry, especially chemical equilibrium materials while implementing ESD programs (Nalliveettil, 2016). Learning media that can be developed include mobile learning. In line with this, several studies have found that students who use mobile learning as a learning resource, can learn freely anytime and anywhere (Litchfield, Dyson, & Lawrence, 2007). The development of mobile learning media associated with ESD programs is important and can be a solution in the application of ESD during the learning process, especially learning chemistry in relation to chemical equilibrium material in accordance with a needs analysis. It is expected that the development of this mobile learning media can help teachers overcome learning constraints for students and implement ESD programs (Ally, 2013).

2 METHOD

This study uses the research and development method Gall, Gall and Borg (Gall, Gall, & Borg, 2003) which is modified into several main stages, namely needs analysis, product planning and development, and product trials which include feasibility tests by experts, small-scale trials, teacher trials and large-scale trials with research subjects who are students of class XI and two chemistry teachers. The research was conducted at the chemistry learning laboratory, UNJ and a trial in one of the senior high schools in Jakarta in the 2017–2018 school year.

The questionnaire was designed with a Guttman scale and a Likert scale at the feasibility test and trial phase. Data collection techniques were carried out by questionnaire needs analysis to respondents, a feasibility test questionnaire to media experts and material experts as well as a trial questionnaire to respondents. The data collected were then interpreted into a rating scale score and the reliability was calculated to determine the consistency of the experts in providing an assessment based on the Intraclass Correlation (ICC) by Fleiss Kappa (Mandrekar, 2011).

3 RESULTS AND DISCUSSION

3.1 *Needs analysis results*

The results of the need's analysis state that, as many as 64% of respondents said that the topic of chemical equilibrium was a difficult topic. One reason is that as many as 40% are presented with less interesting. Based on these results, 86% said that there is a need for learning media in the form of applications on devices or gadgets to help understand chemical equilibrium material outside school hours. As many as 96% of respondents said that they did not know about ESD.

3.2 *Development phase*

The development of the learning media was conducted through two stages, namely the planning stage and the development stage.

3.2.1 *Planning phase*

Learning media are designed in the form of story boards. Furthermore, to develop learning media used Adobe Photoshop and Adobe Flash CS6 software. Development of learning media is also linked to the implementation of the ESD program in studying the topic of chemical equilibrium. One of the objectives of the ESD program that was adapted was clean water and sanitation through reducing wastewater to improve the quality of clean water. Clean water and good sanitation will create a healthy environment. The implementation of the ESD program is carried out through the practice of factors that affect chemical equilibrium using environmentally friendly materials. After being successfully tested, the program was included in the learning media developed.

3.2.2 *Development phase*

At this stage, the design of learning media was developed using Adobe Photoshop software, then to make the application become a mobile learning using Adobe Flash CS6 software. The resulting application was called 'Chemical Equilibrium' in the form of .apk with a capacity of 130 MB.

3.3 *Feasibility test phase*

Mobile learning media were developed and then tested for feasibility by media experts and material experts to determine the feasibility of learning media in terms of media and material. Assessment was done by testing the implementation of the media and scoring through a questionnaire (U. Cahyana, Paristiowati, & Fauziyah, 2018).

Figure 1. Display of the main page before and after revision.

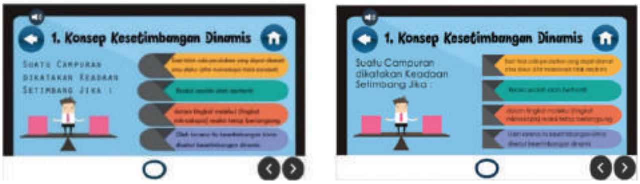

Figure 2. Display of the design of buttons and fonts before and after revision.

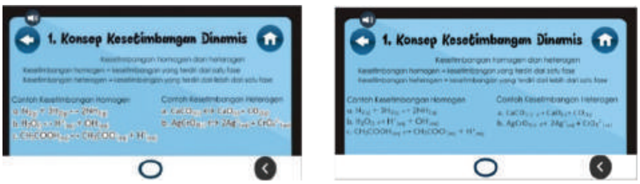

Figure 3. Display of writing before and after revision.

Figure 4. Display of font usage before and after revision.

3.4 *Feasibility test by a media expert*

In the results of the feasibility test by the media expert, the results of the inter-rater reliability test were 0.77, which means that the consistency of the results of the inter-rater assessment was very good. Based on these results, the ESD-based mobile learning media on chemical equilibrium material should be used as learning media with very good criteria from a media perspective.

3.5 *Feasibility test by subject matter expert*

In the results of the feasibility test by the subject matter expert, the results of the inter-rater reliability test were t = 0.85, which means that the consistency between the rater assessment results was very good. Based on these results, ESD-based mobile learning media on chemical equilibrium material deserve to be used as learning media with very good criteria from the material point of view.

3.6 *Trial stage*

At this stage, a trial was conducted in the field which aimed to find out the implementation of instructional media in the field before being used in bulk. The stages in the trial included a small-scale trial, trial by chemistry teachers and a large-scale trial. Respondents at this trial stage were students of class XI MIA and two chemistry teachers in one of the high schools in Jakarta.

Table 1. Results of due diligence by a media expert.

Aspect	Percentage of feasibility	Criteria
Display of audio and visual	92%	Very good
Operation of media	99%	Very good
Average	95.5%	Very good

Table 2. Results of due diligence by a subject matter expert.

Aspect	Percentage of feasibility	Criteria
The relevance of this substance with the competence that must be achieved by students	94%	Very good
Quality of media content	93%	Very good
Quality of language	97%	Very good
Average	95.6%	

Table 3. Results of the trials.

	Small-scale trial		Large-scale trial		Trial by chemistry teacher	
Aspect	Percentage of feasibility	Criteria	Percentage of feasibility	Criteria	Percentage of feasibility	Criteria
Media suitability	88%	Very good	89%	Very good	100%	Very good
Media content	97%	Very good	97%	Very good	92%	Very good
Quality of language	91%	Very good	86%	Very good	90%	Very good
Quality of audio and visual	88%	Very good	82%	Very good	79%	Very good
Operation of media	84%	Very good	89%	Very good	97%	Very good
Benefit of media	89%	Very good	86%	Very good	98%	Very good
Average	89.5%	Very good	88.2%	Very good	92.6%	Very good

The small-scale trial phase aimed to find out the implementation and assessment on a small scale before being tested on a large scale (Ucu Cahyana, Paristiowati, Savitri, & Hasyrin, 2017). Respondents in this small-scale trial consisted of 15 students in class XI MIA in one of the high schools in Jakarta. Based on the results of the small-scale trial, it can be seen that the ESD-based mobile learning media on chemical equilibrium material can be accepted and used for ESD-based learning media.

The next step aimed to determine the implementation and assessment by the chemistry teacher as a form of use of learning media in the learning process. Based on the results of the trial by the chemistry teacher, it can be seen that ESD-based mobile learning media using chemical equilibrium material can be used in the learning process with overall very good criteria and can improve students' insight with very good criteria.

The large-scale trial phase aimed to determine the implementation and assessment of learning media on a large scale. Respondents on this large scale are 36 students of class XI MIA in one high school in Jakarta. Based on the results of the large-scale trial, it can be seen that ESD-based mobile learning media using chemical equilibrium material can be used as learning media with very good criteria.

In line with the results of the learning media test stages, (Ozdamli & Uzunboylu, 2015) in their research, showed that teachers need to use mobile learning applications to support the learning process. (Cavus & Alhih, 2014) their research showed that most students enjoyed using devices or gadgets for learning. Similarly, (Sari & Purtadi, 2013) stated that ESD-based media can be used individually and is easily accessible. Mobile learning is 'green learning' because it can reduce paper printing and is easy to access anywhere. In addition, based on the theory put forward by Locatis and Atkinson quoted from (Naz & Akbar, 2010) the use of media for learning must be designed intentionally to make learning activities more interesting.

4 CONCLUSIONS

Based on the overall stages of the study, it can be concluded that ESD-based mobile learning media using chemical equilibrium material is suitable for use as a learning medium that suits the needs and provides insight into ESD for students as a provision in facing the challenges of the twenty-first century. It was found to have very good criteria in the feasibility test by media experts and subject matter experts, and was very good in small and large scale trials.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Enhancing senior high school student scientific literacy in physics through a water rocket enrichment book and augmented reality application

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ABSTRACT: This paper presents the development of an enrichment book based on an Augmented Reality (AR) application of a water rocket for senior high school students to enhance their literacy in physics. A total of 69 students from SMAN 77 Jakarta participated in this research. They did a pretest and post-test, before and after reading the enrichment book and running the AR application. The data collection was conducted by applying the OECD's Programme for International Student Assessment (PISA) literacy instrument test. Through virtual objects in the AR application, students got the real experience of physics theory application. The data show that the book and the AR application are appropriate to enhance student literacy in physics.

1 INTRODUCTION

Today, students need to acquire twenty-first-century skills to revel in science and technology development. These skills are digital literacy, invention, effective communication and high productivity. Science literacy is essential in digital literacy (Turiman et al., 2012). Here, students are capable of accessing, reading and understanding the global world in the scientific dimension, as well as generating an accurate evaluation for daily life (Okada, 2013). According to the OECD's Programme for International Student Assessment (PISA), scientific literacy is the knowledge and understanding of the scientific concept in the modern world, applying scientific knowledge, problem identification, characterizing the scientific phenomenon, gaining a conclusion based on facts, and participating in scientific subject ideas (OECD, 2016a).

Based on the scientific literacy test conducted by PISA in 2009, the scientific literacy of Indonesian students is low. Indonesia was the 38th of 40 countries in 2009 (Suwono, 2017), the 64th of 65 countries in 2012 (OECD, 2012) and the 62nd of 70 countries in 2015 (OECD, 2016b). This evidence agrees with UNESCO data from 2012; that only one in every 1,000 Indonesians reads a book (Kemendikbud, 2016).

For enhancing scientific literacy capabilities, the Indonesian government stimulates student interest in reading through the school literacy program. The program consists of three phases: habituation, development and learning. In the habituation phase, the student reads a book for 15 minutes every day. In the development phase, students discuss an enrichment book. In the last phase, the student reads an enrichment book in every course subject (Kemendikbud, 2016). Therefore, the student has to read non-text books or enrichment books in the learning process.

A scientific literacy book has several criteria: (1) science as the body of knowledge; (2) science as the investigative nature; (3) science as a way of thinking; and (4) interaction of science, technology and society (Chiappeta et al., 1991). According to those criteria, we produced a literacy book: The Physics of the Water Rocket. This is because a water rocket is suitable to demonstrate the concept of inertia, gravitation, acceleration, air drag, the Newton Law of motion, work, energy, impulse, momentum, projectile motion and free-falling object (Pathan et al., 2016; Romanelli et al., 2013). Moreover, the water rocket is also relevant to Indonesia's 2013 Curriculum.

Some factors cause the low reading interest. These include uninteresting book presentation, tough material, formulas and no connection of the theory with daily life application. This invention enables us to develop a book through new technology, for example, the Augmented Reality (AR) application. An enrichment book combined with an AR application helps the student to gain information and senses interactive, real-world experience through a smartphone (Dias, 2009; Mehta et al., 2016). The AR technology is superimposed on text, sound, image, video and picture. Therefore, the enrichment book, through the AR application, is suitable to enrich student interest in reading and literacy in a fun way (Kun, 2017).

2 METHOD

The research conducted utilized a quasi-experimental method to study student literacy enhancement with the one group, using a pretest–post-test design approach. The test are carried out on specific samples (Sugiyono, 2013). The experiment design is shown in Figure 1.

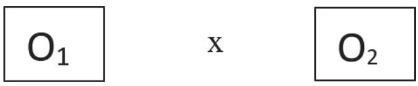

Figure 1. One group pretest–post-test design.

where O_1 is the pretest, O_2 is the post-test and x is the treatment, where the treatment is reading the enrichment book and running the AR application. The pretest and post-test scores were then analyzed by the normalized gain test (Sunal et al., 2014). The normalized gain test was introduced by Hake in 1999, as a rough measure of the effectiveness of a course. The formula is written as follows:

$$\text{Normalized Gain} < g > = \frac{\text{post-test\%} - \text{pre-test\%}}{100\% - \text{pre-test\%}} \tag{1}$$

where <g> is the normalized gain, post-test % is the percentage of post-test score, pretest % is the percentage of pretest score. The ideal score of the test is 100. The results are then interpreted in several categories as shown in Table 1.

The research object is 11th-grade students at SMAN 77 Jakarta. The students are arranged in two groups. The first group consists of 35 students, while the second group consists of 34 students. Both groups underwent the same treatment. The research instrument is a multiple-choice assessment test which consists of 20 pretests and 25 post-tests. After doing the pretest, students read the enrichment book, use their smartphones to run the AR application of the water rocket and take part in a discussion. After that, they did the post-test. The scores of pretest and post-test undergo the normalized and homogeneity tests.

Table 1. Gain score interpretation.

Gain score	Category
$g < 0.3$	Small
$0.3 \le g \ge 0.7$	Medium
$g > 0.7$	Large

3 RESULTS AND DISCUSSION

Table 2 shows the scores of the pretests and post-tests. Based on those data, the mean of both groups is similar. Therefore, their scientific literacy is similar.

Table 3 shows the tests of normality results with one sample Kolmogorov–Smirnov technique. This result carried out from more 69 samples.

Table 3 shows the normality test of the two groups. The pretest score of the first group is 0.08 and the second group is 0.2. This score is larger than the significances score ($\alpha = 0.05$). The post-test score of the first group is 0.190 and the second group is 0.92, which is above the significance score as well. Therefore, the normality test shows that the data are normally distributed. Furthermore, the data are evaluated using Levene's homogeneity test. When the significance score is greater than 0.05, the data are homogenous.

Table 4 shows the homogeneity test result; the pretest score is 0.798, while the post-test score is 0.259. Both scores are more significant than 0.05. Therefore, the data are homogenous. Moreover, the data are analyzed using the N-gain test. The N-gain test result in Table 5 shows the enhancement of student scientific literacy.

Table 5 shows that the N-gain test result is 0.52. According to the criteria in Table 1, the enhancement of student scientific literacy is medium. This is because the student capacities

Table 2. Pretest and post-test scores.

Group		*n*	Ideal score	Minimum score	Maximum score	Mean
Pretest	1st group	35	100	20	60	37.28
	2nd group	34	100	20	65	40.29
Post-test	1st group	35	100	52	92	70.63
	2nd group	34	100	56	88	71.00

Table 3. Tests of normality.

		Kolmogorov–Smirnov[a]			Shapiro–Wilks		
	Kelas	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	1st group	0.140	35	0.082	0.968	35	0.387
	2nd group	0.110	34	0.200*	0.968	34	0.403
Post-test	1st group	0.124	35	0.190	0.959	35	0.214
	2nd group	0.139	34	0.092	0.952	34	0.143

* This is a lower bound of the true significance.
a. Lilliefors Significance Correction.

Table 4. Test of homogeneity of variances.

	Levene statistic	df1	df2	Sig.
Pretest	0.066	1	67	0.798
Post-test	1.297	1	67	0.259

Table 5. N-gain test of student scientific literacy.

		Mean				
	n	Pretest	Post-test	Gain	N-gain	Category
Scientific literation	69	38.76	70.84	32.07	0.52	Medium

Table 6. Paired-samples test.

	Paired differences							
				95% Confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1 Pretest–Posttest	–32.07	13.55	1.63	–35.32	–28.81	–19.65	68	.000

in the comprehension, evaluation and interpretation of the scientific facts in the book are medium.

To get the information the significances score of pretest and post-test, was get from t-test. The test used compare means paired-sample t-test analysis because the data are homogenous. When the significance scores are lower than 0.05, then H_0 is rejected and H_1 is accepted. Therefore, there is a significant difference between pretest and post-test scores.

Table 6 shows that the probability is 0.00 or smaller than α. Therefore, H_0 is rejected and H_1 is accepted. There is a significantly different score between pretest and post-test so that there is a significant enhancement of student scientific literacy competencies. The mean, which is –32.07, shows that the treatment can raise the level of student scientific literacy competencies by 32.07 per student.

4 CONCLUSION

The physics of a water rocket enrichment book based on an AR application can enhance student scientific literacy. This is shown by a significant increase from pretest to post-test scores, which averaged 32.07 percent for each student.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

The development of new learning media through a Mach-Zehnder interferometer simulation

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ABSTRACT: The research aim was to develop a new learning media through an event-by-event computer simulation of the Mach-Zehnder interferometer experiment with an absorber. The computer simulation was applied in a quantum physics course. This learning media helped students to figure out the wave-particle duality phenomenon. The research and development method (Dick and Carey model) (Dick, 1996) was applied, the subjects were the fifth-semester students of a physics education department who have passed the pre-requisite classical mechanics course. The data were gained from a questionnaire. The first research product is the validation of the computer simulation. Media and material experts did the validation. A user test was also done. The validation and user test results show that the event-by-event simulation of the Mach-Zehnder interferometer experiment with an absorber is appropriate for use as a new learning media in a quantum physics course.

1 INTRODUCTION

Learning media are applied in a course to help students learn, visualize and comprehend the material. The learning media also helps to link teacher–student communication It is well known that physics theory is difficult to understand. Students often get into difficulties linking the theory with daily life applications (Sarabando et al., 2014). Therefore, the teacher has to find appropriate learning media to help them comprehend physics theory and its application, for instance through a computer simulation.

This research developed a learning media through an event-by-event computer simulation of the Mach-Zehnder interferometer experiment with an absorber to help the students understand a quantum physics phenomenon. The learning media was applied in a quantum physics course in a wave-particle duality subject. The research objects were the fifth-semester students at the Physics Education Department of Universitas Negeri Jakarta, Indonesia.

The computer simulation was validated in several aspects before implementation in the quantum physics course. These aspects were subject matter, auxiliary information, affective consideration, interface, navigation, pedagogy and robustness (Alessi & Trollip, 2001). In the subject matter aspect, the material must be suitable to the essential goal of the computer simulation. The material scope must be convenient to the student grade. The second aspect is auxiliary information. The auxiliary information aspect consists of additional information which does not have a direct connection to the material. For example, the introduction, instruction, support and conclusion. The third aspect is affective consideration. Here, the learning media should be able to motivate the students to study harder. The fourth aspect is the interface, where product presentation is influenced by text, animation, graphs, audio and video. Furthermore, the navigation aspect is a crucial aspect for a user. Hence, the user finds it easy to run and access

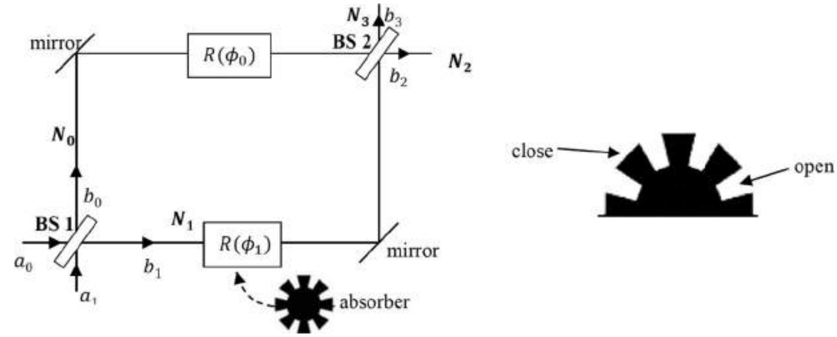

Figure 1. Diagram of the Mach-Zehnder interferometer experiment with an absorber.

the computer simulation. The following aspect is pedagogy. The pedagogy aspect consists of ten components: methodology, interactivity, cognitive capacity, cooperative learning, learning strategy, user control, question, answer, feedback quality and material proficiency. The last aspect is robustness. The robustness aspect is a product persistence which means the learning media cannot be bankrupt. Therefore, the learning media is proper. This study employed the research and development methods of the Dick and Carey model (Dick, 1996).

2 WAVE-PARTICLE DUALITY

Light consists of particles moving with high velocity. This theory is also known as Newton's Particle Theory. In quantum theory, light shows the nature of waves and particles (Dürr et al., 1998). This is known as the wave-particle duality of light phenomenon. This phenomenon is also explained by Young's double-slit experiment. The wave-nature is presented by interferences. Interferences are formed after a collection of particles pass through the slits and are recombined. While the particle-nature is shown by which path the particles take (Dürr & Rempe, 2000), a particle cannot pass through two slits at the same time. Several experiments were proposed to study the wave-particle duality of light. One of them is the Mach-Zehnder interferometer experiment with an absorber (Rauch & Summhammer, 1998).

A diagram of the Mach-Zehnder interferometer experiment with an absorber is shown in Figure 1. The experiment consists of a photon source (not shown), two beam splitters (BS 1 and BS 2), two mirrors, a detector and a dynamic absorber. The particle source produces a particle and sends it to Beam Splitter 1 (BS 1). BS 1 sends the particle to path b_0 or b_1 randomly and directs the particle to Beam Splitter 2 (BS 2) via the mirrors. In BS 2, the photons are recombined and interfered. Then, detectors N_2 and N_3 count the particles (Delina, 2014).

In BS 1, the photon has to choose whether to use path b_0 or b_1. A photon cannot pass through both paths at the same time. This event demonstrates the particle-nature of light phenomenon. In BS 2, the photon recombines or interferes. This interference shows the wave-nature of light phenomenon.

This research developed a new learning media through the event-by-event simulation of the Mach Zehnder interferometer experiment with an absorber. The information detail of the simulation is described in previous work (Delina, 2014).

3 EVENT-BY-EVENT COMPUTER SIMULATION

Event by event is a new computer simulation method developed by De Raedt et al. (2005). The method has several advantages: it simulates the quantum phenomenon event by event; the contribution of each photon influences the interference; it reproduces the results of quantum theory; and it does not need to solve the Schrödinger equation. The simulation uses classical wave theory and quantum particle concept only (De Raedt et al., 2012).

The method is described in term of events, messages and processing units. An event correlates to the detection of a particle or a photon. The message is the properties carried by a particle. A processing unit is a beam splitter that processes the events and messages (Michielsen et al., 2012). In the event-by-event simulation of the Mach-Zehnder interferometer experiment with an absorber, a dynamic absorber (a periodic chopper) is placed on path b_1. As a consequence, the number of particles on path b_1 reduced because the periodic chopper absorbed them. Therefore, the intensity of interference decreased. If path b_1 is totally blocked by the absorber, then there was no interference because of no recombination of particles in BS 2. BS 2 did not receive particles from path b_1.

The event-by-event simulation of Mach-Zehnder interferometer experiment with an absorber is suitable to study microscopic object in quantum mechanics phenomenon. It is because the event-by-event method is well to visualize the part of Mach-Zehnder interferometer experiment with an absorber (a source, beam splitters, mirrors, a detector, an absorber), and the contribution of each photon to interference pattern as well. The graph of interferences pattern help student to figure out the correlation of absorbing percentage with the interferences. The students can figure out the wave-particle duality phenomenon through this computer simulation. Therefore, the event-by-event simulation of Mach-Zehnder interferometer with an absorber can be used as a new learning media in a quantum physics course, especially in wave-particle duality subject.

4 LEARNING MEDIA VALIDATION

The learning media was validated and tested to a limited degree. Colleagues in the Educational Physics department of Universitas Negeri Jakarta did the validation. The validation is qualitative data from several intensive discussions. From the discussions, the media received several inputs and was then revised accordingly. The validation result is shown in Table 1.

Figure 2 show properness percentages from several aspects: auxiliary information, interface, navigation, pedagogy and robustness. The properness percentage is the validation result from two media experts. The mean percentage of auxiliary information aspect is 80.5%, the mean of the interface aspect is 87%, the mean of the navigation aspect is 82.5%, the mean of the pedagogy aspect is 87.5% and the mean of robustness aspect is 85%. The mean total percentage of all aspects is 84.44%. The scores show that the event-by-event simulation of the

Table 1. Validation data.

No	Topics	Input	Product
1	The syllabi of physics teaching media development course.	The syllabi should provide a clear boundary in scope, strategy, assignment and the course product; therefore, there is no overlapping with the other courses.	The syllabi of a physics teaching media development course.
2	Teaching media for the event-by-event Mach-Zehnder interferometer simulation.	The simulation should be interactive; therefore, the students can input some variables which influence the interferences.	The improvement of the event-by-event Mach–Zehnder interferometer simulation.
3	Teaching media.	The teaching media should be organized according to the scientific skill process; therefore, the students have an analytical skill process.	Student activity and performance sheet based on scientific skill processes are used to produce an activity sheet for the wave-particle duality subject.

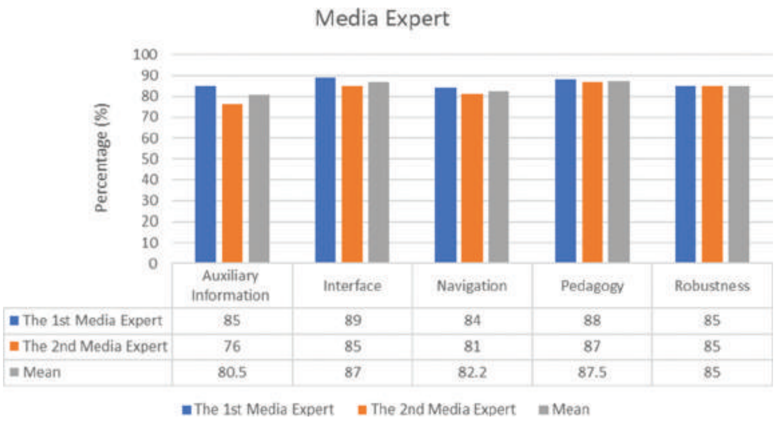

Figure 2. Validation results from media experts.

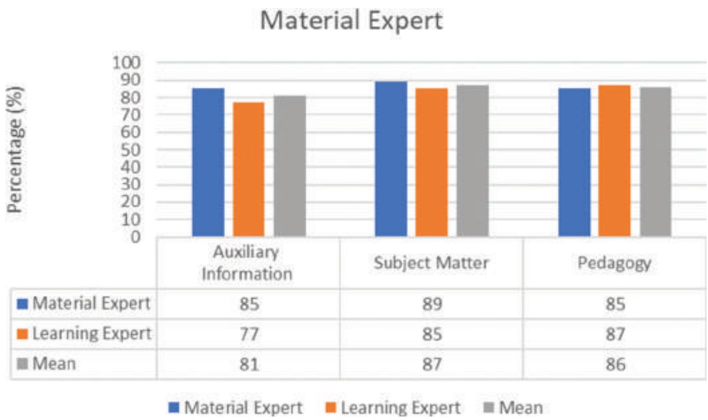

Figure 3. Validation results from material experts.

Mach-Zehnder interferometer experiment with an absorber is appropriate for use as a new learning media (Arikunto & Jabar, 2009).

Apart from two media experts, two material experts also validated the event-by-event simulation. The results are shown in Figure 3. Figure 3 shows the properness percentage from three aspects: subject matter, auxiliary information and pedagogy. The mean percentage of the subject matter aspect is 87%, the mean percentage of the auxiliary information is 81%, and the mean percentage of pedagogy aspect is 86%. The mean total percentage of all aspects is 85.83%, which indicates that the event-by-event simulation of the Mach-Zehnder interferometer experiment is appropriate for use as a new learning media.

5 USER TEST

The learning media also underwent a limited test with the fifth-semester students consisting of 26 persons. The students were part of the quantum physics course. Figure 4 shows the test results.

Figure 4 shows the effectivity test result. The data are taken from a questionnaire instrument which has five aspects: attitude, ability to understand instruction, perseverance, opportunity, and quality of instruction. The mean percentage of the attitude aspect is 82.5%, the mean percentage of the ability to understand instruction aspect is 69.5%, the mean percentage

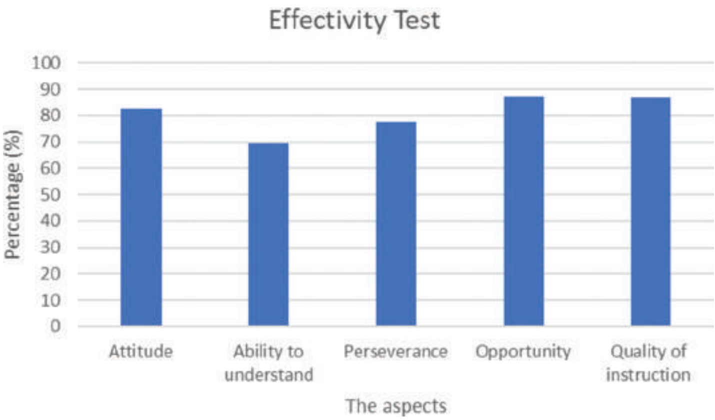

Figure 4. Effectivity test results of the computer simulation.

of the perseverance aspect is 77.5%, the mean percentage of the opportunity aspect is 87.5% and the mean percentage of the quality of instruction aspect is 87%. Therefore, the effectiveness of the learning media through the event-by-event simulation of the Mach-Zehnder interferometer experiment with an absorber has a moderate increment.

6 CONCLUSION

Based on the research, it may be concluded that the event-by-event simulation of the Mach-Zehnder interferometer experiment is appropriate for use as a new learning media in a quantum physics course. This learning media is capable of drawing the wave–particle duality phenomenon. This is shown by the validation scores from media and material experts, which are 85.83% and 84.44%, respectively. For further development, the computer simulation should be more interactive so that the students are more active in the learning process.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Modeling skills in chemistry education to win students on global competitiveness

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ABSTRACT: The 4.0 industrial revolution digital technology based make some workplace are lost and appear automatically. Higher education must prepare students to be ready to win in the global competitiveness in this era. New orientation is needed by educators and learning processes in higher education to develop students' higher order thinking skills to solve problems in their lives. Chemistry education focuses on preparing students to comprehend modeling skills to develop their cognitive capacity, higher order thinking skills and higher order mental skills. The results of this research show that using modeling skills in the chemistry learning process enable students to comprehend the concepts, connect the concepts in daily life and advance technology, and also predict the future application of materials based on their structures. It gives the insight that integrating modeling skills in higher chemistry learning as an innovation learning to prepare students' global competitiveness in order to be survivors.

1 INTRODUCTION

1.1 *Chemistry education in the fourth industrial revolution*

Multiple representations in chemistry convey much information. Representational competence is students' capabilities to associate multiple representations through meaningful techniques and apply them in solving problems or explaining a phenomenon (Grove et al., 2012). Therefore, multiple representations are known as a language of chemical science that can be used to communicate and develop thinking skills, process skills or scientific methods of students. Connecting multiple representations is highly recommended in the chemistry learning process in order to enhance students' knowledge of chemical content as well as the development of students' thinking skills.

Previous empirical studies have shown that students' representational competence is low. They only focused on recognizing and understanding chemical phenomena at a macroscopic level. Meanwhile, submicroscopic and symbolic representations are the most difficult representations for many students (Nursa'adah, 2018). Students lack the proficiency level to visualize the structure and the process of chemical phenomena, merely focusing on memorizing submicroscopic and symbolic representations. As a consequence, they are not able to imagine the process and structures of the phenomena well (Adadan, 2014; Luxford & Bretz, 2014; Stojanovska et al., 2017). Therefore, to overcome these limitations, the chemistry learning process should intend to develop and enhance students' spatial thinking skills.

Currently, the world is undergoing a rapidly developing industrial revolution, known as the 4.0 industrial revolution era. This is a great opportunity to accelerate industrialization and modernization for every country. Thai and Anh (2017) stated that the 4.0 industrial revolution is based on three areas, which are digital (big data, artificial intelligence), biotechnology (medicine, chemistry and material, renewable energy) and physics (next-generation robots, new materials, nanotechnology). Learning in higher education, especially in chemistry education, needs a new orientation in order to make students fight and competitive in the 4.0 industrial revolution.

Much research has been committed to understanding how people learn and what the best approach is for teaching them to think critically and creatively (Gleason, 2018). How educators themselves understand the concepts of problem solving, critical thinking and creativity is discipline specific and subjectively realized. Based on that statement, it is important to prepare students in higher education to comprehend those skills. Therefore, learning chemistry in the 4.0 industrial revolution era requires more complex learning as students should combine their skills in learning with the very fast and wide development of chemistry content in real life.

Integrating modeling skills in the chemistry learning process challenges students to focus on relating structure and properties of matter based on the applications needed. This could develop their higher order thinking skills.

1.2 *Modeling skill in chemistry education*

Modeling skill is the skill to connect analogs and targets. In chemistry, an analog is a symbolic representation that explains the targets of macroscopic and submicroscopic phenomena. The scientific model of chemical structure helps students to develop science knowledge as well as a bridge between chemistry concepts, real life and advanced technology. Through modeling activities, students are able to comprehend the phenomena in real life, advance technology and the phenomena of science as well as without any separations (Carey & Gougis, 2017; Liu et al., 2017).

A model of chemical structure is known as a simplification of chemical phenomena or processes that focus on specific aspects or components of a system such as ideas, concepts, objects, events, processes, compositions and molecular structures that are represented both in physical and computational form. Models of chemical structure can help students to imagine and visualize molecular structures and develop their cognitive skills (Dori & Kaberman, 2012).

Models of molecular structures or representations in chemistry learning demand a high spatial ability. Students are expected to be able to explain and predict the nature and concept involved in the phenomenon based on the model (Al-Balushi et al., 2017; Chen et al., 2015). Therefore, models and modeling activities in chemistry learning are not only activities to see the models presented, but also involve students' skills to think and act critically.

Inorganic chemistry deals with the structure and properties of inorganic compounds and can be described broadly (all remaining elements in the periodic table and as well as carbon which play major in organic chemistry). The characteristics of its concepts are abstract with a real phenomenon context that could be found in daily human life and in advanced technology. It allows students to make connections between science and daily human life applications.

Applying models and modeling activities in inorganic learning processes allows students to focus on relating structure and properties of matter based on the application needed. Students easily find the application of the concept in daily human life and technology. The most important thing is they do not assume that science or chemistry in the school is different from daily human life and advanced technology.

The introduction and application of modeling skills are also used in the organic chemistry learning process to explain the structure and properties, energy, stability, intermediate product regioselectivity and mechanism reactions of organic compounds (Cheng et al., 2015; Schuster et al., 2018; Barbiric et al., 2015; Dood et al., 2018). The development Cheminformatics also makes the computer assistance in synthesis design for fulfill the needed of the chemist (Coley et al., 2017). It is known that modeling skills become important in learning organic chemistry because students can direct their attention to spatial reasoning. In another way, students feel the liberating effect by using modeling to combine their understanding of the organic concepts with their spatial reasoning (Hii et al., 2015).

2 METHOD

2.1 *Research method*

This research is intended to develop higher order thinking skills using modeling skills in the chemistry learning process to improve students' competitiveness in the 4.0 industrial revolution. This research used a mixed method with an embedded experimental model (Creswell & Clark, 2007).

The quantitative and qualitative analyses before interventions are done by analyzing students' conceptions in a pretest. The model and modeling activities and students' modeling skills are applied in the chemistry learning process. Quantitative and qualitative analyses after interventions are done by analyzing students' conceptions in a post-test. Finally, quantitative and qualitative data are interpreted.

2.2 *Participants and research setting*

The participants involved in this research were 23 pre-service chemistry teachers who were enrolled in the inorganic chemistry course at the Islamic Teachers Education College in Bandung, Indonesia and 16 pre-service chemistry student teachers who were enrolled in the organic chemistry course at one state university in Papua, Indonesia. They were in the third year and attended the advanced organic chemistry course. The research setting used a one group pretest and post-test embedded experimental design.

2.3 *Instruments*

This study used a combination of modeling skill criteria proposed by Dori and Kaberman (2012) and Wang et al. (2017) as the modeling skills focus on students' skills to connect structures and properties, either macroscopic or submicroscopic properties of a substance or phenomenon. Understanding of structures and properties is expected to enable students to interpret or evaluate the concept. Therefore, they are able to predict the application of a material in their life.

The three indicators of modeling skills developed in this research are: 1) modeling the chemical structure; 2) using structural models to explain properties; 3) using structural models to evaluate or predict the properties (Table 1).

All the questions and rubrics developed in this study were validated by five chemistry education experts. They were asked to: 1) review the suitability of indicators, question items, score as well as key answers; 2) check the accuracy of the data presented on each question, word/sentence or paragraph on each item question. Experts' advice was considered to correct each item.

Validity was analyzed by experts and the Content Validity Ratio (CVR). The CVR value was 0.99 (acceptable) (Wilson et al., 2012) as mentioned before. All items were tested with 63 pre-service chemistry teachers who have received an inorganic chemistry course on the topic of solid state chemistry, to measure the reliability. The Cronbach's alpha coefficient was calculated to measure the reliability of the instrument test. The results show a value of $\alpha = 0.77$ (accepted). A Cronbach's alpha value between 0.70 and 0.80 is considered reliable (Cohen et al., 2007). A paired sample *t*-test was used to analyze the differences between students' modeling skills pretest and post-test. The hypothesis test with the p-value $<.05$ was considered significant.

In organic chemistry learning, a worksheet was provided to determine students' performance. Therefore, in this research students were given a worksheet about the Student Spartan V6 task, and students had to complete the task. The task concerned drawing a structure compound, analyzing the stability of the compound based on isomer geometry and

Table 1. Criteria for modeling skills.

Modeling skills	Criteria
Sub-modeling skill 1	Students create the structure model
Sub-modeling skill 2	Students create and analyze the model and use the model to explain the scientific phenomena and daily life
Sub-modeling skill 3	Students create and analyze the model and use the model to predict phenomena or properties

conformers. This research percentages according to the number of students who had the capability to compete the task.

3 RESULTS AND DISCUSSION

3.1 *Results*

3.1.1 *Students' modeling skills: Inorganic learning process*

The data concerning students' modeling skills were obtained by analyzing students' answer patterns on each question that measured modeling skills. Students' modeling activities during the learning process were analyzed through their work on the provided worksheets as described. There were three categories of students' modeling skills developed in this study: (1) modeling the structure; (2) using the model to explain properties of the compound; (3) using the model to evaluate or predict the properties of compounds.

The result shows the scores of each modeling skills were converted to N-gain (Figure 1). The figure portrayed that the percentage post-test score in all sub-modeling skills was higher than the pretest, with the N-gain category all in the middle category except sub-modeling three which is in a low category.

3.1.2 *Students' modeling skills: Organic learning process*

Initially, the instruction given to the students was to look carefully the demonstrations using the Student Spartan V6 media and have the opportunity for them to use it in groups. Although students were given the opportunity to try this application, they still had difficulty applying the media and answering the questions related to the tasks of analyzing the stability of compounds from geometrical isomers and compound conformations. Based on the results, we can create a graph like that in Figure 2.

3.2 *Discussion*

Sub-modeling skill 1 is a skill to create a structural model of material. This modeling needs skill to select the correct information from the various knowledge and use it for modeling a structure that illustrates the right concept and helps students to make a scientific model. Dori and Kaberman (2012) suggested that modeling skills in basic categories, such as transforming the molecular structure to molecular formulas or vice versa, are often performed by students in the chemistry course. Most students give the correct responses when asked to do.

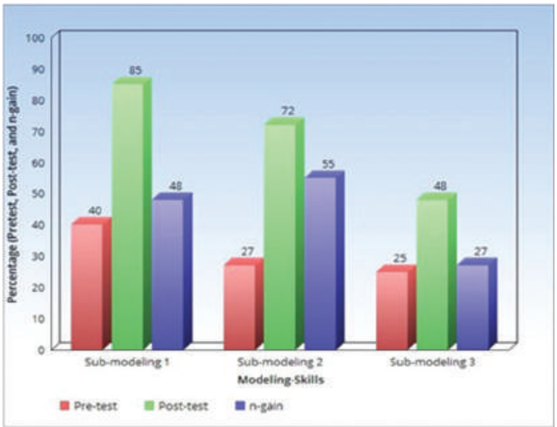

Figure 1. Average percentages of pretest, post-test and N-gain scores of students in each modeling skill.

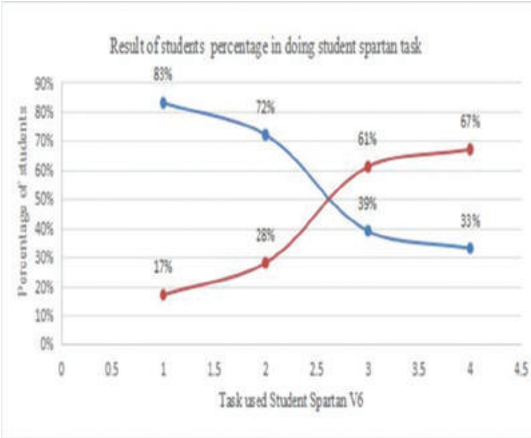

Figure 2. Students' percentages in doing a spartan task.

In this study, students were asked to model a compound or material based on the conceptual information presented. This is more than transforming from formula to structure or vice versa. Therefore, even if the student could create the requested model, if the information they selected is interpreted incorrectly it will result the model character created based on conceptual knowledge to be incorrect.

Sub-modeling skill 2 is the skill of using a model to explain properties or phenomena. The models presented make it easier for students to explain the properties of the material. Analysis of the structure is the most appropriate way for students to solve problems. If students do not complete the analysis, then most likely, they will not be able to solve the problem.

In this sub-modeling skill, students are no longer required to model, but rather to focus on connecting a model with its properties. In accordance with the suggestions of Dori and Kaberman (2012), it prepares students for connecting the structure or symbol with its properties. Therefore, students are able to give a good argument when asked to explain the chemistry in macroscopic, submicroscopic and also symbolic representations. This skill provides the basis for strengthening students' cross-representation cognitive linkage (Patwardhan & Sahana, 2017) who put forward the term representational competence. Modeling skill 3 is the skill of using structural models to evaluate or predict the properties of compounds, as Dukerich (2015) argues that the purpose of modeling is to construct and use models to explain, evaluate, predict and control material properties.

One example of a real issue and advanced technology in inorganic chemistry concerns the conductivity of material based on the metallic bonding concept and predicting the way to change the conductivity of material. The materials selected were graphite and polymer. Students were asked to analyze the conductivity of the materials and find a way to change the conductivity. At first, most students did not answer. Some students gave two possibilities, that both graphite and polymer cannot conduct electricity and both graphite and polymer are conductors. Some students also said that graphite conductivity is larger than the metal because electrons are easier to enter, graphite and polymer have a complex structure, it cause electrons do not move; metal and polymer are conductor it is caused by delocalized electron; metal is conductor, it is caused by delocalized electron, graphite is a conductor because there are free electrons.

After the interventions, they answered that the ease of metal in conducting electricity is simply explained through the 'sea' electron model. In graphite, each carbon atom is only covalently bonded to three other carbon atoms (sp2), graphite has delocalized electrons. These mobile electrons allow graphite to conduct electricity, but only in the plane of the sheets. In polyacetylene, there is no electron delocalization.

When they were asked to explain a way to change the conductivity, they answered that graphite conductivity can be changed by converting graphite to graphene. Graphene, on the other hand, being a single layer of atoms and having very high electron mobility, offers fantastic levels of electronic conduction due to the occurrence of a free phi (π) electron for each carbon atom. Carbon atoms have a total of six electrons; two in the inner shell and four in the outer shell. The four outer shell electrons in an individual carbon atom are available for chemical bonding, but in graphene, each atom is connected to three other carbon atoms on the two-dimensional plane, leaving one electron freely available in the third dimension for electronic conduction. These highly-mobile electrons are called phi (π) electrons and are located above and below the graphene sheet. These phi orbitals overlap and help enhance the carbon to carbon bonds in graphene; whereas, the conductivity of polyacetylene can be changed by doping. The halogen doping that transforms polyacetylene to a good conductor of electricity is oxidation (or p-doping). Reductive doping (called n-doping) is also possible using an alkali metal.

The most well-known application doping processes are conductive polymer and glass. They are the materials used to produce one type of solar cell, the Dye-Sensitized Solar Cell (DSSC). It is recognized that solar energy supply from the sun is so incredible that it reaches 3×1024 joules every year. This amount is equivalent to 10,000 times the energy consumption worldwide today. If we were able to cover only 0.1% with solar cell devices, it would be very profitable. Currently, researchers have undertaken various studies to produce solar cells with high efficiency such as the DSSC. Meanwhile, polyacetylene and polyaniline are most well known as prototypes of conductive polymers. Polyaniline has been used in various applications such as chemical sensors especially gases, electrochromic devices, polymer LEDs and many other applications.

In the organic learning process (Figure 2), student percentage that can completed their task take the higher percentage in drawing the structure compound, but lower in analysis the stability based on the conformation. It is inverse with students' percentage that cannot complete their task. From the results, we find that when the task given to the students becomes more complex, they failed. According to previous research, it was found that students must integrate their understanding about the concepts with their spatial reasoning to complete their task. Students' understanding about the concepts was affected by spatial reasoning. If they cannot integrate their skills, they failed (Graulich, 2015). It also can impact from habits to rote memorization and make them cannot raised their understanding and having a meaningful learning (Grove & Bodner, 2012).

Modeling skills in organic chemistry are very useful in real life, such as in industry, medicine and biotechnology. By using modeling skills, the scientist can show the real image of a chemistry reaction and this helps the scientist to predict and create the synthesis of a new drug compound, as well as new and available pathways of the synthesis of organic compounds. Moreover, we know that students should have modeling skills to face global competitiveness in order to be a survivor in learning through the era of the 4.0 industrial revolution.

According to students' results and benefit of comprehend the modeling skills based on real issues as an innovation learning process could develop students' their higher order thinking skills. Using their higher order thinking skills allows them to solve the crucial problems faced in their lives, select abundant information and make good decisions.

While we know that higher education needs to respond the 4.0 industrial revolution impact, substantial changes to the science and technology learning process are required to allow students to develop capacity in rapid technology. Besides this research, Liliana and Zunin (2015) also made an innovation within chemistry.

These strategies also consider the human condition as a social individual, the way in which new technology is adopted and also the shifting economic power impacting people of all socio-economic levels. This approach maximizes the development of the skills which will be a hallmark of the future 4.0 industrial revolution workplace.

4 CONCLUSION

Modeling skills give challenge to develop students' need in facing the 4.0 industrial revolution. Integrating modeling skills in chemistry learning is challenging for students to enhance their higher order thinking skills and solve the crucial problems faced in their lives, select abundant information and make good decisions. Therefore, the 4.0 industrial revolution era has great opportunities to prepare humans to accelerate industrialization and modernization. The learning process in higher education, especially the chemistry learning process, has a main role, as learning chemistry becomes more complex and requires higher order thinking skills to achieve students' global competitiveness.

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Motor ability based on traditional games in junior high school

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ABSTRACT: The purpose of this research is to develop children's motor skills through traditional games. In addition, this study was conducted to obtain in-depth information about the development and application of materials to teach traditional game material to improve the ability of motor skills that are the effectiveness, efficiency and attractiveness of students towards physical education learning. This study used a qualitative approach based on the method of Borg and Gall (1983). namely using a questionnaire to collect data about: (1) Needs analysis; (2) Expert evaluation (initial product evaluation); (3) Limited trials (small group trials); (4) Main test (field of testing). Testing the effectiveness of applying models for motor skills based on traditional games using the 't-test' technique. Before the data were analyzed, normality tests were performed on the pretest and post-test material for the capability of motion using the Lilliefors test at a significance level of $\alpha = 0.05$. The following results are obtained: (1) through traditional games students have effective and efficient motor skills; (2) through traditional games, children are more motivated and active in following the physical education learning process.

1 INTRODUCTION

The ability to move is an important fitness indicator in each individual to support their appearance. This is in line with the opinion of Widiastuti (2011), who stated that motor skills are one of the most important indicators of fitness that are closely related to the achievement of physical quality and the quality of skills or ability to move. Motion ability, according to Nurhasan (2010), is considered as a person's general ability to move, more specifically the ability of motion is the capacity of a person to be able to perform various movements that require courage in exercising.

According to Dadang (2003), movement skills are a model of motion that form the basis of a more complex motion skill. The basic motion capability, according to Singer (2010), has the same meaning as motor ability, which means the immediate state of a person to display a variety of motion skills. The ability to move is seen as the level of one's ability in a series of activities. Motion ability is considered as an integrated ability of individual characteristics, such as strength, endurance, speed, balance, reaction time and coordination. These characteristics are needed as a foundation in displaying a complex, precise and efficient series of motion. Knowledge of a person's ability to move will help estimate some of the obstacles that will be faced in the process of mastering movement skills. Furthermore, the ability to move is closely related to physical fitness.

Physical fitness has several components. These can be grouped into two aspects, namely: (1) physical fitness related to health; (2) physical fitness related to aspects of skills (Hastie & Martin, 2006e components of physical fitness related to health consist of body composition, cardiorespiratory endurance, flexibility, muscular endurance and muscular strength. While the components of physical fitness related to aspects of skills are agility, development, balance, coordination, strength, speed and reaction time (Wuest & Bucher, 2009, Lacy, 211).

This is in line with the purpose of games and sports, used as a way to improve the ability to move in accordance with the level of child development. Gallahue and Ozmun (2006) argue that games are often classified into three types from simple to complex, namely: (1) games with low organization and running relay; (2) games that lead to sports (lead-up games); (3) real sports.

Various traditional games on the island of Java, among others, are *Pathil Lele, Pandhe, Dakon, Cublek-Cublek Suweng, Gobak Sodor, Karambol, Beteng-Betengan, Egrang, Engkle*, and so on. All of these games are often found, but the ones most often used to fill race events and regional custom events are traditional Javanese *Egrang* games. The traditional Javanese *Egrang* game consists of two games namely, bamboo *Egrang* and *Egrang*. Bamboo *Egrang* is *Egrang* that uses two meters of bamboo material and given a 50 cm footing from the ground. In addition to knowing bamboo *Egrang*, Javanese people also know the game of *Egrang* that uses a coconut shell as a footing and is given a hook to lift the feet that are raised. The benefits of *Egrang* games are found more in bamboo *Egrang*, such as maintaining balance, hard work, tenacity, creativity, skill and speed.

The game of bamboo *Egrang* can be found in various regions in Indonesia with different names, among others, from the area of West Sumatera with the name of noses, from the Bengkulu region as *Ingkau* which means bamboo shoes, or from South Kalimantan as the Batungkau and from the Java region namely *Egrang*. *Egrang* on Java Island, can be played by all people, especially children, both individually and in groups. The bamboo *Egrang* game is more often used and found in events and competitions compared to other traditional games. However, the game is now rarely played.

Each region has a game that has almost the same implementation or many similarities with games in other regions. About the name of the games there is the same in other place in Indonesia, As an example, it can be stated that in Central Java it is known as the *Gobak So*dor game, in Jakarta it is called *G*alasin, while in North Sumatra it is called Margalah. However, clearly the same game rules apply Observation activities and interviews with physical education teachers and students of physical education and physical education teaching materials based on traditional Indonesian games showed that material motor abilities were still very rarely delivered using traditional games. For this reason, researchers are motivated to develop physical education teaching materials that bring local wisdom, namely by re-raising traditional games that are now being abandoned by modern children. Other reasons, besides developing local wisdom, include the fact that traditional games are also entertaining, inexpensive, easy to do and do not require a large room or place, as these games can adjust to the field environment in the school. Based on this description, there is a need for an in-depth study through research in accordance with Kerlinger's (2013) statement, which defines scientific research as a systematic, controlled, empirical and critical investigation of natural phenomena, guided by theories and hypotheses.

Therefore, the researcher is interested in doing research by making the development of teaching materials with the title: motor ability based on traditional games in junior high school The resulting product certainly has the advantage of delivering motor ability material in schools, such as the delivery of teaching material that is more interesting and easier to do. The resulting product is expected to be useful as a reference for physical education teachers to overcome the limitations of facilities and infrastructure in the process of learning physical sports and health education, especially games that promote agility, speed and foresight.

2 METHOD

The design of this study refers to Borg and Gall's (1983) development model. Of the ten steps, some have been modified by the researcher as necessary. The steps taken include: (1) needs analysis and field observation; (2) preparing a research plan; (3) initial product development; (4) early stage trials; (5) initial product revision; (6) main trial test; (7) product revision; (8) main trial; (9) final revision; and (10) dissemination and implementation. The subjects of this study were seventh graders at Probolinggo City Public Middle School who were selected using a random sampling technique. The type of data produced was in the form of quantitative data and qualitative data. Qualitative data was obtained from the review of suggestions and input from experts. Quantitative data uses descriptive quantitative analysis techniques with percentage and T-test statistics on product effectiveness tests. The subjects involved in this development are as follows: (1) subjects as initial research (needs analysis) conducted interviews with one teacher and 24 students of Probolinggo City Junior High School; (2) expert evaluation subjects consisting of three motor movement experts, one expert in physical education learning; (3) the first stage trial subjects were ten students from Probolinggo City Junior High School; (4) phase II trial subjects (field trials) were 60 students of Probolinggo City Junior High School.

3 RESULTS AND DISCUSSION

The study was carried out in a junior high school by involving teachers and junior high school students as a place of implementation. Researchers carry out preliminary research or needs analysis; from the results of filling out the questionnaire by the health teacher of Probolinggo City Junior High School, it can be seen that: (1) the teacher has taught some material motor skills, for example, running 100 m, running in zig-zags, sometimes also doing competitions; (2) at present, the teacher uses mats and cones in delivering motor skills ability teaching; (3) students are quite enthusiastic in following the learning process using games; (4) during this time, physical education teachers have tried to make students interested in following the learning process with existing game models and tools; (5) teachers need various kinds of motor skills ability teaching materials.

From the students' needs analysis data, it was concluded that the results obtained were zero students or 0% citing modules, one student or 1% citing books, 23 students or 24% citing display tools, three students or 3% citing videos. For the media desired by students with one instrument, six students or 6.3% cited the module, 23 or 24% cited the book, four students or 4.2% cited the teaching aids, and 11 students cited the video. From needs analysis recorded 24 students or 25% citing baskets, and 13 students or 14% citing cones. Variables supporting learning activities desired by students with one instrument obtained results of 11 students or 11.5% citing baskets, 17 students or 18% of students citing hula-hoops, 23 students or 24% citing plastic balls, and 19 students or 20% citing cones. As many as 67.7% of students wanted to include elements of the game, 86.5% of students were interested in the ability to teach new motor skills. In the desired model delivery variables obtained by 16 students or 16% varied, ten students or 10% of students answered easily understood, 12 students or 12% answered happily and 11 students or 11% of students answered simply.

After collecting data and compiling teaching materials, the next step is to carry out expert tests. The purpose of this expert review is to determine the feasibility or validity of the model, the accuracy and adequacy of the products developed for the needs in the field. Expert opinions were collected using a questionnaire. Based on the expert test conducted, it can be concluded that the variation of material for mobility ability resulted in 45 variations of traditional game-based teaching materials, namely, Race Sack, Egrang and Gobak Sodor for school-age middle school. The next step, after 45 models experienced revisions from experts, then continued with the main trial using the subjects of the study as many as 60 students from the Junior High School of Probolinggo. In the opinion of experts on the development of traditional game-based motion capability materials for junior high school students, which have been piloted in the main trial (testing field), it turns out that the use of the developed model does not need to be revised as all aspects have met the standards to be used, so product trials can be carried out by testing the effectiveness and efficiency in the learning process. The next step of the operational trial (test of effectiveness) involves a wider audience. The main purpose of this step is to determine the effectiveness of the results of applying the design of the model to the research objectives. The research at this stage used a quantitative approach, with a pre-experimental research design in the form of a one group pretest–post-test design.

Based on Table 1, because of the value of α (0.005) > ½ Sig. (two-tailed) (0.000) then H_0 is rejected, as there is a significant increase in physical fitness test results before and after receiving the material for traditional game-based motion skills.

The results of the model effectiveness test carried out in this study were testing 60 students from three schools, namely: Probolinggo Middle School 1, Probolinggo Middle School 4, and Probolinggo Middle School 8, which were treated using 45 material models for motor skills. Traditional game for junior high school students. This treatment is given for five meetings. While the tests used in this study used the Indonesian Physical Fitness Test (TKJI) to determine physical fitness results, which contain elements of student motor movements and by using observation guidelines for students' attitudes to find out attitudes/affective students in the learning process that occurs. The following are the results of the tT test statistics for physical fitness tests and student attitudes/affective observations:

Based on Table 2, because of the value of α (0.005) > ½ Sig. (two-tailed) (0.000) then H_0 is rejected, as there is a significant increase in affective students before and after traditional game-based motion ability material. Based on Tables 1 and 2, a significant increase in motor movement and attitudes/affective students after treatment with traditional game-based motion ability material is demonstrated. The model of motion game material based on traditional games for junior high school students developed and made by the researchers is a product that aims to assist teachers in conveying the material regarding the ability to move, increase physical fitness and attitudes/affective students, and as a reference for teaching materials. The advantages of this product include making students motivated in the teaching and learning process, and making students more active, collaborative, appreciative, and like sports in the learning process, so that the objectives of physical education learning are achieved effectively and efficiently.

Table 1. Research design in the effectiveness testing model.

Subject	Pretest	Treatment	Post-test
R	O_1	P	O_2

Table 2. Paired samples test.

		Paired differences							
					95% Confidence interval of the difference				
		Mean	Std. deviation	Std. error mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pretest–post-test	–32.561	1.628	0.200	–32.961	–32.160	–162.492	65	0.000

Table 3. Paired samples TKJI test.

		Paired differences							
					95% Confidence interval of the difference				
		Mean	Std. deviation	Std. error mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pretest–post-test	–3.015	1.949	0.240	–3.494	–2.536	–12.566	65	0.000

4 CONCLUSION

From the results of field research it can be concluded that:Based on the results of expert evaluations and trials that have been conducted, the final model includes: (1) Gobak Sodor, (2) Gobak Sodor Bola, (3) Gobak Sodor Gawang, (4) Go-bak Sodor Holahop, (5) Gobak Sodor Basket, (6) Sack Racing, (7) Bottle Sack Racing, (8) Ball Sack Race, (9) Moving Ball Sack Race, (10) Zig-Zag Sack Race, (11) Reverse Zig-Zag Sack Race, (12)) Triangular Track Sack Race, (13) Cone Hurdle Sack Race, (14) Square Boundary Sack Race, (15) Backward Square Boundary Sack Race, (16) Flag Sack Race, (17) Backward Flag Sack Race, (18) Race Circle and Square Limit Sacks, (19) Rat and Cat Sack Race, (20) Sack Sack Race, (21) Switch Sack Race, (22) L Movement Sack Race, (23) L Strip Sack Race, (23) Sack Race Reverse L Line, (24) Who's Fast Sack Race, (25) Red Blue Sack Race, (26) Mini Goal Sack Race, (27) Stilts, (28) Back Stilts, (29) Side Stilts, (30) Zig Stilts—Zag, (31) Egrang Ling-karan, (32) Egrang Est afet, (33) Reverse Circle Stilts, (34) Reverse Relay Stilts, (35) Flag Stilts, (36) Striped Stilts, (37) Backing Stilts, (38) Spotted Relay Stilts, (39) Reverse Relay Stilts are plotted, (40) Flag Relay Stilts, (41) Relay Flag Stilts, (42) Race and Stilts, (43) Race and Stilts Retreat, (44) Racing, Stilts and Flags, and (45) Flag Stilts. Based on the results of the model effectiveness test, it is empirically proven that the product results in the form of teaching materials based on traditional motor skills for middle school age have very good effectiveness. This is based on the results of the physical fitness test which shows that the average post-test results are greater than the average results of the pretest. Thus, it can be stated that the ability to move material based on traditional junior high school age games is effectively used to improve motor skills of junior high school age students.

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Analysis of chemical identity thinking through problem-based learning based on redox and electrochemistry concepts

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ABSTRACT: This study aims to analyze the chemical identity thinking of students in problem-based learning based on redox and electrochemistry concepts. The subjects of this study were a class of a senior high school in Bogor. A qualitative method was used through a chemical identity thinking test, class observation, interview and reflective journal writing. Learning was carried out with case studies relating to several chemicals and their applications. The learning process using problem-based learning affects students' chemical identity thinking. The improvement of chemical identity thinking occurs in eight categories (functional usage, surface similarity, historically, substantialization, additivity, elementalism, structuralism, emergence), have been showed in student's thinking process. Before the learning process, students focus only on objectivization and after the learning process other chemical identity thinking increases. The positive impact of the development of chemical identity thinking is that students can use their chemical knowledge to solve problems in everyday life.

1 INTRODUCTION

At present, the use of chemicals is very excessive and worrying. The large variety of chemicals in the environment requires humans to have a basic understanding of how to use, manage and even analyze chemicals (Ngai et al., 2014). This understanding can be formed through formal education at school. Students must be able to understand the cost-benefit-risk of chemical use (Banks et al., 2015). Understanding or knowledge of a chemical substance is called chemical identity thinking.

Chemical identity is based on the identification of any chemical that has at least one distinguishing characteristic that makes it unique (Enke, 2001). Situations involving chemical identities often occur in everyday life because they can be found everywhere both in laboratories, grocery stores and homes. Information about the chemical identity of a substance allows students to process, use and treat these chemicals properly in life (Ngai & Sevian, 2016). In addition, the knowledge of chemical identity of each student will provide information for teachers about how students think about chemicals. This information will be used by the teacher to find out and evaluate the results of classroom teaching. Previous research has shown that many students do not use the concepts they have learned to develop their chemical knowledge framework, let alone apply them outside the classroom (Eilks & Hofstein, 2015).

The focus of this research is to analyze chemical identity thinking or the way students think about chemical identity. The necessary and most important first step in the study to identify chemical identity thinking is the creation of instruments identifying Chemical Identity Thinking (CIT) based on the principles of qualitative research and the need to be validated by experts in order to properly understand and characterize students' chemical identity thinking. In addition, several questions were added concerning the concept of material so that students' understanding of the material remained controlled. Next, researchers must choose a learning model that supports research and Problem-Based Learning (PBL) was selected. The use of this learning model supports research because students are encouraged by teachers to develop the ability to think and solve problems during the learning process (Jonassen & Hung, 2008). Chemical identity thinking occurs through questions given by the teacher through the provision of problems to stimulate students' critical thinking skills toward the characteristics of a substance and its application in daily life.

The development of learning in the classroom to identify and improve the chemical identity thinking of students needs to be addressed Therefore, a learning model is needed that stimulates students' ways of thinking in solving problems in chemistry. Problem-based learning was chosen as a learning model in this study. This is in accordance with Savery (2006), who stated that PBL is an instructional-centered approach that empowers students to conduct research, integrate theory and practice, and apply knowledge and skills to find the right solution for the problem given. Problem-based learning involves case studies by utilizing open questions, which can reveal the ways in which students use chemical identity thinking to classify and differentiate substances (Ngai & Sevian, 2016).

2 METHOD

The research method used in this study is a qualitative method. The qualitative method was chosen because the focus of this study was to analyze the chemical identity of students through the application of problem-based learning models using redox and electrochemical materials. Data collection was based on observations made during the study, student reflective journals, teacher reflective journals, chemical identity thinking questions, chemistry understanding questions and student interviews. Chemical identity thinking questions were adapted and modified based on the Chemical Subtances Identification survey developed by Ngai and Sevian (Ngai & Sevian, 2016). The CSI survey is intended to be used for collecting data that can be analyzed using qualitative research methods, and uses open-ended questions to elicit CIT in response to various contexts. Students' responses were processed and presented in the form of percentages which were obtained from the number of student answers in a particular category compared to the total number of students (Table 1). The subjects of this study were science students in a senior high school comprising 38 students consisting of 11 males and 27 females.

3 RESULTS AND DISCUSSION

Learning in the classroom is carried out using problem-based learning through the provision of cases. Before learning begins, students are asked to write down what they know about some chemicals, such as NaOCl, NaCl, silver, $NaHCO_3$, oxygen and gold. Many students write down physical characteristics, uses and even the history of the formation of these substances. Furthermore, the teacher explains the concepts of redox and electrochemistry by linking several chemicals that had been identified at the beginning of learning through the provision of cases (Figure 1).

Table 1. Percentage of four students' mindset before and after the learning process.

Question about substance	Objectivization		Principlism		Compositionism		Interactionism	
	Before	After	Before	After	Before	After	Before	After
NaOCl	0%	82%	0%	6%	0%	3%	0%	9%
NaCl	65%	21%	27%	30%	0%	3%	8%	46%
Silver	97%	10%	3%	39%	0%	13%	0%	38%
$NaHCO_3$	6%	53%	3%	13%	0%	21%	0%	13%
Oxygen	82%	27%	18%	33%	0%	30%	0%	10%
Gold	29%	17%	55%	29%	16%	40%	0%	14%

Case
Gold and Brass
The high sales of fake gold make people worry about buying gold. However gold is a promising investment because the price always rises from year to year and its function as jewelry is very popular, especially among women.
One day, your mother bought a gold ring in jewelry shop. Unfortunately your mother was fooled by a gold seller. Fake gold bought by your mother is a brass ring. It made her sad because she really liked the shape of the ring. Then you help your mother and tell her how to determine gold and brass.
Question:
1. What are the characteristics of gold and brass?
2. How do you help your mother keep using the ring without damage like rusting? Explain your opinion!
3. If you use the principle of electrolysis,
   a. Write down the electrolysis reaction that occurred in the event!
   b. Based on the electrolysis reaction that you choose, how much metal is formed for 10 minutes with a current of 20 amperes?

Figure 1. Case.

The question of Chemical Identity Thinking
1. How would you be able to determine if a jewelry is gold ?
2. How do you differentiate a jewelry from gold or brass ?
   a. Is there any further information (other aspects) you would like to know in order to make decision ? If so, what is it?
   b. How would this information help you make decision ?

Figure 2. Chemical identity thinking questions.

In addition to giving questions and cases, at the end of the lesson students also fill out chemical identity thinking questions that are done individually (Figure 2).

Analysts' results of student answers indicate that at the beginning and end of learning all the chemical identity thinking categories appear with different presentations for each substance. According to Ngaiand Sevian (2016), chemical identity thinking consists of four thought patterns, namely objectivization, principlism, compositionism and interactionism. Table 1 illustrates students' chemical identity thinking before and after learning.

Based on the results of coding of the students' answers before the learning process in the classroom, more than half of the students used chemical identity thinking in the form of objectivization to determine the substance. However, this number decreases after learning using the problem-based learning model given. Students' answers after learning not only focus on the characteristics of the object they see but increase in relation to the chemical properties and chemical structure of the substance.

At the beginning of the study, more than half of students used the objectivization mindset to determine the chemical identity of substances. Objectivization is a mindset used by students to classify substances based on the macroscopic view of the substance. Based on the literature, the objectivization mindset is specifically divided into two categories to classify substances, namely based on functional usage and surface similarity of substances (Ngai & Sevian, 2016). Generally, students at the beginning of learning still rely on their knowledge of the application of these substances in their daily lives. In addition to the initial knowledge, students can also determine the chemical identity of a substance based on their learning experience related to chemicals. This is consistent with the opinion of Sevian and Talanquer (2014) that most reasoning is based on the experience and knowledge that students get from everyday life.

Next, students' statements about a substance can be formed according to the surface features they see and feel, as shown in the following statement:

> '*Gold is a metal with the symbol Au, bright yellow, shiny, the material is flexible but not easily changed, the price is more expensive, obtained by mining*'
>
> *(Chemical identity thinking questions for 29 students, April 10, 2018)*

Students' statements are consistent with that expressed by Talanquer (2009) that novice students have ideas and ideas about certain categories of identity and membership are limited only by the surface features and appearance of a substance. The students' statements show that students are able to identify NaCl, silver, oxygen and gold, based on their shape, color, form and smell. This is because beginner students use perceptual marks to distinguish different types of materials. They pay attention to material properties that can be understood such as shape, color, texture and odor to make judgments about the membership of certain substances (Liu & Lesniak, 2006; Smith et al., 1985).

Students' statements on NaCl, silver, gold and oxygen at the beginning of learning show that students can identify and classify substances based on their usefulness in daily life (Lynch & Jones, 1995; Krnel et al., 1998). Students successfully identify NaCl as a flavoring, students also identify silver for jewelry and oxygen to breathe. Whereas for the substances $NaHCO_3$ and NaOCl, new students can determine chemical identity after the learning process is given. Students' statements on these two substances indicate that students can recognize NaOCl as a cleaning agent (Bretz & Emenike, 2012) and $NaHCO_3$ as a food ingredient (Liu & Lesniak, 2006) after teaching using the problem-based learning approach is delivered.

The results of the analysis of student answers indicate a decline in the mindset of objectivization and an increase in other mindsets such as principlism, compositionism and interactionism. This proves that after learning students not only focus on what they see (objectivization) but on what they know about the chemical properties of the substance (interactionism). This increase can be caused during learning using problem-based learning, as students have been accustomed to finding characteristics and identifying substances using a higher mindset. This is in accordance with Ngai and colleagues' statement (2014) that students' understanding is expected to develop as students are asked to recognize various types of substances, explore the nature of substances and identify their chemical composition and structure at the submicroscopic level.

The next mindset is principlism. Principlism is used to classify substances based on the principal properties of the constituent components of the substances that can be added or removed without changing the chemical identity of the substance. Principlism is divided into two categories, namely historicality and substantialization of substances. The number of students who use historicality is very little, both at the beginning and at the end of learning. In NaCl and gold substances, students succeed in using historicality after the learning process. The student statement states that NaCl is the result of the reaction between acids and bases. The students' answers are influenced by their initial knowledge of the acid and base chapters. Besides NaCl, students can identify gold by mentioning gold is a pure metal in contrast to brass which is a mixed metal. This is influenced by learning material by comparing the brass and gold that students are studying. This is consistent with Domin et al. (2008), who state that learners struggle to distinguish relevant from irrelevant features, as they are strongly influenced by the content being discussed in class.

The next category is substantialization. This category classifies substances based on their properties which are influenced by the typical principal properties resulting from the reaction of these substances with other substances. The number of students who successfully use this category has increased except for gold. Improvement is seen after students are given group learning and discussion. During the interview, students tried to detect NaOCl with heating experiments and measure pH with litmus paper. Data from the student experiments match the data during group discussion looking for the characteristics of NaOCl. This is in accordance with Johnson's statement that students experience limited perceptions of identifying or differentiating material and understanding the need for experimental testing of selected differentiating properties (e.g. melting points) of unknown substances (Johnson, 2000).

The next mindset is compositionism which classifies substances based on the nature of the constituent elements that can contribute to the nature of a substance. Compositionism is divided into two categories, namely additivity and elementalism. In the additivity category, the number of students who succeeded in using this category in the substances NaOCl, $NaHCO_3$, oxygen, and gold increased after the learning process was given. The students succeeded in identifying the additivity category in the four substances, namely warming up NaOCl which can produce a pungent odor which is the Cl_2 gas, heating $NaHCO_3$ can produce bubbles containing CO_2 gas, oxygen is a constituent of water so it is easily soluble in water. Experiments carried out can give rise to macroscopic features that can be observed because basically, students tend to think about substances as a mixture of atomic elements with typical properties added simply to produce macroscopic features that can be observed (Talanquer, 2008).

The last mindset is the interactionism. We can assume this mindset as the mindset that has the highest thinking in which the grouping of substances is based on the nature of substances that arise due to dynamic interactions between the components of the substance (Solominodou & Stavridou, 2000). Interactionism has two categories, namely recognizing substances based on structuralism and emergence. Structuralism looks at the point of view of substances as chemical structures, for example, a substance consisting of ions that can conduct electricity. The number of students who use structuralism increased after learning was given. In oxygen substances, students identify chemical structures based on tenuous particles. In addition to oxygen, students can relate their experience to heating sugar and NaCl where the sugar turns to caramel while NaCl does not. Students say NaCl is an ionic compound consisting of ions, so it is difficult to melt if heated. This is in accordance with the statement of Ngai et al. (2014) that the ability of students to recognize types of substances can develop in different ways depending on prior knowledge and personal experience with certain types of material.

The teacher's efforts help students to establish a relationship between macroscopic and submicroscopic experiences so that they can understand the different properties of temperature responses and electrical power proposed by Chi et al. (2012). The teacher's efforts are reflected in this research, namely, the teacher uses the case through the problem-based learning model. Examples of cases given are the NaCl function of the voltaic cell circuit as a neutralizer of the excess ion. In chemical identity thinking, students can identify NaCl based on their chemical structure as neutralizing the excess of electrons containing ions.

The learning process of problem-based learning through cases can develop the mindset of students in which students are trained to carry out a continuous investigation of the chemical identity of substance and their application to everyday life. This supports the results of the research by Sevian and Talanquer (2014) which reveals that students' ideas and ways of thinking about chemical synthesis, analysis, and transformation (chemical identity thinking) can develop through formal education, in the context of learning approaches that involve investigation, design and evaluation.

4 CONCLUSION

The learning model of problem-based learning through the provision of cases can identify and improve the chemical identity thinking of students using redox and electrochemical material. This learning model requires students to investigate, analyze, formulate solutions related to chemicals and their application in daily life. Students become accustomed to using chemical identity thinking in the categories of compositionism and interactionism (microscopic representation) compared to objectivization and principlism (macroscopic representation). At the beginning of learning, many students used the objectivization mindset in the functional usage category, with the highest value of 55% in oxygen substances. Then, after the learning process, students' chemical identity thinking increases in the emergence of the interactionism mindset, with the highest value of 33% in silver. Another benefit of developing chemical identity thinking that students have is that students can use their chemical knowledge related to chemicals to solve problems in everyday life.

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Value at Risk for the portfolio problem with copulas

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ABSTRACT: Value at Risk (VaR) is known to give a benchmark risk measure in the area of modern risk management. Here we show the unique determination of VaR for the portfolio problem which consists of two risk random factors. We consider the situation that these two random variables are not necessarily independent but possess certain nonlinear relation which is assumed to be represented by a copula. As is well known, a copula function provides an analytical tool to investigate a possibly nonlinear connection among random variables. Because of its flexibility, the method of copulas has now become a standard method in the risk management. We derive a computation formula of VaR for the portfolio problem in the presence of copulas. We show the unique solvability of the formula and give an example.

1 INTRODUCTION

It is well recognized that Value at Risk (VaR) serves as a principal risk measure. VaR is commonly defined for a single random variable. On the other hand, we here deal with VaR for the portfolio problem, which involves two random factors.

Let X and Y denote random variables, which are not necessarily assumed to be independent. We consider the portfolio represented by a random variable Z of the form

$$Z = \lambda X + (1-\lambda)Y \quad (0 < \lambda < 1). \tag{1}$$

Our concern is the VaR for Z; namely,

$$\mathrm{VaR}_{\beta}(Z) = F_Z^{(-1)}(\beta) \quad (0 \le \beta < 1) \tag{2}$$

where $F_z(z)$ denotes the distribution function of Z and $F_Z^{(-1)}(\beta)$ its inverse. The details will be given in the next section.

This kind of problem is typical in the area of finances and there has been much study already so far; however, mostly on the basis of the assumption that X and Y are independent.

Our additional flavor is taken with respect to the theory of copula; to be more specific, X and Y are nonlinearly related and represented by:

$$H(x,y) = C(F_X(x), F_Y(y)). \tag{3}$$

Here $H(x,y)$ denotes the joint distribution function of X, Y, and $F_X(x), F_Y(y)$ the distribution function of X, Y, respectively. The function $C = C(u,v)$ is called a copula function, where detailed definition and properties are recalled in the next section. We note that the independence of X, Y is equivalent to $C(u,v) = uv$.

Now our goal in this paper is to provide a computation formula for $\mathrm{VaR}_\beta(Z)$ in the above setting that X, Y are not necessarily independent, and show that the unique determination of $\mathrm{VaR}_\beta(Z)$ is really assured by this formula. Our main result is stated in Section 3 where an example is also calculated.

Since the portfolio problem is important in the field of risk management, we hope that our observation will be useful.

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2 METHOD

2.1 *Value at risk*

We recall the definition of Value at Risk (VaR) for completeness of our presentation.

Let X be a random risk variable and denote by $F_X(x) = P(X \le x)$ its distribution function. VaR at a level β $(0 \le \beta < 1)$ is then simply defined by

$$\mathrm{VaR}_\beta(X) := F_X^{(-1)}(\beta) = \inf\{u | F_X(u) \ge \beta\}. \tag{4}$$

Because of its simplicity and readiness for use, VaR now becomes a standard benchmark of risk factors. We mention that, however, VaR is defined for a single random variable and the treatment in the case of the portfolio problem seems to be not so well investigated despite its importance in the study of risk management.

For further information and background materials of VaR, we refer for instance to Duffie and Pan (1997) and/or McNeil, Frey & Embrechts (2005) and the references therein.

2.2 *Copula*

Next we recall the definition of copula in the case of bivariate joint distribution.

Definition. A function C defined on $I^2 := [0,1] \cdot [0,1]$ and valued in I is called a copula if the following conditions are fulfilled.

i. For every $(u,v) \in I^2$,

$$C(u,0) = C(0,v) = 0, \quad C(u,1) = u \text{ and } C(1,v) = v \tag{5}$$

ii. For every $(u_i, v_i) \in I^2\ (i = 1,2)$ with $u_1 \le u_2$ and $v_1 \le v_2$,

$$C(u_1,v_1) - C(u_1,v_2) - C(u_2,v_1) + C(u_2,v_2) \ge 0 \tag{6}$$

The requirement (ii) is referred to as *the* 2-*increasing condition*. We also note that a copula is continuous by its definition.

The well-known result due to Sklar (1973), who employed the term "copula" almost for the first time, gives the basic property of copulas. We here recall Sklar's theorem in bivariate case, for completeness of our presentation.

Theorem (Sklar's theorem). *Let H be a bivariate joint distribution function with marginal distribution functions F and G; that is,*

$$\lim_{x\to\infty} H(x,y) = G(y), \qquad \lim_{y\to\infty} H(x,y) = F(y), \tag{7}$$

Then there exists a copula, which is uniquely determined on RanF × RanG, such that

$$H(x,y) = C(F(x), G(y)). \tag{8}$$

Conversely, if C is a copula and F and G are distribution functions, then the function H defined above gives a bivariate joint distribution function with margins F and G.

Copulas have now become a standard issue in the risk management, since the method is so flexible. We provide several examples of copulas:

$$\begin{aligned} &C(u,v) = \prod(u,v) := uv : \text{product copula}, \\ &M(u,v) = \min\{u,v\}, \quad W(u,v) = \max\{u+v-1,0\}. \end{aligned} \tag{9}$$

There also exist a family of one-parametrized copulas, which is known as Archimedean copulas. Here we present just one example.

$$C(u,v) = \exp\left(-\left[(-\log u)^{\theta} + (-\log v)^{\theta} \right]^{\frac{1}{\theta}} \right) \quad \left(\theta \in [1,\infty) \right) : \text{Gumbel copula.} \tag{10}$$

It is known that the next general inequality on copula is true. This is called as the Fréchet-Hoeffding bound.

Theorem (Fréchet-Hoeffding bound). *For any copula* $C = C(u,v)$ *we have the inequalities:*

$$\max\{u+v-1,0\} = W(u,v) \le C(u,v) \le M(u,v) = \min\{u,v\} \tag{11}$$

We employ this inequality in the proof of our main theorem. For further properties and issues of copulas, we refer to the nice book of Nelsen (2006), and/or an excellent paper by Frees and Valdez (1998).

3 RESULT

3.1 *Main theorem and proof*

Now we state our main theorem of this paper.

Theorem. *Let X, Y be nonnegative random variables, whose joint distribution function H is represented by a copula C with*

$$H(x,y) = C(F_X(x), F_Y(y)), \tag{12}$$

where $F_X(x), F_Y(y)$ *are marginal distribution functions of X, Y, respectively. Then,* VaR_{β} *for the portfolio* $Z = \lambda X + (1-\lambda) Y \ (0 < \lambda < 1)$ *at a level* $\beta (0 \le \beta < 1)$ *can be uniquely determined by the solution* z^* *of the equation*

$$\beta = \int_0^Z C\left(F_X\left(\frac{t}{\lambda} \right), \ F_Y\left(\frac{Z-t}{1-\lambda} \right) \right) dt, \tag{13}$$

so that

$$\beta = \int_0^{\mathrm{VaR}_{\beta}(Z)} C\left(F_X\left(\frac{t}{\lambda} \right), F_Y\left(\frac{\mathrm{VaR}_{\beta}(Z) - t}{1-\lambda} \right) \right) dt. \tag{14}$$

Proof. First we show that $\mathrm{VaR}_{\beta}(Z)$ is provided by the solution of the above equation. By the definition (1) of VaR, $\mathrm{VaR}_{\beta}(Z)$ is given by the solution of the equation:

$$\beta = P(Z \le z) = P(\lambda X + (1-\lambda) Y \le z). \tag{15}$$

The right hand side is reduced to

$$\int_0^z P\left(\lambda X \le t, (1-\lambda)Y \le z-t\right) dt = \int_0^z C\left(F_X\left(\frac{t}{\lambda}\right), F_Y\left(\frac{z-t}{1-\lambda}\right)\right) dt, \tag{16}$$

which is (3) and thus we have done the first part. Next we prove that the equation has the unique solution. Let

$$f(z) = \int_0^z C\left(F_X\left(\frac{t}{\lambda}\right), F_Y\left(\frac{z-t}{1-\lambda}\right)\right) dt. \tag{17}$$

Then it is easy to see that $f(0) = 0$ and $f(z)$ is monotone increasing. It thus suffice to show that

$$\lim_{z\to\infty} f(z) = \infty. \tag{18}$$

To accomplish this, we infer that, invoking the Fréchet-Hoeffding bound $C(u,v) \ge \max\{u+v-1, 0\} \ge u+v-1$ of (2),

$$f(z) \ge \int_0^z \left(F_X\left(\frac{t}{\lambda}\right) + F_Y\left(\frac{z-t}{1-\lambda}\right)\right) dt - z. \tag{19}$$

We divide the integral as follows:

$$f(z) \ge \left(\int_{\frac{\lambda z}{2}}^{\lambda z} + \int_{\lambda z}^{z} \right) F_X\left(\frac{t}{\lambda}\right) dt + \left(\int_0^{\lambda z} + \int_{\lambda z}^{\frac{(1+\lambda)z}{2}} \right) F_Y\left(\frac{z-t}{1-\lambda}\right) dt - z. \tag{20}$$

Since the distribution function is nondecreasing, we derive

$$f(z) \ge \int_{\frac{\lambda z}{2}}^{\lambda z} F_X\left(\frac{z}{2}\right) dt + \int_{\lambda z}^{z} F_X(z)\, dt + \int_0^{\lambda z} F_Y(z)\, dt + \int_{\lambda z}^{\frac{(1+\lambda)z}{2}} F_Y\left(\frac{z}{2}\right) dt - z, \tag{21}$$

which is resulted in

$$f(z) \ge \frac{\lambda z}{2} F_X\left(\frac{z}{2}\right) + (1-\lambda) z F_X(z) + \lambda z F_Y(z) + \frac{(1-\lambda)z}{2} F_Y\left(\frac{z}{2}\right) - z. \tag{22}$$

We therefore conclude that

$$f(z) \ge \frac{z}{2} \min\left\{ F_X\left(\frac{z}{2}\right), F_Y\left(\frac{z}{2}\right)\right\} + z \min\left\{ F_X(z), F_Y(z)\right\} - z. \tag{23}$$

If we choose M so large that there holds

$$\min\left\{ F_X\left(\frac{z}{2}\right), F_Y\left(\frac{z}{2}\right)\right\} \ge 5/6 \quad \text{for } z \ge M. \tag{24}$$

Then we learn that

$$f(z) \geq \frac{z}{2} \cdot \frac{5}{6} + z \cdot \frac{5}{6} - z = \frac{1}{4} z \quad \text{for } z \geq M. \tag{25}$$

This completes the proof of main theorem.

It is to be noted that the formula is already employed for numerical valuation of VaR_β. See for instance Fantazzini (2008). However, there seems to be no proof on the unique solvability and this seems to be a new observation.

3.2 *Example*

Here we merely deal with one example. Other examples are of course possible.

Assume that *X, Y*~Exp (α) (α > 0) and $C(u, v) = \min\{u, v\}$. Namely, *X, Y* are identically distributed and follows the exponential distribution with parameter α. We remark that *X*, *Y*, are not independent. We have

$$F_X(x) = 1 - e^{-\alpha x}, \; F_Y(x) = 1 - e^{-\alpha y}. \tag{26}$$

We want to find the solution of the equation

$$\beta = \int_0^z C\left(F_X\left(\frac{t}{\lambda} \right), F_Y\left(\frac{z-t}{1-\lambda} \right) \right) dt = \int_0^z \min\left\{ 1 - e^{-\alpha \frac{t}{\lambda}}, 1 - e^{-\alpha \frac{z-t}{1-\lambda}} \right\} dt. \tag{27}$$

This can be further computed as

$$\beta = \int_0^{\lambda z} \left(1 - e^{-\alpha \frac{t}{\lambda}} \right) dt + \int_{\lambda z}^{z} \left(1 - e^{-\alpha \frac{z-t}{1-\lambda}} \right) dt. \tag{28}$$

Consequently, we will seek a solution of

$$z + \frac{1}{\alpha} e^{-\alpha z} = \beta + \frac{1}{\alpha}. \tag{29}$$

The equation surely has the unique solution.

4 CONCLUSION AND DISCUSSION

We have dealt with Value at Risk (VaR) for the portfolio problem. The portfolio consists of the linear combination of two random variables; random variables is not necessarily independent but is assumed to be connected through a copula function. Copula is known to describe the nonlinear relations and due to its flexibility, copula now becomes an important method of studying the dependence structure. Therefore it is very natural to discuss about the portfolio problem in the presence of copulas.

We derive the formula for the valuation of VaR in the form of the integral equation; VaR should give a solution to this equation. We have also proved the unique solvability of the equation so that VaR is really provided as the unique solution of this formula. Example shows that our procedure works well.

Since the dependence structure among several risk factors is important in the study of risk management, we believe that our establishment will be employed further in the field of mathematical finance and quantitative risk management.

Finally we remark that the formula can be extended to several random variables. It seems, however, the proof of the unique determination seems to be still open; we will return to this issue in the near future.

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Median polish kriging model for circular-spatial data

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ABSTRACT: In this paper, a new model for kriging or predicting the spatial value of a circular random field at a non-observed location is introduced. This model employs the median polish algorithm that has been adapted for circular data. The median polish algorithm for circular data is used to remove spatial trends, often present in circular-spatial data. Removing spatial trend in the circular-spatial data is required to meet the stationarity assumption, prior to predicting a circular-spatial value using the circular ordinary kriging method. The new model is evaluated on simulated and real-world datasets. Leave-one-out cross-validation is used to evaluate performance of the new model. The Mean Absolute Cosine Error (MACE) and Mean Cosine Difference Error (MCDE) are two metrics used to measure the performance of the new model. The experiments on both types of dataset (i.e. simulated and real-world) show that the new model can be considered as a promising tool for predicting the realization value of a circular random field at non-observed points.

1 INTRODUCTION

Kriging is a method used in geostatistics for spatial prediction. This term is used in honor of the South African mining engineer, Daniel Gerhardus Krige. Kriging aims to predict the realization value of a random field at one or more non-observed points from a collection of data observed at several locations. There are many different kriging methods, depending on model assumptions: Simple Kriging, Ordinary Kriging and Universal Kriging. Simple kriging assumes that the mean of the attribute being modeled is known. Ordinary kriging assumes that the mean of the attribute is unknown. Another necessary condition required by simple kriging and ordinary kriging methods (and some of other kriging methods) is the existence of second-order stationarity about the mean, and the existence of a finite variance (Matheron, 1967). There are some problems in interpolating using simple kriging and ordinary kriging when spatial trends are present, since second-order stationarity about the mean is no longer valid.

In the presence of spatial trend, the estimator is no longer unbiased, and in this case the random field can be separated into two components (i.e. the spatial trend component and the residual component). The residual is the difference between the actual value and the spatial trend. The residuals hold the stationarity property. Ordinary kriging is used to estimate the residual component, which is added to the estimated spatial trend to obtain the final prediction value. However, we need to know the structure of the spatial trend, which is mathematically considered complex by many practitioners. When the spatial trend is difficult to model in a functional way, a non-parametric approach to detrend the spatial data can be performed. The popular non-parametric algorithm to detrend data is median polish. The median polish algorithm for two-way tables was introduced by Tukey (1977) and also by Emerson and Hoaglin (1983). Cressie (1986) adapted the concept for use in combination with kriging. Median polish kriging methods have been used in many diverse applications such as in climatology (Martínez et al., 2017), geology (Tutmez, 2014), medicine (McShane et al., 1997) and pedology (Crawford & Hergert, 1997).

Most kriging methods we have today were developed for predicting spatial data resulting from measurement made on a linear scale, such as weight, volume and length. Only a few kriging methods have been introduced for spatial data that have a direction in nature, for example wind direction and ocean wave direction. This type of data is named circular data. Circular data analysis is a developing field of statistics (Wang, 2013; Ley & Verdebout, 2017). Circular data are generated by a range of common measurements across scientific disciplines, for instance in meteorology, biology, oceanography, geology and geophysics. Wind direction, flight direction of bird migrations, ocean wave direction, fault orientation and magnetic field direction are some examples of circular data. Studying wind direction is important in environmental research. Wind direction can have a great influence in many phenomena such as the spread of forest fire, and the spread of pollutant or toxic particle matter through the air.

One of the key characteristics of circular data is that they can be represented as angles from an arbitrarily chosen origin (e.g. east). Circular data has special characteristics; for example, angle 5° is much nearer to an angle of 355° than to an angle of 45°. Therefore, standard statistical approaches to modeling linear data may not be valid for modeling the circular data. In such cases, a specific modeling framework for circular data is required. For good general reviews of non-spatial circular data modeling, see, for example, Fisher (1993), Mardia and Jupp (2000), Jammalamadaka and Sengupta (2001), Pewsey et al. (2013), and Ley and Verdebout (2017).

This paper introduces a new model for predicting spatial value of a circular random field at non-observed points. This model employs the median polish algorithm adapted for circular data, to remove spatial trend often present in circular-spatial data. The remainder of the paper is organized as follows. Section 2 presents the proposed median polish kriging model for circular-spatial data. The experimental results of the proposed kriging model using simulated datasets, as well as the application to a real-world dataset, are presented in Section 3. Section 4 draws conclusions from these results.

2 METHODOLOGY

2.1 *Median polish kriging*

Median polish kriging is an estimation method, developed to provide unbiased estimates when the studied spatial data exhibit spatial trends. The median polish kriging method consists of extracting the spatial trends from the original spatial data using the median polish algorithm and then using the ordinary kriging method to interpolate the residuals. This idea has some similarities to the approach presented by universal kriging in decomposing the random field into two components: one deterministic and the other stochastic, which can be treated as an intrinsically stationary random field.

Median polish kriging uses this decomposition to generate two new sets of data (i.e. the deterministic component and the residuals component). The residuals are analyzed for spatial continuity. After a semivariogram model is fitted to the empirical semivariogram of the residuals, ordinary kriging is used to estimate the residual value at a non-observed point. Finally, the prediction at a non-observed point is obtained by adding back the estimation of the spatial trend at such a point to the estimated value of residual.

Typically, median polish is used for lattice data, but it can be used with non-lattice data by overlaying a grid on the observations. With respect to the observed locations, we define a $p \times q$ rectangular grid to be laid over the studied area. Furthermore, the sample data $Z(\boldsymbol{s}_i), i = 1, \ldots, n$ are associated to the closest grid knot $\boldsymbol{s}_{kl}, k = 1, \ldots, p; l = 1, \ldots, q,$ and the coordinates of the observed locations $\boldsymbol{s}_i$ are converted to the corresponding gridlines $\boldsymbol{s}_{kl}$. For multiple data associated with a single grid knot, the data is replaced by their median. The edited sample data, $Z(\boldsymbol{s}_{kl})$, now have the structure of a two-way table or matrix and therefore the structure of data is suitable for the median polish process.

Median polish is an iterative process. It proceeds by repeated extraction of the row and column medians until reaching convergence. The iteration stops when an identical matrix to the previous matrix is obtained, or within a pre-established level of tolerance. The detailed process of the median polish algorithm is described in Cressie (1993) and Montero et al. (2015). For observed location data $Z(\boldsymbol{s}_{kl}), k = 1, \ldots, p; l = 1, \ldots, q,$ the median polish algorithm provides the estimation of the spatial trend (i.e. $\hat{\mu}(\boldsymbol{s}_{kl}),$ at location $\boldsymbol{s}_{kl}$). The estimation of the spatial trend can be decomposed as $\hat{\mu}(\boldsymbol{s}_{kl}) = \hat{a} + \hat{r}_k + \hat{c}_l,$ where $\hat{a}$ is the estimation of the overall effect, $\hat{r}_k$ is the estimation of the row effect for row k, and $\hat{c}_l$ is the estimation of the column effect for column l expressed in a matrix dimension of $p \times q$.

After the median polish estimates of the spatial trend component are obtained, then spatial interpolation is needed to estimate the spatial trend at the desired non-observed point $\boldsymbol{s}_0$, and is obtained by:

$$\hat{\mu}(\boldsymbol{s}_0) = \hat{a} + \hat{r}_k + \left(\frac{y_0 - y_k}{y_{k+1} - y_k} \right) \left(\hat{r}_{k+1} - \hat{r}_k \right) + \hat{c}_l + \left(\frac{x_0 - x_l}{x_{k+1} - x_l} \right) \left(\hat{c}_{l+1} - \hat{c}_l \right)$$

where $\boldsymbol{s}_0 = (x_0, y_0)', x_l \le x_0 \le x_{l+1}, y_k \le y_0 \le y_{k+1}.$

Finally, the median polish kriging prediction is the sum of the median polish estimation of the spatial trend at the desired non-observed point (i.e. $\hat{\mu}(\boldsymbol{s}_0)$), plus the estimation of the residual at the desired non-observed point (i.e. $\hat{R}(\boldsymbol{s}_0)$, obtained from the process of ordinary kriging of the residuals.

2.2 *Proposed model*

For circular-spatial data such as wind direction, the median polish kriging method described in Section 2.1 will not be able to properly predict or estimate the spatial value of non-observed points, due to the special characteristics of circular data. In circular statistics, the median direction is defined to be any angle ω for which half of the data points lie in the arc $(\omega, \omega + \pi)$ and the majority of the points are nearer to ω than $\omega + \pi$. As such, determining the median for circular data is different from determining the median for linear data. For example, in circular data such as: 0°, 15°, 350°, the median direction is 0° and is not 15°. Therefore, the above median polish algorithm needs to be adapted for circular data to correctly determine the median direction.

Similar to median polish kriging for linear data, the sample of circular-spatial data $Z(\boldsymbol{s}_i) = \theta_i, i = 1 \ldots, n$ are associated or aligned to the closest grid knot $\boldsymbol{s}_{kl}, k = 1, \ldots, p; l = 1, \ldots, q,$ and the coordinates of the observed locations $\boldsymbol{s}_i$ are converted to the corresponding gridlines $\boldsymbol{s}_{kl}$. Now, the sample data, $Z(\boldsymbol{s}_{kl}) = \theta_{kl}$, have the structure of a two-way table and are suitable for the median polish process.

The approach that we propose is to adapt median polish kriging to the specific characteristics of circular data by decomposing the observed angles $\theta_{kl}, k = 1, \ldots, p; l = 1, \ldots, q$ into two components: horizontal component (i.e. $cos\ \theta_{kl}$) and vertical component (i.e. $sin\ \theta_{kl}$) for $k = 1, \ldots, p; l = 1, \ldots, q.$ These components are now linear data. Therefore, we can use the standard median polish algorithm for each set of data to extract the spatial trend. Once the spatial trends have been extracted from the horizontal and vertical components, the estimates of residuals, row effect, column effect and overall effect of horizontal and vertical components should be transformed back to the circular data.

The circular kriging method based on a model of circular-spatial correlation was introduced by Morphet (2009). The cosineogram and cosine model with nugget, range and sill were introduced to perform circular kriging. The cosineogram is a graph expressing the empirical correlation of circular-spatial data. The cosineogram is a two-dimension plot of $\hat{\varsigma}(d) = \frac{1}{n(d)} \sum_{\left| \|\boldsymbol{s}_j - \boldsymbol{s}_i\| - d \right| < \varepsilon} cos(\theta_j - \theta_i)$ as y axis and d (distance) as x axis, where $\hat{\varsigma}(d)$ is the estimate of the mean cosine, which depends on the Euclidean distance d between measurement locations; $\|\boldsymbol{s}_j - \boldsymbol{s}_i\|$ is the Euclidean distance between location $\boldsymbol{s}_j$ and $\boldsymbol{s}_i$; $N(d)$ is the number of pairs of observations separated by a distance $\|\boldsymbol{s}_j - \boldsymbol{s}_i\|$ within a tolerance ε of d; and θ_i and θ_j are the measured directions at location $\boldsymbol{s}_i$ and $\boldsymbol{s}_j$. The positive definite cosine model with best fit to the cosineogram characterizes the spatial properties of circular-spatial data. Cosine models introduced by Morphet (2009) were adapted from three common covariance models from kriging for linear data (i.e. exponential, Gaussian and spherical models). The cosine models used in this paper are the exponential, Gaussian and spherical cosine models.

The steps to perform median polish kriging for circular-spatial data are as follows:

i. Start with a matrix Θ of $(p+1) \quad (q+1)$ dimensions which contains the $p \times q$ original data θ_{kl} , $k = 1, ..., p; l = 1, ..., q$ and the last row and column elements that are null.

ii. Decompose matrix Θ into two matrices H (horizontal matrix) and V (vertical matrix) as follows:

$$\mathrm{H} = \begin{bmatrix} h_{11}^{(0)} & h_{12}^{(0)} & ... & h_{1q}^{(0)} & 0 \\ h_{21}^{(0)} & h_{22}^{(0)} & ... & h_{2q}^{(0)} & 0 \\ ... & ... & ... & ... & ... \\ h_{p1}^{(0)} & h_{p2}^{(0)} & ... & h_{pq}^{(0)} & 0 \\ 0 & 0 & ... & 0 & 0 \end{bmatrix} \text{and } \mathrm{V} = \begin{bmatrix} v_{11}^{(0)} & v_{12}^{(0)} & ... & v_{1q}^{(0)} & 0 \\ v_{21}^{(0)} & v_{22}^{(0)} & ... & v_{2q}^{(0)} & 0 \\ ... & ... & ... & ... & ... \\ v_{p1}^{(0)} & v_{p2}^{(0)} & ... & v_{pq}^{(0)} & 0 \\ 0 & 0 & ... & 0 & 0 \end{bmatrix}$$

where $h_{kl}^{(0)} = \begin{cases} cos\ \theta_{kl,}\ k = 1,\ldots,p; l = 1,\ldots,q \\ 0 \qquad\qquad\qquad\qquad otherwise \end{cases}$

and $v_{kl}^{(0)} = \begin{cases} sin\ \theta_{kl,}\ k = 1,\ldots,p; l = 1,\ldots,q \\ 0 \qquad\qquad\qquad\qquad otherwise \end{cases}.$

iii. Perform iterative process of median polish:

For matrix H:

– For the odd iteration, $i = 1, 3, 5, ...$

$$h_{kl}^{(i)} = h_{kl}^{(i-1)} - Med\left\{ h_{kl}^{(i-1)}; l = 1, ..., q \right\} \text{ if } k = 1,..., p+1; l = 1, ..., q$$

$$h_{k,q+1}^{(i)} = h_{k,q+1}^{(i-1)} + Med\left\{ h_{kl}^{(i-1)}; l = 1, ..., q \right\} \text{ if } k = 1, ..., p+1$$

– For the even iteration, $i = 2, 4, 6, ...$

$$h_{kl}^{(i)} = h_{kl}^{(i-1)} - Med\left\{ h_{kl}^{(i-1)}; k = 1, ..., p \right\} \text{ if } k = 1, ..., p; l = 1, ..., q+1$$

$$h_{p+1,l}^{(i)} = h_{p+1,l}^{(i-1)} + Med\left\{ h_{kl}^{(i-1)}; k = 1, ..., p \right\} \text{ if } l = 1, ..., q+1$$

For matrix V:

– For the odd iteration, $i = 1, 3, 5, ...$

$$v_{kl}^{(i)} = v_{kl}^{(i-1)} - Med\left\{ v_{kl}^{(i-1)}; l = 1, ..., q \right\} \text{ if } k = 1, ..., p+1; l = 1, ..., q$$

$$v_{k,q+1}^{(i)} = v_{k,q+1}^{(i-1)} + Med\left\{ v_{kl}^{(i-1)}; l = 1, ..., q \right\} \text{ if } k = 1, ..., p+1$$

– For the even iteration, $i = 2, 4, 6, ...$

$$v_{kl}^{(i)} = v_{kl}^{(i-1)} - Med\left\{ v_{kl}^{(i-1)}; k = 1, ..., p \right\} \text{ if } k = 1, I, p; l = 1, ..., q+1$$

$$v_{p+1,l}^{(i)} = v_{p+1,l}^{(i-1)} + Med\left\{ v_{kl}^{(i-1)}; k = 1, ..., p \right\} \text{ if } l = 1, ..., q+1$$

Iterations are carried out accordingly until convergence is achieved.

iv. The iterative process in step (iii) stops when convergence is achieved (i.e. an identical matrix to the previous matrix is obtained or approaches within a pre-established level of tolerance). Once the iterative process has concluded, the estimated overall effect, row effect and column effect for horizontal and vertical components are derived as follows:

For matrix H:

– $\hat{a}_h = h^{(\infty)}_{p+1,q+1}$

– $\hat{r}_{hk} = h^{(\infty)}_{k,q+1}, \quad k = 1, \ldots, p$

– $\hat{c}_{hl} = h^{(\infty)}_{p+1,l}, \quad l = 1, \ldots, q$

For matrix V:

– $\hat{a}_v = v^{(\infty)}_{p+1,q+1}$

– $\hat{r}_{vk} = v^{(\infty)}_{k,q+1}, \quad k = 1, \ldots, p$

– $\hat{c}_{vl} = v^{(\infty)}_{p+1,l}, \quad l = 1, \ldots, q$

v. Transform back the estimated overall effect, row effect, column effect and residuals of each matrix to circular data by using the following rule:

$$\theta^{(\infty)}_{kl} \begin{cases} arctan\left(\dfrac{h^{(\infty)}_{kl}}{v^{(\infty)}_{kl}}\right) & if\, h^{(\infty)}_{kl} > 0 \\ arctan\left(\dfrac{h^{(\infty)}_{kl}}{v^{(\infty)}_{kl}}\right) + \pi & if\ v^{(\infty)}_{kl} \geq 0, h^{(\infty)}_{kl} < 0 \\ arctan\left(\dfrac{h^{(\infty)}_{kl}}{v^{(\infty)}_{kl}}\right) - \pi & if\ v^{(\infty)}_{kl} < 0, h^{(\infty)}_{kl} < 0 \\ \dfrac{\pi}{2} & if\ v^{(\infty)}_{kl} > 0, h^{(\infty)}_{kl} = 0 \\ -\dfrac{\pi}{2} & if\ v^{(\infty)}_{kl} < 0, h^{(\infty)}_{kl} = 0 \\ not\ defined & if\ v^{(\infty)}_{kl} = 0, h^{(\infty)}_{kl} = 0 \end{cases}$$

After having obtained estimates of the spatial trend component (i.e. row, column, and overall effect), then the following steps must be followed to carry out the median polish kriging procedure for circular-spatial data:

vi. Perform ordinary kriging for circular-spatial data for the residuals, as set out by Morphet (2009):

a. Construct the empirical cosineogram of the residuals.
b. Select a valid cosine model using the empirical cosineogram of the residuals as a basis.
c. Perform the ordinary kriging procedure for circular-spatial data on the residuals, using the selected valid cosine model to obtain an estimation of the residual at the desired non-observed point, $\boldsymbol{s}_0$, in the domain under study (i.e. $\hat{R}(\boldsymbol{s}_0)$).

vii. Finally, the estimation of the spatial trend at that non-observed point (i.e. $\hat{\mu}(\boldsymbol{s}_0)$) is added to the result of the ordinary kriging on the residual (i.e. $\hat{R}(\boldsymbol{s}_0)$), obtaining an estimated spatial value $Z(\boldsymbol{s}_0)$ where $Z(\boldsymbol{s}_0) = \hat{\mu}(\boldsymbol{s}_0) + \hat{R}(\boldsymbol{s}_0)$. The estimated spatial trend at a non-observed point (i.e. $\hat{\mu}(\boldsymbol{s}_0)$) can be obtained by:

$$\hat{\mu}(\boldsymbol{s}_0) = \hat{a} + \hat{r}_k + \left(\frac{y_0 - y_k}{y_{k+1} - y_k}\right)(\hat{r}_{k+1} - \hat{r}_k) + \hat{c}_l + \left(\frac{x_0 - x_l}{x_{k+1} - x_l}\right)(\hat{c}_{l+1} - \hat{c}_l)$$

where $\boldsymbol{s}_0 = (x_0, y_0)', \ x_l \leq x_0 \leq x_{l+1}, y_k \leq y_0 \leq y_{k+1}$.

3 EXPERIMENTS AND RESULTS

For testing and evaluating the performance of the proposed kriging model, we experimented with the proposed kriging model using simulated and real-world datasets. The proposed kriging model and the generation of the simulated dataset were implemented using R software.

3.1 *Simulation experiments*

We first evaluated the proposed kriging model on simulated datasets because we know the correct answers for this case. Our primary goal is to show that the proposed kriging model was able to properly predict spatial values at non-observed points from a collection of circular-spatial data observed at several locations. We used three simulated wind-direction datasets that were generated from three different circular distributions (i.e. von Mises, Cardioid and Wrapped Cauchy distributions). To simulate circular-spatial datasets that have spatial trend, wind trend direction was added to each original wind-direction dataset generated from respective circular distribution. Figure 1 below displays the resulting wind direction for each simulated dataset.

The median polish algorithm for circular data was applied to remove spatial trend present in those three simulated datasets. Figure 2 displays the result of detrending the wind direction for each simulated dataset, using the median polish algorithm for circular data. The spatial trend of the wind direction is displayed in brown, while the original wind direction is shown in black.

The difference between the original wind direction value and its spatial trend value is the residual. The next step was to calculate the residual of each observed point. Then, we constructed an empirical cosineogram of the residuals. Using the empirical cosineogram of the

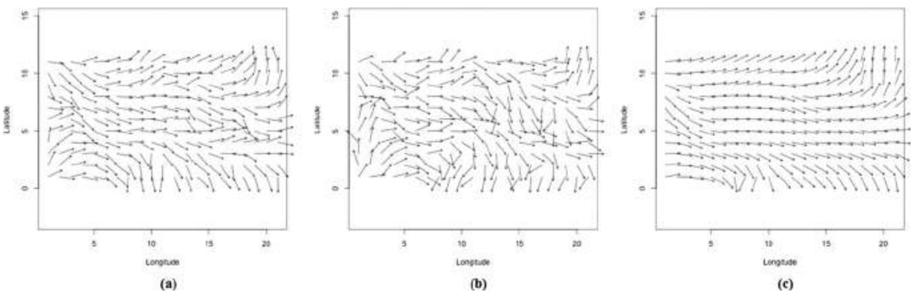

Figure 1. Wind direction for each simulated dataset: (a) von Mises; (b) Cardioid; (c) Wrapped Cauchy.

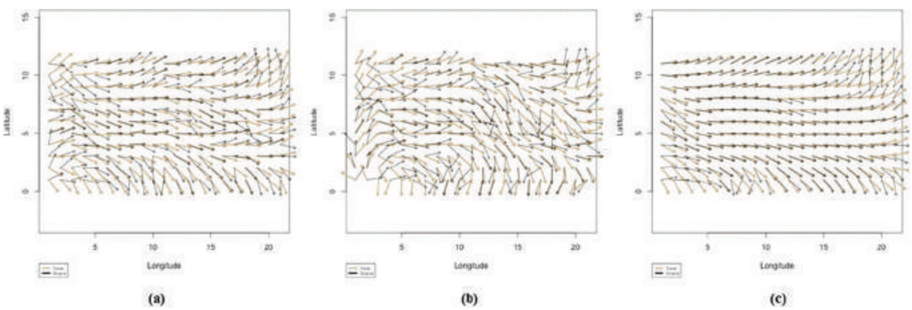

Figure 2. Original wind direction (black color) and its spatial trend (brown color), resulting from the median polish algorithm for circular data for each simulated dataset: (a) von Mises; (b) Cardioid; (c) Wrapped Cauchy.

residuals as a basis, a valid cosine model and its parameters' value were selected. Selecting the cosine model and its parameters' value is the key step in the prediction process.

The selected cosine model was used to perform ordinary kriging for circular-spatial data on the residuals to obtain a prediction of the residual at the desired non-observed point. The non-parametric estimation of the trend at that non-observed point was calculated, as described in Section 2.2 (vi). The overall predicted wind direction at the desired non-observed point was obtained by adding the predicted residual value to the estimated value of wind direction trend at the desired non-observed point. For brevity, we only show the result of the wind direction prediction at the desired non-observed points for each simulated dataset in Figure 3, displayed in red color.

To evaluate performance of the proposed kriging model, we used the leave-one-out cross-validation method. The cross-validation process is performed as follows:

i. Obtain the predicted value of wind direction $\hat{\theta}_i$ at each observed point $i(i = 1, \ldots, n)$ from the actual value of wind direction at the $n-1$ remaining observed points.

ii. Calculate the following metrics:

– Mean Absolute Cosine Error (MACE)

$$MACE = \frac{1}{n}\sum_{i=1}^{n} |\cos(\theta_i) - \cos(\hat{\theta}_i)|$$

– Mean Cosine Difference Error (MCDE)

$$MCDE = \frac{1}{n}\sum_{i=1}^{n} \cos(\theta_i - \hat{\theta}_i)$$

where $\hat{\theta}_i$ is predicted value of wind direction and θ_i is actual value of wind direction at observed point $i(i = 1, \ldots, n)$. If the model is good, then MACE will be closer to 0 and MCDE will be closer to 1 (Modlin et al., 2012).

The result of the MACE and MCDE values for each simulated dataset can be found in Table 1.

Based on the performance evaluation results on three simulated datasets, it shows that the proposed kriging model can be considered as being a promising tool for predicting the value

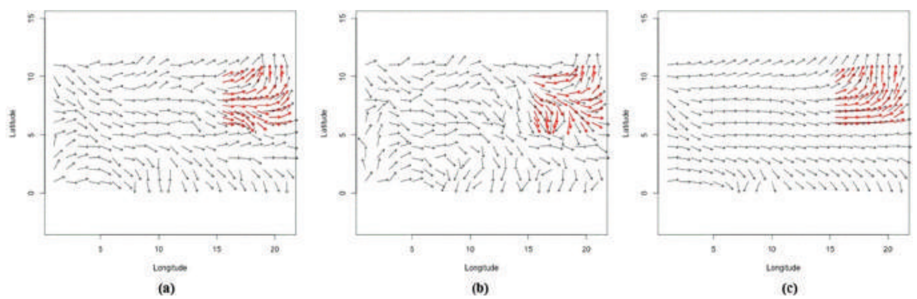

Figure 3. Predicted wind direction at desired non-observed points for each simulated dataset: (a) von Mises; (b) Cardioid; (c) Wrapped Cauchy.

Table 1. Cross-validation result for simulated datasets.

Dataset	MACE	MCDE
Von Mises	0.067013	0.967651
Cardioid	0.123069	0.926183
Wrapped Cauchy	0.011498	0.998375

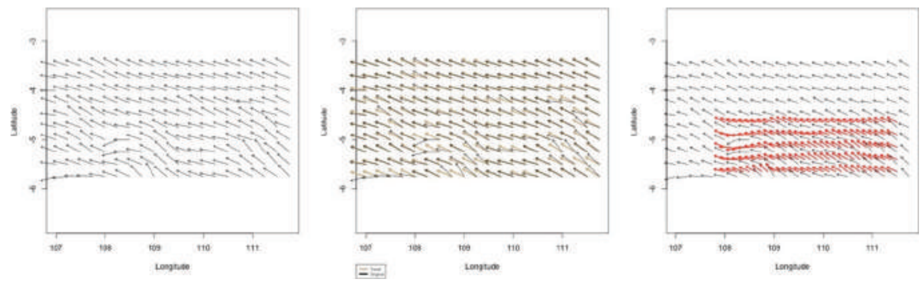

Figure 4. (a) Java sea wind direction at 12:00 UTC, August 17, 2017; (b) trend of Java sea wind direction; (c) predicted Java sea wind direction at desired non-observed points.

Table 2. Cross-validation result for simulated datasets.

Dataset	MACE	MCDE
Java sea wind	0.010487	0.994836

of a circular random field at non-observed points since the value of MACE is close to 0 and the value of MCDE is close to 1.

3.2 *Real-data experiments*

To illustrate the ability of the proposed kriging model to predict realization of the spatial value at non-observed points from a collection of circular-spatial data observed at several locations, we use a real dataset (i.e. a Java sea wind dataset). This Java sea wind dataset was downloaded from National Centers for Environmental Information (https://www.ncei.noaa.gov/thredds/blended-global/oceanWinds.html). Figure 4a displays the Java sea wind direction at 12:00 UTC for August 17, 2017 at coordinate Longitude 3.50°–5.75° and Latitude 107.00°–111.75°. The direction of wind was measured at every 0.25° interval.

The median polish algorithm for circular data was applied to remove spatial trend present in the Java sea wind dataset. The result of detrending the Java sea wind direction is shown in Figure 4b, displayed in tan color. As the next step, we performed circular-spatial data ordinary kriging for the residuals, which involved constructing an empirical cosineogram of the residual, and fitting a cosine model to the empirical cosineogram. Lastly, the estimation of the spatial trend at that non-observed point was added to the result of the ordinary kriging on the residual. The result of the wind direction prediction at the desired non-observed points for the Java sea wind dataset is shown in Figure 4c, displayed in red.

The result of the performance evaluation of the proposed kriging model using the leave-one-out cross-validation method can be found in Table 2.

Based on the performance evaluation results on Java sea wind datasets, it shows that the proposed kriging model produces a good result in predicting a value of a circular random field at non-observed points since the value of MACE is close to 0 and the value of MCDE is close to 1.

4 CONCLUSION AND FUTURE WORKS

In this paper, we propose a new kriging model for circular-spatial data. The proposed kriging model employs the median polish algorithm to remove spatial trend that is often present in circular-spatial data. Removing spatial trend in the circular-spatial data is required to meet the stationarity assumption. Leave-one-out cross-validation is used to evaluate performance of the new model. The performance of the proposed kriging model for circular-spatial data is measured using mean absolute cosine error and mean cosine difference error metrics. The experimental results on simulation and real-world datasets show that the proposed kriging model can be considered as a promising tool for predicting the value of a circular random field at non-observed points.

For future works, we consider to include comparative analysis of the proposed kriging model with other kriging models for circular-spatial data.

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Determinants of health complaints of Bodetabek commuter workers using Bayesian multilevel logistic regression

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ABSTRACT: Commuting cannot be separated from a worker's routine. By being mobile in this way, workers can obtain some benefits such as earning higher wages from the city and lower living costs in the suburbs. However, these benefits must be paid for by disruption to the commuter worker's health. This poor health condition will harm both the company and the commuter. This study aims to determine the variables that affect health complaints suffered by workers who commute from Bogor, Depok, Tangerang, and Bekasi (Bodetabek) to Jakarta. Data was obtained from the 2014 Jabodetabek Commuter Survey. The data used in this study has a hierarchical structure because it is selected by two-stage sampling. Hierarchical structured data is more appropriate when analyzed using multilevel logistic regression. The limited number of units at level two forces the Bayesian method to be used in parameter estimation. The results show that commuting distance, commuting time, commuting mode, stress due to travel, traffic congestion, education level, and employment status are important factors that affect health complaints of Bodetabek commuter workers. Thus, the government is expected to improve the quality of public transportation services in terms of convenience, timeliness, ease of access, and low cost, especially for commuters.

1 INTRODUCTION

The number of commuters has increased, especially in metropolitan regions such as Jabodetabek (Jakarta, Bogor, Depok, Tangerang, and Bekasi). Jabodetabek has the highest rate of commuters among the metropolitan regions in Indonesia (Handiyatmo, 2009). According to the Central Statistics Agency of Indonesia, known as Badan Pusat Statistik (BPS), the pattern of commuter movement in metropolitan regions is to go to the center of the area in the morning, and return to the suburbs in the afternoon and evening (BPS, 2009). This condition also happens in the Jabodetabek region. Commuting in this region is dominated by commuters from Bodetabek (Bogor, Depok, Tangerang, and Bekasi) who conduct activities in the center of the region, namely Jakarta.

As the capital of the country, Jakarta not only becomes the government center but also the economic center of Indonesia. It has an impact on the more rapid development in Jakarta than in other regions in Indonesia. The various advantages offered by Jakarta have become the main attraction for migrants from various regions in Indonesia. The increase of migrants entering Jakarta year by year will cause residential land to be limited. The unaffordable land price and high living costs in Jakarta ultimately encourages both the original residents of Jakarta, and also the migrants, to find cheaper housing outside of Jakarta.

However, the large number of Jakarta residents who moved out of Jakarta was not accompanied by a shift in their workplaces. The dependence of people to live in the outskirts of Jakarta (which is Bodetabek) has caused shuttle mobility (Warsida et al., 2013), which involves going to Jakarta and returning to the outskirts of Jakarta on the same day. People who practice shuttle mobility are known as commuters.

Commuting has become a regular part of the daily routine for most workers (Wener & Evans, 2011a). This mobility is dominated by residents whose main activity is working.

Based on data from the 2005 Intercensal Population Survey (SUPAS), it is known that 73.85 percent of commuters in Indonesia are working (BPS, 2010). Handiyatmo (2009) mentioned that working was the main commuter activity in Jabodetabek, which reached 75.60 percent.

The existence of commuter workers can provide benefits for the city, suburbs, and the commuters themselves. For the city, the existence of commuters will not add to the population administratively (BPS, 2009). It will not increase population density in the city. The suburb's economy will be growing with the existence of commuters who are living there (BPS, 2014). In addition, higher wage rates in the city accompanied by the lower cost of living in the suburbs will provide benefits for commuter workers (BPS, 2013).

But on the other hand, the expected benefits of commuting must be paid for by the disruption to the commuter workers' health conditions. Physical and mental burdens caused by commuting can trigger health complaints (Urhonen et al., 2016). Commuting can cause health complaints (such as cold or flu, and chest pain) that can affect mood related to job satisfaction, and there is work absence because of illness (Novaco et al., 1990). In addition, commuting is also associated with health complaints such as increased blood pressure, cardiovascular problems, stroke, back pain, hernia, stomach pain, and visual impairment (Koslowsky et al., 1995).

Health complaints experienced by commuter workers can harm the company where they work. Poor health conditions will decrease the performance of workers and cause loss of productivity. Productivity lost due to poor performance is greater than that due to workers' sick leave (Kirsten, 2010). It can also reduce the quality and quantity of work output that can be completed. This will have an impact on the income earned by the company. In addition, health complaints experienced by commuter workers will also trigger additional expenditure on medical treatment. The commuters will lose income, which should be allocated to other needs.

Based on the negative impacts arising from health complaints experienced by commuter workers, it is necessary to conduct a study to analyze the health complaints of Bodetabek commuter workers. The focus of this research is commuter workers. According to Handiyatmo (2009), commuting in the Jabodetabek region is dominated by commuters whose main activity is working. So, the commuter group that will be most affected by the negative influence of commuting is commuter workers. The commuter workers that this study focuses on are only those who live in the Bodetabek area but work in the Jakarta area. It is also necessary to consider contextual factors in analyzing the relationship between the characteristics of travel and commuter health (Hansson et al., 2011). Therefore, this study aims to determine variables that affect health complaints of Bodetabek commuters. The results of this study are expected to be taken into consideration in formulating a policy development in the Jabodetabek metropolitan region.

2 METHOD

The data used in this study is from the 2014 Jabodetabek Commuter Survey. This survey is the only BPS survey (until now) that specifically gathers the characteristics of commuters, with regional coverage in 13 regencies/municipalities, which are South Jakarta City, East Jakarta City, Central Jakarta City, West Jakarta City, North Jakarta City, Bogor Regency, Bogor City, Depok City, Tangerang Regency, Tangerang City, South Tangerang City, Bekasi Regency, and Bekasi City.

The sample is selected with the two-stage sampling method. In the first stage, census blocks for each stratum were selected using Systematic Proportional to Size (PPS), where the size used is the number of the population aged 15 years and over who work. Then in the second stage, ten sample households were taken from each census block using systematic sampling. The survey included 13,120 sample households out of a total of 1,312 census blocks. This study focuses on individuals aged 15 years and over who work and routinely commute from the Bodetabek area to the Jakarta area, and the final sample analyzed are 1,922 commuter workers.

The response variable used in this study is health complaints experienced by commuter workers. This variable is dichotomous, divided into two categories as follows: commuter workers who do not experience health complaints (as references) and commuter workers who experience health complaints. Based on the definition used by BPS, experiencing health complaints is defined as the condition where commuter workers have in the last 30 days experienced at least one health complaint, such as fever, cough, headache, sore throat, eye pain, shortness of breath or asthma, colds, or aches.

The explanatory variables used in this research are commuting distance, commuting time, main commuting mode, stress due to travel, severe congestion, education level, employment status, and growth rate of Gross Regional Domestic Product (GRDP). Commuting distance is obtained from the answer to the question: 'Distance traveled from place of residence to the place of activity (in minutes)?' This variable is categorized into two categories: less than or equal to 30 km and more than 30 km. According to the study conducted by Kageyama et al. (1998), we categorized commuting time into three categories: below 60 minutes, 60–90 minutes, and 90 minutes or more. The main commuting mode is the mode of transportation commonly used to go to the place of activity. We categorized the main commuting mode into four groups: two-wheel vehicle, car, train, and bus/minibus. Stress due to travel is obtained from the answer to the question: 'Do you feel stress due to travel from and to the place of activity?'. Severe congestion is obtained from the question: 'Have you ever experienced severe congestion?'. The education level was categorized into two categories: senior high school or less, and higher than senior high school. We categorized employment status into informal and formal status.

The relationship between the characteristics of commuter workers and health complaints can also be influenced by the characteristics of the regency/municipality where the commuter workers live. A high GRDP growth rate in an area will affect the population consumption of commodities that can support health. In addition, the government can also increase spending in the health sector, which includes the provision of health facilities, health workers, and the improvement of transportation facilities to reach these health facilities.

The data used in this study has a hierarchical structure because the sample is selected by multistage sampling method, where the first level (level 1) is individual level (commuter workers). Then the second level (level 2) is the area where the commuter workers live (regency/municipality). Multistage sampling causes observation at the individual level that is not entirely independent (Hox, 2010). A violation of the assumption of independence will generate underestimation of standard error and the estimation would be spurious (Hox, 2010). Therefore, the multilevel regression model will be more appropriately used to accommodate violations of this assumption. Because the dependent variable in this study is dichotomous, a multilevel binary logistic regression model will be used. If there are N units at level 2, then on unit j of level 2 ($j = 1, 2,..., N$) there will be n_j units at level 1. So, the multilevel binary logistic regression model with random intercept can be stated as follows:

$$logit\left(P_{ij}\right) = \gamma_{00} + \sum_{h=1}^{p} \gamma_{h0} x_{hij} + \sum_{k=1}^{q} \gamma_{0k} z_{kj} + U_{0j} \tag{1}$$

where P_{ij} is probability of experiencing health complaints for the commuter worker i at level 1 in the regency/municipality j. The γ_{00} is the fixed intercept or population mean, γ_{h0} is the fixed effect of explanatory variable at level 1, γ_{0k} is the fixed effect of explanatory variable at level 2, x_{hij} is the explanatory variable h for the commuter worker i at level 1 in regency/municipality j, z_{kj} is the explanatory variable k for regency/municipality j, and U_{0j} is the random deviation from the mean for regency/municipality j at level 2. The U_{0j} assumes that there is a normal distribution with mean 0 and variance τ_0^2.

Level-two units in this study are regencies/municipalities in the Bodetabek area, and there are eight regencies/municipalities for level-two units. Parameter estimation using maximum likelihood when level-two units are less than 20 units will produce a large bias (Stegmueller, 2013). Solving this problem, the Bayesian approach is applied in parameter estimation. This approach can produce an estimator with lower bias than the maximum likelihood approach (Stegmueller, 2013). According to Box and Tiao (1973), Bayes' theorem can be stated as follows:

$$p(\boldsymbol{\theta}|\boldsymbol{y}) = \frac{p(\boldsymbol{y}|\boldsymbol{\theta})\, p(\boldsymbol{\theta})}{p(\boldsymbol{y})} \tag{2}$$

In Equation 2, $p(\boldsymbol{\theta})$ states the prior distribution of $\boldsymbol{\theta}$, related to what is known about $\boldsymbol{\theta}$ without previous information of data distribution. Then, $p(\boldsymbol{y}|\boldsymbol{\theta})$ shows a conditional distribution that contains information of the data, while $p(\boldsymbol{\theta}|\boldsymbol{y})$ expresses the posterior distribution of $\boldsymbol{\theta}$ if $\boldsymbol{y}$ is known, related to what is known about $\boldsymbol{\theta}$ with previous information about the data (Box & Tiao, 1973). In the Bayesian approach, each unknown parameter was assumed to follow a particular distribution, called the prior distribution (Browne, 2017). The prior distribution and the likelihood function of the observed data will be combined to form a posterior distribution (Browne, 2017).

When the posterior distribution was difficult to derive mathematically, it was approximated using Markov Chain Monte Carlo (MCMC) (Hox, 2010). MCMC is a simulation technique that can generate random samples from a complex posterior distribution. Through a large number of simulated random samples, it will be possible to calculate the posterior mean, standard deviation, density plot, and quintiles of this distribution (Browne, 2017). In the Bayesian MCMC approach, to test the model fit (goodness of fit), we can compare the Deviance Information Criterion (DIC) from each model.

$$DIC = \bar{D} + pD \tag{3}$$

where $\bar{D}$ = average of deviance from all iteration; pD = effective number of parameters.

We can calculate DIC by adding the average of the deviance from all iterations $(\bar{D})$ with the effective number of parameters (pD). The smaller the DIC of a model, the more fit the model has. This study also calculates the Intraclass Correlation Coefficient (ICC) from the two-level null model. The ICC indicates the proportion of variance explained by the existence of a hierarchical structure. Many researchers use the uninformative prior, because this prior will not affect the posterior distribution formed (Hox, 2010). In this study, we use 5 percent significance level. When the p-value is less than 0.05, it is considered statistically significant.

3 RESULT AND DISCUSSION

3.1 *Heath complaints according to commuter workers characteristics*

In general, there are 64.7 percent of Bodetabek commuter workers (who work in the Jakarta area) who experience health complaints. Table 1 shows the percentage experiencing health complaints according to the characteristic of commuter workers. The percentage of commuter workers who experience health complaints is higher in the group of workers who commute more than 30 km compared to those who commute 30 km or less, reaching 71.7 percent. Commuter workers who commute for more than 90 minutes have the highest percentage of health complaints (68.1 percent) compared to those with a shorter commuting duration.

Two-wheeled vehicles have the highest percentage for commuter workers who experience health complaints, reaching 70.2 percent, compared to by other main commuting modes. Commuter workers who experience stress due to travel have a higher percentage of health complaints, reaching 78.4 percent. The percentage of commuter workers experiencing health complaints who have experienced severe congestion (67.1 percent) is higher than workers who have never experienced severe congestion (55 percent).

Commuter workers with lower levels of education have a higher percentage of health complaints (71.3 percent) compared to commuter workers with a higher level of education (56.7 percent). Commuter workers working in the informal sector have a higher percentage

Table 1. Percentage of health complaints according to the characteristics of commuter workers.

Commuter workers characteristic		Health complaint	
		Not experienced	Experienced
Commuting distance	≤ 30 km	38.5	61.5
	> 30 km	28.3	71.7
Commuting time	< 60 minutes	33.2	66.8
	60–90 minutes	41.5	58.5
	≥ 90 minutes	31.9	68.1
Main commuting mode	Two wheels	29.8	70.2
	Car	51.4	48.6
	Train	34.4	65.6
	Bus/minibus	38.8	61.2
Stress due to travel	No stress	43.9	56.1
	Stress	21.6	78.4
Experiencing severe congestion	Never	45.0	55.0
	Frequently	32.9	67.1
Education level	Senior high school or below	28.7	71.3
	Higher than senior high school	43.3	56.7
Employment status	Informal	18.6	81.4
	Formal	36.5	63.5

Source: BPS, 2014 Jabodetabek Commuter Survey.

of health complaints (81.4 percent) compared to those working in the formal sector (63.5 percent).

3.2 *Model selection and ICC*

Based on Table 2, the DIC for a one-level null-model binary logistic regression is 2,530.58. A null model or empty model is a model that does not contain explanatory variables. In the first step, by comparing the DIC of a one-level null model with a two-level null model, we can conclude that DIC has decreased from 2,530.58 to 2,394.49. It indicates that the two-level regression model with random effects is more appropriate to be used. In the next step, we compare the DIC null two-level binary logistic regression model with the two-level DIC conditional model. A conditional model is a model that includes all explanatory variables. Based on Table 2, the two-level null-model DIC is greater than the two-level DIC conditional model. Thus, it can be concluded that a two-level binary logistic regression model containing all explanatory variables is more appropriate to be used to analyze health complaints experienced by Bodetabek commuter workers.

3.3 *Determinant of health complaints of Bodetabek commuter workers*

As shown in Table 3, the intraclass correlation coefficient is 12.57 percent, which means that the diversity of health complaints for commuter workers in Bodetabek caused by differences in regency/municipality characteristics is 12.57 percent. The ICC value of 12.57 percent also means that the correlation between individuals in the same regency/municipality is 0.1257.

Based on the p-value column of Table 3, commuter workers in the Bodetabek area who have a commuting distance of more than 30 km and a commuting time of 60–90 minutes, who use a car and bus/minibus, who experience stress due to travel, who frequently experience severe congestion, who have a higher education level, or who work in the formal sector, show significant effects to their health complaints experienced.

Table 2. Comparison of DIC for each model formed.

Model formed	Bayesian deviance information criterion			
	Dbar	D (thetabar)	pD	DIC
One-level null model	2,529.58	2,525.58	1.00	2,530.58
Two-level null model	2,386.97	2,379.46	7.51	2,394.49
Two-level conditional model	2,224.90	2,207.49	17.41	2,242.32

Table 3. Estimation of parameters, standard error, p-value, and odds ratio for each explanatory variable.

Explanatory variables	Two-level null model		Two-level conditional model			
	Estimate	SE	Estimate	SE	p-value	OR
Cons	0.793	0.273	0.541	1.516		
Level-one explanatory variables						
Commuting distance						
≤ 30 km (ref.)						
> 30 km			0.427	0.140	0.002*	1.533
Commuting time						
<60 minutes (ref.)						
60–90 minutes			–0.458	0.150	0.002*	0.632
≥ 90 minutes			–0.221	0.154	0.151	0.802
Main commuting mode						
Two wheels (ref.)						
Car			–1.003	0.152	0.000*	0.367
Train			–0.179	0.172	0.298	0.836
Bus/minibus			–0.494	0.165	0.003*	0.610
Stress due to travel						
No stress (ref.)						
Stress			0.867	0.120	0.000*	2.379
Experiencing severe congestion						
Never (ref.)						
Frequently			0.623	0.141	0.000*	1.864
Education level						
Senior high school or below (ref.)						
Higher than senior high school			–0.371	0.112	0.001*	0.690
Employment status						
Informal (ref.)						
Formal			–0.688	0.264	0.009*	0.503
Level-two explanatory variable						
Growth rate of GRDP			0.106	0.241	0.660	1.112
Variance of error at level two	0.473	0.431	0.372	0.341		
ICC	0.1257					
Deviance (MCMC)	2,386.97		2,224.90			

Source: BPS, 2014 Jabodetabek Commuter Survey.
*p-value < 0.05; (ref.) is reference category; SE is Standard Error; OR is Odds Ratio.

At a 5-percent significance level, the growth rate of GRDP has no significant effect on the health complaints experienced by commuter workers in the Bodetabek area. GRDP growth will trigger income increase, so it will make the residents' access to health services for treatment easier. However, the income increase will be in vain if the population's awareness of health is still low. In general, someone will seek treatment at a health facility when the health complaints experienced have disrupted their daily activities. The research data shows that 71.9 percent of commuter workers who experienced health complaints state that their daily activities were not interrupted, making them have low motivation to go to a health facility.

The other reason is that there is no difference between the commuters with high or low GRDP growth rate in terms of the use of transportation modes. Commuter workers from regions with higher GRDP growth rates, such as South Tangerang City and Depok City, are similar in preferring two-wheeled vehicles, as well as are workers from lower GRDP growth rates regions such as Tangerang City and Tangerang Regency. This shows that the increase of income reflected by GRDP growth does not make a difference in the choice of transportation modes, even though the choice of modes can affect the health condition of commuters.

Commuter workers who travel more than 30 km are 1.5 times more likely to experience health complaints compared to those who travel 30 km or less. The farther the commuter's trip, the more likely that the commuter faces heavy traffic with high-stress levels. Stress levels were positively associated with physiological complaints such as high blood pressure (Hoehner et al., 2012). Commuter workers who have a commuting time between 60–90 minutes are less likely (OR = 0.632) to experience health complaints as compared to those who commute less than 60 minutes. This finding is consistent with evidence from a study conducted in Kent and Medway (UK) that found commuters who traveled more than 45 minutes reported better health than commuters who traveled less than 45 minutes (Lyons & Chatterjee, 2008).

Commuter workers who commute using a car and bus/minibus are less likely to experience health complaints as compared to those who commute using two wheels. The odds ratio for those using cars and bus/minibus is less than one, which indicates that commuter workers who use two-wheeled vehicles are more likely to experience health complaints. This happened because those who commute using on-roadway modes like two-wheeled vehicles will be exposed to Particulate Matter (PM) pollution, especially $PM_{2.5}$ with a higher concentration as compared with in-cabin modes like car, train, and bus/minibus (Wu et al., 2013).

Commuter workers who experience stress due to travel are 2.4 times more likely to experience health complaints as compared to those who not experience stress. This could be explained by the fact that chronic exposure to stress can reduce circulating lymphocytes (white blood cells that fight disease) and increase levels of the hormone cortisol, a substance that suppresses the function of the immune system (Baron & Branscombe, 2012). As a result, the body becomes more susceptible to an illness. In line with stress due to travel, commuter workers who ever experience severe congestion are 1.9 times more likely to experience health complaints than those who never experience severe congestion. Traffic congestion will increase exposure to vehicle emissions. Exposure to pollutants could cause respiratory and cardiovascular disease (Wener & Evans, 2011b).

Commuter workers who have a higher education level are less likely (OR = 0.690) to experience health complaints than those who have a lower education level. This is in line with the result of studies conducted by Li et al. (2017), Berglund et al. (2016), and Sari et al. (2007), which state that people who have a lower education level are more likely to have poor health status. In general, people with a higher education level better understand how to achieve optimal health status. They know how to prevent an illness and what nutritious foods are (Sari et al., 2007). This will lead to achieving good health status. Commuter workers who work in the formal sector are less likely (OR = 0.503) to experience health complaints as compared to those who work in the informal sector. This condition is caused by differences in workload and workplace environment in the formal and informal sectors. According to Rios and Nery (2015), working in the informal sector needs high physical effort, and quick and continuous physical activity. In addition, most workers in the informal sector work under high pressure, which can cause fatigue, anxiety, depression and physical complaints. In addition, López-Ruiz et al. (2015) stated that working conditions in the informal sector are usually worse than those in the formal sector. Workers in the informal sector have long working hours and unsafe workplaces, experience musculoskeletal problems, and are exposed to traffic pollution and bad weather.

4 CONCLUSION

There are several significant explanatory variables for health complaints experienced by commuter workers in Bodetabek, such as commuting distance, commuting time, commuting mode, stress due to travel, severe congestion, education level, and employment status. Our result suggests that the government or policy makers in the Bodetabek region should improve public transport mode services through the addition of Transjakarta buses (Bus Rapid Transit) and a commuter line train during rush hour in the morning and evening. The government also should focus on providing mass transport like the Mass Rapid Transit (MRT) and the Light Rail Transit (LRT).

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The determination of the area where disease spreads with a generalized space-time autoregressive kriging (GSTAR-Kriging) model

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ABSTRACT: Monitoring the spread of diseases, especially in cases with very high levels of dissemination, is urgently needed by researchers, practitioners, and policymakers in the health sector, in order to make accurate decisions as quickly as possible. Allied to such efforts, the availability of a spatial-temporal information system capable of monitoring the spread of disease in a particular geographic location over a period of time is a vital necessity. The system can provide clear information, about in which areas the disease is spreading and the extent of its spread, so policymakers will be able to predict the pattern of spread of the disease and as early as possible identify areas vulnerable to infectious diseases. There are various spatial-temporal models that have been developed: Space-Time Autoregressive Moving Average (STARMA) model, Space-Time Autoregressive (STAR) model, Generalized Space-Time Autoregressive (GSTAR) model, and Generalization Space-Time Autoregressive Kriging (GSTAR-Kriging) model. The data observed in this study only comes from one region, namely Dr. Wahidin Sudirohusodo Hospital, Makassar, South Sulawesi, because the number of cases of dengue sufferers at the hospital significantly increased during January 2017. Data used in this research is data of dengue fever patients in 2017. So, for the locations that are not used, samples used GSTAR-Kriging modeling by borrowing inter-sample data from other related areas, or even from all small areas in the city of Makassar. The problem is therefore limited to models in the orders of 1 in time lag and 1 for spatial lag.

Keywords: Geographic location, Spread of diseases, Generalization Space-Time Autoregressive model Kriging (GSTAR-Kriging), Wahidin Sudirohusodo Hospital

1 INTRODUCTION

Models capable of representing spatial factors are commonly referred to as spatial-temporal models, or are sometimes called space-time models (Bild et al., 2002). The spatial-temporal model is a collection of data, sorted by time from several different locations. Often the value of an object does not only change over time, but it also depends on the surrounding location (Peña-García et al., 2016).

Dr. Wahidin Sudirohusodo Hospital, Makassar, South Sulawesi, Indonesia, acknowledged an increase in cases of dengue fever patients throughout January 2017. The cause is the unconsciousness of the residents to maintain the cleanliness of the surrounding environment Usually summer shifts to the rainy season, prone to cases of dengue fever are present. This can be seen from the number of existing patients throughout the year or throughout the season (Gu et al., 2016). This is also a phenomenon to watch out for. However, the media reports that the number of patients with dengue fever continues to increase. This condition must be taken seriously because it can lead to death (Cohen et al., 2009).

The data observed in this study only comes from one region, so the problem is limited to models in the orders of 1 in time lag and 1 for spatial lag (Tinungki, 2018). Data used in this research is data of dengue fever patients in Makassar City in 2017.

To find out where the disease is found and when it occurs, how many victims there were, and how many died, a temporal spatial model is used (Ankenman et al., 2010). Development of the temporal spatial model for dengue mapping in Makassar City uses the Generalized Space-Time Autoregressive (GSTAR) and GSTAR-Kriging models. Both the GSTAR and GSTAR-Kriging models will be examined to find the model that is most appropriate in dengue fever mapping in the city of Makassar, using the Akaike Information Criterion (AIC) (Fan et al., 2015).

2 LITERATURE REVIEW

2.1 *Spatial-temporal model generally*

There are several spatial-temporal models that have recently been developed. The spatial-temporal model approach in the form of the Space-Time Autoregressive Moving Average (STARMA) model was studied by Cressie et al. (2011), which was developed from the Autoregressive Moving Average (ARMA) time series model from Box-Jenkins for predict the outbreak of a disease based on a certain time, in several locations, or called the time series vector models (Peña-García et al., 2016).

Furthermore, the Space-Time Autoregressive (STAR) model, which is part of the STARMA model, assumes the parameters of the STAR model, the autoregression parameters and the space-time parameters are the same for all locations. It is assumed that the model applies only to locations with homogeneous characteristics (Casella & Berger, 2002).

The STAR model has its limitations, that is, the model assumes that the parameters for all the sampled locations are of equal value, meaning that the observed locations are either identical or homogeneous. The spatial-temporal model, especially the GSTAR model, is the development of the STAR model from studies by De Oliveira (2006). The GSTAR model is the development of univariate time series model study from Box-Jenkins and the time series vector model from Hastie et al. (2001), assuming the parameters in each location of the observation has different estimation values (Suhartono et al. 2016) The expansion of the spatial-temporal model is the Generalized Space-Time Autoregressive Kriging (GSTAR-Kriging) model, which in this GSTAR-Kriging model estimates the least squares of GSTAR model parameters used as inputs in the kriging model. The GSTAR-Kriging model is an extension of the GSTAR model to be used in predictions in non-sampled locations (Pedrielli et al., 2015).

With the GSTAR model, it is assumed that the auto regressive parameters and space-time parameters are different for each location; this assumption is more realistic for the application field. To overcome the weakness of the STAR model, the GSTAR model was then developed, which expanded again on the GSTAR-Kriging model Space Time Autoregressive Moving Average (STARMA).

2.2 *Space-time autoregressive moving average*

The STARMA model involves double variable time series data modeling that has spatial linkages between the observed locations (Zhou & Buongiorno, 2006). STARMA model data not only has time, but also linkages between regions. In the STARMA model, all locations must have homogeneous characteristics. The parameter asset value for all locations is the same value.

The STARMA is a model for the space-time series. It follows the three-stage iterative model building procedure, developed and extended to space-time modeling. This model is designed with large datasets because the package has been optimized (Suhartono, et al., 2016. Furthermore, the parameter estimation can be used, computationally, but very expensive so a

Kalman filter is used (see Damian et al., 2003). This makes it extremely efficient when dealing with large datasets.

In general, the STARMA model can be written in the form (Zhou & Buongiorno 2006):

$$\mathbf{Z}_{(t)} = \sum_{k=1}^{p}\sum_{l=0}^{\lambda_k}\Phi_{kl}W^{(l)}Z_{(t-k)} - \sum_{k=1}^{p}\sum_{l=0}^{m_k}\theta_{kl}W^{(l)}\xi_{(t-k)} + \xi_{(t)}$$

where z_t is a vector with dimension N; p is an autoregressive order; W is a moving average order; λk is the spatial order of conditions autoregressive to-p m_k is the spatial order of the moving average condition to k; Φ_{kl} is diag ($\Phi_{kl}^{(1)}, \Phi_{kl}^{(2)}, \ldots \Phi_{kl}^{(N)}$); $W^{(\ell)}$ is the weighting matrix spatially sized N x N for the ℓ spatial order, which is the zero diagonal and the number for each row is equal to one; the matrix $W^{(0)}$ is defined as the identity matrix I; θ_{kl} is diag ($\theta_{kl}^{(1)}, \theta_{kl}^{(2)}, \ldots \theta_{kl}^{(N)}$); and $\xi_{(t)}$is an error at t-time, which is assumed to be normal with a zero average and constant range.

2.3 *GSTAR and GSTAR-Kriging models*

2.3.1 *STAR model*

There are at least some ways for spatial-temporal data modeling. First, using spatial statistical techniques and entering time through the inclusion of temporal dichotomous variables. Second, correlation observation can be directly between observations as a function of time and location (Roustant et al., 2012). Third, the data can include enough spatial, spatial-temporal, and also temporal-dependent lag and independent variables, so that the residue (residual value) produced does not show gross spatial-temporal dependence (i.e. general autoregressive specification) (Gneiting & Guttorp, 2010).

(De Iaco et al., 2012) provide a model $\mathrm{STAR}_N(1_1)$:

$$\begin{gathered} \boldsymbol{Z}_{(t)} = \phi_{10}\mathbf{Z}_{(t-1)} + \phi_{11}\mathbf{W}\mathbf{Z}_{(t-1)} + \varepsilon_{(t)}, \\ \mathrm{E}\varepsilon_{(t)} = 0,\ \mathrm{E}\boldsymbol{\varepsilon}_{(t)}\boldsymbol{\varepsilon}_{(t)}^{t} = \sigma^2\mathbf{I},\ \mathrm{E}\mathbf{Z}_{(t)}\boldsymbol{\varepsilon}_{(t+s)}^{t} = \mathbf{0},\ s = 1, 2, \ldots \end{gathered} \tag{1}$$

where **W** is the weight matrix of the size location N × N. The $\mathrm{STAR}_N(1_1)$ model can be written as a linear model:

$$\boldsymbol{Z}_{(t)} = (\mathbf{Z}_{(t-1)}\mathbf{W}\mathbf{Z}_{(t-1)})\boldsymbol{\Phi} + \boldsymbol{\varepsilon}_{(t)} \tag{2}$$

with $\Phi = (\phi_{10}\phi_{11})^t$ and t = 1,2,…T. The estimated least squares of the model parameters Φ is:

$$\begin{aligned} \hat{\boldsymbol{\Phi}} &= \begin{pmatrix} \sum_{t=1}^{T} Z_{(t-1)}{}^{t} Z_{(t-1)} & \sum_{t=1}^{T} Z_{(t-1)}{}^{t} W Z_{(t-1)} \\ \sum_{t=1}^{T} Z_{(t-1)}{}^{t} W Z_{(t-1)} & \sum_{t=1}^{T} Z_{(t-1)}{}^{t} W^{t} W Z_{(t-1)} \end{pmatrix}^{-1} \begin{pmatrix} \sum_{t=1}^{T} Z_{(t-1)}{}^{t} Z_{(t)} \\ \sum_{t=1}^{T} Z_{(t-1)}{}^{t} W^{t} Z_{(t)} \end{pmatrix} \\ &\cong \begin{pmatrix} \hat{\gamma}_{00}(0) & \hat{\gamma}_{10}(0) \\ \hat{\gamma}_{10}(0) & \hat{\gamma}_{11}(0) \end{pmatrix}^{-1} \begin{pmatrix} \hat{\gamma}_{00}(1) \\ \hat{\gamma}_{10}(1) \end{pmatrix} \end{aligned} \tag{3}$$

where $\hat{\gamma}_{lk}(s)$ is the space-time auto correlation, expressed as:

$$\hat{\gamma}_{lk}(s) = \frac{1}{N(T-s)} \sum_{t=1}^{T=s} Z_{(t)}{}^{t} W^{t} W Z_{(t+s)} \tag{4}$$

Because the STAR model of Tinungki, 2018, can only be used for homogeneous locations, assuming the autoregression parameters and space-time parameters are the same for each location, for heterogeneous locations Ruchjana et al. (2013) developed the STAR model into a GSTAR model. The GSTAR model was developed to overcome the weakness of the STAR model described above.

2.4 *GSTAR model*

Ankenman et al., (2002) developed the STAR model into a GSTAR model for heterogeneous locations. For a common model (e.g. the order p in time and order $l = 0,1, \ldots, \lambda_k$ in space), GSTAR notation (p;l) is written as:

$$\mathbf{Z}_{(t)} = \sum_{k=1}^{p} \sum_{l=0}^{\lambda_k} \Phi_{kl} W^{(l)} Z_{(t-k)} + e_{(t)} \tag{5}$$

For order 1 model, both in space and time. GSTAR (1:1) is stated by:

$$\begin{aligned} Z_{(Nx1)(t)} &= \Phi_{10(NxN)} Z_{(Nx1)(t-1)} + \Phi_{11(NxN)} W^{(l)}{}_{(NxN)^{(l)}} Z_{(Nx1)(t-1)} + e_{(Nx1)(t)} \\ &= \text{diag}\,(\phi_{10}^{(1)},\ldots,\phi_{10}^{(N)}) Z_{(t-1)} + diag(\phi_{11}^{(1)},\ldots,\phi_{11}^{(N)}) W^{(1)} Z_{(t-1)} + e_{(t)} \end{aligned} \tag{6}$$

where:

$diag\ (\phi_{10}^{(1)},\ldots,\phi_{10}^{(N)})$: matrix diagonal parameter autoregression lag time 1
$diag\ (\phi_{11}^{(1)},\ldots,\phi_{11}^{(N)})$: matrix diagonal space-time parameter lag spatial 1 and lag time

1 $\mathbf{W}$: matrix of uniform weight of measure $(N \times N)$
$Z_{(t)}$: random vector time t
$\mathbf{e}_{(t)} \overset{\text{iid}}{\sim} \mathbf{N(0, \sigma^2 I_N)}$

GSTAR model (1;1) is a special case of the autoregression vector model, VAR(1), so GSTAR model (1;1) can also be expressed as a linear model, and the model parameter estimation can be done using the least squares method (Montero et al., 2015).

Representation of GSTAR linear model (1;1) is written as:

$$\mathbf{Y} = \mathbf{X}\vec{\beta} + \mathbf{e} \tag{7}$$

For location $i \in \{1,2,\ldots,N\}$, observation GSTAR(1;1) at time t is stated as:

$$\mathbf{Z}_{i(t)} = \phi_{10}^{(i)} Z_{i(t-1)} + \phi_{11}^{(i)} \sum_{j \neq i} W_{ij} Z_{j(t-1)} + e_{i(t)} \tag{8}$$

GSTAR model (1;1) can be expressed in the model VAR(1)

$$\mathbf{Z}_{(t)} = \mathbf{\Phi Z}_{(t-1)} + \boldsymbol{\varepsilon}_{(t)}$$

Equation 8 for t = 2,3, ..., T gives the linear model of location i:

$$\mathbf{Y}^{(\mathbf{i})} = \mathbf{X}^{(\mathbf{i})} \vec{\beta}^{(i)} + \mathbf{e}^{(i)} \tag{9}$$

In Equation 9, N the linear model is connected through the explanatory variable $(\tilde{Z}_{i(t-1)})$. Simultaneous regression for all locations is expressed by:

$$\begin{bmatrix} Z_{(2)} \\ Z_{(3)} \\ \vdots \\ Z_{(T)} \end{bmatrix} = \begin{bmatrix} diag\left[Z_{(1)}\right] & diag\left[\tilde{Z}_{(1)}\right] \\ diag\left[Z_{(2)}\right] & diag\left[\tilde{Z}_{(2)}\right] \\ \vdots & \\ diag\left[Z_{(T-1)}\right] & diag\left[\tilde{Z}_{(T-1)}\right] \end{bmatrix} X\vec{\beta} + \begin{bmatrix} e_{(2)} \\ e_{(3)} \\ \vdots \\ e_{(T)} \end{bmatrix} \tag{10}$$

In Equation 10, diag [Z] denotes the matrix with diagonal elements of the vector Z, and the parameter vector is:

$$\vec{\beta} = (\phi_{10}^{(1)}, \phi_{10}^{(2)}, \cdots, \phi_{10}^{(N)}; \phi_{11}^{(1)}, \phi_{11}^{(2)}, \cdots, \phi_{11}^{(N)})^t$$

The least squares parameter $\vec{\beta}$ is given by the equation:

$$\hat{\vec{\beta}} = (X^t X)^{-1} X^t Y \tag{11}$$

where $\mathbf{Y}$ is $\mathbf{Z}_{(t)}$, and $\mathbf{X} = [\mathrm{diag}[\mathbf{Z}_{(t-1)}]\ \mathrm{diag}\ [\tilde{Z}_{(t-1)}]]$.

The $GSTAR_N(1_1)$ model for N location is written as (Suhartono et al., 2016):

$$Z_{(t)} = \Phi_{10} Z_{(t-1)} + \Phi_{11} W Z_{(t-1)} + \varepsilon_{(t)} \tag{12}$$

For $N = 2$ locations, the $GSTAR_2(1_1)$ model can be written as:

$$\begin{cases} Z_{(s_1,t)} = \phi_{10(s_1)} Z_{(s_1,t-1)} + \phi_{11(s_1)} Z_{(s_2,t-1)} + \varepsilon_{(s_1,t)} \\ Z_{(s_2,t)} = \phi_{11(s_2)} Z_{(s_1,t)} + \phi_{10\,(s_2)} Z_{(s_2,t-1)} + \varepsilon_{(s_2,t)} \end{cases} \tag{13}$$

The GSTAR(1;1) for $N = 3$ locations, denoted $GSTAR_3(1;1)$, is written as:

$$\begin{aligned}
\begin{pmatrix} Z_{(s_1,t)} \\ Z_{(s_2,t)} \\ Z_{(s_3,t)} \end{pmatrix} &= \begin{pmatrix} \phi_{11} & \phi_{12} & \phi_{13} \\ \phi_{21} & \phi_{22} & \phi_{23} \\ \phi_{31} & \phi_{32} & \phi_{33} \end{pmatrix} \begin{pmatrix} Z_{(s_1,t-1)} \\ Z_{(s_2,t-1)} \\ Z_{(s_3,t-1)} \end{pmatrix} + \begin{pmatrix} \varepsilon_{(s_1,t)} \\ \varepsilon_{(s_2,t)} \\ \varepsilon_{(s_3,t)} \end{pmatrix} \\
\begin{pmatrix} Z_{(s_1,t)} \\ Z_{(s_2,t)} \\ Z_{(s_3,t)} \end{pmatrix} &= \left[\begin{pmatrix} \phi_{10(s_1)} & 0 & 0 \\ 0 & \phi_{10(s_2)} & 0 \\ 0 & 0 & \phi_{10(s_3)} \end{pmatrix} + \begin{pmatrix} \phi_{11(s_1)} & 0 & 0 \\ 0 & \phi_{11(s_2)} & 0 \\ 0 & 0 & \phi_{11(s_3)} \end{pmatrix} \begin{pmatrix} 0 & 0.6 & 0.4 \\ 0.7 & 0 & 0.3 \\ 0.6 & 0.4 & 0 \end{pmatrix} \right] \begin{pmatrix} Z_{(s_1,t-1)} \\ Z_{(s_2,t-1)} \\ Z_{(s_3,t-1)} \end{pmatrix} \\
&= \left[\begin{pmatrix} \phi_{10(s_1)} & 0 & 0 \\ 0 & \phi_{10(s_2)} & 0 \\ 0 & 0 & \phi_{10(s_3)} \end{pmatrix} + \begin{pmatrix} 0 & 0{,}6\phi_{11(s_1)} & 0{,}4\phi_{11(s_1)} \\ 0{,}7\phi_{11(s_2)} & 0 & 0{,}3\phi_{11(s_2)} \\ 0{,}6\phi_{11(s_3)} & 0{,}4\phi_{11(s_3)} & 0 \end{pmatrix} \right] \begin{pmatrix} Z_{(s_1,t-1)} \\ Z_{(s_2,t-1)} \\ Z_{(s_3,t-1)} \end{pmatrix}
\end{aligned} \tag{14}$$

or:

$$\left\{ \begin{aligned} Z_{(s_1,t)} &= \phi_{10(s_1)} Z_{(s_1,t-1)} + 0{,}6\phi_{11(s_1)} Z_{(s_2,t-1)} + 0{,}4\phi_{11(s_1)} Z_{(s_3,t-1)} \\ Z_{(s_2,t)} &= 0{,}7\phi_{11(s_2)} Z_{(s_1,t-1)} + \phi_{10(s_2)} Z_{(s_2,t-1)} + 0{,}3\phi_{11(s_2)} Z_{(s_3,t-1)} \\ Z_{(s_3,t)} &= 0{,}6\phi_{11(s_3)} Z_{(s_1,t-1)} + 0{,}4\phi_{11(s_3)} Z_{(s_2,t-1)} + \phi_{10(s_3)} Z_{(s_3,t-1)} \end{aligned} \right\} \tag{15}$$

The GSTAR parameter estimation result through the least squares method will be used as the input of the kriging model, especially Ordinary Kriging (OK) (Pedrielli et al., 2015). The OK method is a linear shaped method because its estimators are influenced by a linear combination of data (Gamerman, 2010).

2.5 *GSTAR-Kriging model*

In spatial data analysis, Yin et al. (2011) provide a kriging technique to make predictions in unsampled locations, based on existing data sampled nearby. The GSTAR-Kriging model is an extension of the GSTAR model, to be used in predictions in non-sampled locations. Kriging is a method of appraising the tetragonal variable at a point or region with the criterion of minimizing the estimated variance. OK is a method often associated with the nature of Best Linear Unbiased Estimator (BLUE), that is, the best non-linear unbiased estimator. OK is linear because its estimators are influenced by linear combinations of data; it is not biased as it aims to obtain mR, error. mean, equal to zero; this is because it aims to minimize σ_R^2, the error variance (Gamerman, 2010).

The kriging model can be written as:

$$Z^* = \sum \lambda_i Z_i \tag{16}$$

where λ is the kriging weight, which in this research is the least squares estimate GSTAR(1;1), and Z_i is the observation at location i. So, Z^* is a parameter prediction GSTAR(1;1) in the unsampled locations that will be used for prediction. The GSTAR model in Equation 2.8 can also be stated as:

$$Z_{(s_i,t)} = \phi_{10(s_i)} Z_{(s_i,t-1)} + \phi_{11(s_i)} \sum_{j=1} W_{(s_i,s_j)} Z_{(s_j,t-1)} + \varepsilon_{(s_i,t)} \tag{17}$$

where s_i Є{1,2,... N} and t Є {1,2,…,T}. By the ordinary least squares method, the parameter values $Є_{11(s)}$ are obtained on N, the known sample point, and the problem is how to predict at a new point (location) s_0.

Estimated $\hat{\phi}_{11}(s_0)$ is a linear combination of known N values.

$$\hat{\phi}_{11(s_0)} = \sum_{i\in I_s} \lambda_i \phi_{11(s_i)}, \sum_{i\in I_s} \lambda_i = 1, I_s = \{1,2,\cdots,N\} \tag{18}$$

In the development of this theory, parameters ϕ_{11} are selected as input for the kriging model, as they represent the space and time parameters (Furrer et al., 2012). To shorten the writing, the index (11) is omitted, so writing the kriging model with the GSTAR estimation input becomes simpler, namely:

$$\hat{\phi}_{(s_0)} = \sum_{i\in I_s} \lambda_i \phi_{(s_i)}, \sum_{i\in I_s} \lambda_i = 1 \tag{19}$$

2.6 *Criteria for model selection*

The criteria for selecting the model used are the Akaike information criterion, created by Fanshawe et al. (2008) and first proposed in Akaike (Fuentes et al., 2006). AIC is a measure of goodness of fit from an estimation of a statistical model. This method offers a relative measurement of information, lost when the built model is used to describe reality, and it describes the trade-off between the precision bias and the model complexity (Furrer et al., 2006). AIC is not a model test based on hypothesis testing, but is a tool for model selection. AIC is used to compare several models, where the model with the smallest AIC value is the best model or the model closest to the actual condition. The AIC model seeks to find the model that best describes the data with a minimum of the free parameters. Assuming the error of the model is normal and independently distributed, the AIC model can be formulated (Fanshawe et al., 2008):

$$AIC = 2K + n\left(\ln\left(\frac{2\pi RSS}{n} \right) + 1 \right)$$

where:

k: number of parameters in the model
n: amount of data or observation
RSS: residual sum of squares

3 METHOD

Dengue fever is a disease that can potentially become an outbreak and spread to a wider area. Dengue fever modeling should be done on a small area, so it is expected that all information related to the disease can be found, anticipated, and handling measures can quickly be put in place. Nevertheless, the hope of modeling this disease in the smallest area such as a village cannot be fulfilled because the village and sub-district (or smaller areas of it) are considered incapable of representing dengue cases in a city. In this study, because the city of Makassar is in one of these areas, the main information is only based on data collection conducted by the local health center, whereas usually the person with the disease is taken directly to the nearest hospital. Whereas as previously known, the hospital in a region includes several villages or covers the district as the smallest area, so that with this consideration, the sub-district is used as the base area in this study. Therefore, this study will be conducted directly on sub-districts that have the highest number of dengue fever patients in Makassar City for a small area based on the sub-district; in this case Rappocini, Tamalate and Panakkukang sub-districts are selected. The data used in this study is secondary data obtained from the Health Office of Makassar in the form of data of dengue fever patients for all districts in Makassar City in 2017. In the modeling using GSTAR and GSTAR-Kriging, the districts to be analyzed are Rappocini, Tamalate and Manggala sub-districts, with the consideration that these sub-districts are each endemic, sporadic, and disease-free districts that have the highest number of dengue fever cases in the sub-district status category.

2 RESULTS AND DISCUSSION

2.1 *Variable description*

The following tables contain the descriptions of response variables and predictor variables of the numerical value and for dengue fever patients in several districts which will be analyzed using the generalized space-time autoregressive model.

The distribution of platelet count, as shown in Table 1, shows that the average platelet count of dengue fever patients 6.7% and the platelet variance is 84.2%. The maximum platelet value is 9.5% and the minimum platelet value is 8.6%. For the distribution of the hematocrit number, it can be seen that the average increase of the hematocrit volume of dengue fever patients is 52.2% and the variance of hematocrit volume increase of dengue fever is 36.91984469%. The lowest hematocrit increase amounts to 10.99% and the highest score is 56%.

For the distribution of the number of patients according to their living environment status, the highest percentage of patients with dengue fever lies in the area to be healthy that is equal to 84.2%, while the lowest percentage of patients with dengue fever lies in the healthy area that is equal to 6.7%. In the distribution of patients according to district status, the highest percentage of fever sufferers was in the sub-district with the sporadic status of 52.2%, while the lowest percentage of dengue fever patients was in the sub-district with the disease-free status of 8.6%.

The results of the normal distribution test diagram for the error in the generalized space-time autoregressive model, are shown in Figure 1.

Based on the results of the Kolmogorov–Smirnov test in Figure 1, where the value of p-value > 0.150 is greater than $\alpha = 0.05$, it can be concluded that the remainder fulfills the assumption of a normal distribution.

The results of the normal distribution test diagram for the side in the GSTAR-Kriging are shown in Figure 2.

Table 1. Description of numerical value for patients with dengue fever in Makassar city.

No	Variable name	Average	Variance	Minimum	Maximum	Information
1	83.521	5	149	Response variables		
2	Hematocrit (%)	39.27877	36.91984469	10.99	56	Predictor variables

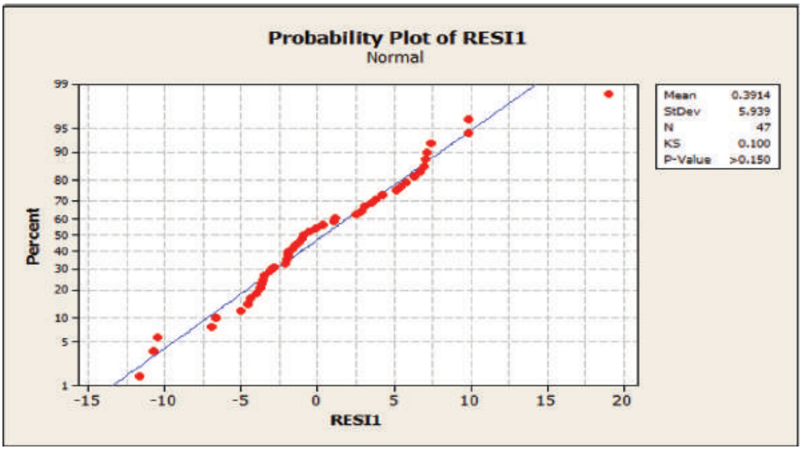

Figure 1. Test for normal distribution for the error (Kolmogorov Smirrnov test).

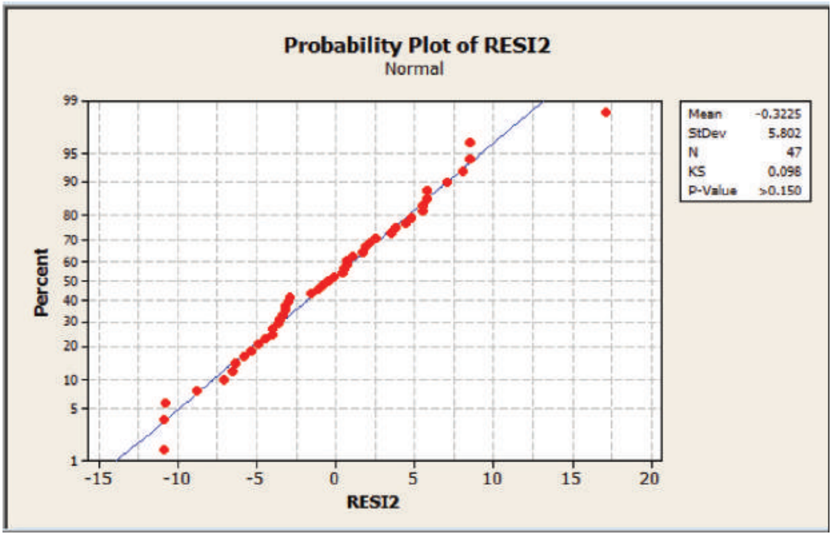

Figure 2. Test for normal distribution for the error (Kolmogorov Smirnov test).

Based on the results of Figures 1 and 2, it is found that the GSTAR model and GSTAR-Kriging model are appropriate. The best model can be determined by comparing the value of the Mean Square Error (MSE). The MSE value obtained is 36.98. The smaller the MSE value, the closer the estimated value is to the actual value, or the chosen model is the best model.

From the value of the MSE, The both models can be used that the value of the GSTAR MSE) is the GSTAR-Kriging < Mean Square Error (MSE) GSTAR) model. So it can be concluded that the MSE GSTAR-Kriging model is the better model. It can also be seen from the AIC that GSTAR-Kriging model (0.01113) is less than that of the AIC GSTAR model value (0.7253), which indicates a better GSTAR-Kriging model.

Furthermore, the AIC values can be obtained from each model

It appears from Table 3 that the AIC value for GSTAR-Kriging is the smallest, or smaller than that of the GSTAR model, so it can be said that the most suitable model for data on dengue hemorrhagic fever is the GSTAR-Kriging model.

Table 2. Description of categorical type for patients with dengue fever in Makassar city.

No	Variable name		Frequency	Percent (%)	Information
1	Environmental Status				
		1 = Healthy	35	6.7	Response Variables
		2 = Becoming hlthy	420	84.2	
		3 = Preparation hlth	47	9.5	
2	District Status				
		1 = Free of disease	42	8.6	Predictor Variables
		2 = Sporadic	258	52.2	
		3 = Endemic	197	38.9	

Table 3. AIC value for each model.

Akaike information	Criterion
GSTAR	GSTAR—Kriging
0.7253	0.01113

4 CONCLUSION

- Modeling by using the GSTAR model can only be used for inter-sample locations. So for the locations that are not used, samples used GSTAR-Kriging modeling by borrowing data inter-sample from other related areas or even from all small areas in the city of Makassar.
- The data observed in this study comes from one region only, so the problem is limited to models with the order of 1 in time lag and order 1 for spatial lag.
- The estimation of a small area in the selected sub-district will borrow strength from other related areas or even all the small areas in Makassar.
- The results of this study indicate that the highest level of dengue fever sufferers occurred in March 2017.
- Akaike information criterion is an information criterion used to choose the best model. In the data on Dengue Hemorrhagic Fever (DHF) in Dr. Wahidin Sudirohusodo's Hospital, the calculation of the AIC value for the GSTAR-Kriging model = 0.01113 and the GSTAR model = 0.7253. From these values, the best model used to represent spatial factors of the highest dengue fever sufferers data is the GSTAR-Kriging model, because it has the smaller AIC value.

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Optimal retention for *stop-loss* reinsurance with distribution-free approximation

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ABSTRACT: In stop-loss reinsurance, the reinsurance company will determine the bound of its ability to guarantee the risk, and the remainder of the risk that cannot be guaranteed will be transferred to the reinsurance company, namely the retention. Therefore, optimal retention is needed for the insurance company to handle a bigger loss. We can optimize the Value-at-Risk (VaR) measure to get optimal retention, but it is not easy if there is incomplete information about the total loss that is accepted by the insurance company (e.g. there are only two first moments and support in interval [0, *b*], where *b* can have value +∞). Therefore, an approximation that utilizes this incomplete information can be used this is called distribution-free approximation. This research will use a study of literature method. With this approximation, we can see from the result that the obtained optimal retention is dependent on two first moments and the safety loading obligation that is determined by the reinsurance company.

1 INTRODUCTION

Stop-loss reinsurance is a reinsurance in which the insurance company will determine its retention limit, and the reinsurance company will cover the risks that exceed the retention limit. Technically, if the losses that are received by the insurance company are below the retention limit, then the insurance company will cover the risks itself. Otherwise, if the losses that are received by the insurance company are above the retention limit, then the insurance company will transfer the risks that cannot be covered to the reinsurance company. After that, the reinsurance company will charge a reinsurance premium to the insurance company as a guarantee of risk that has been transferred to the reinsurance company. This reinsurance premium will depend on the retention limit that is determined by the insurance company.

After *stop-loss* reinsurance is made, then the total cost that must be prepared by the insurance company is the part of the loss that was borne by the insurance company plus the reinsurance premium that must be paid to the reinsurance company. Therefore, an optimal retention is very important to the insurance company to minimize the risks that were borne by the insurance company. There are some ways to find optimal retention, one of which is optimization. One of optimization that can be used is Value-at-Risk (VaR) measure optimization. An optimal retention will be found if the VaR risk measure is at a minimum.

In the previous research, Cai and Tan (2007) explained about how to get optimal retention for stop-loss reinsurance under the VaR and Conditional Tail Expectation (CTE) risk measures. After that, Hu et al. (2015) developed the study of Cai and Tan (2007) to get optimal retention with incomplete information. In this research, we find that in Hu et al. (2015) there is a difference in bounds of the maximum stop-loss transform. In Hu et al. (2015), the denominator that was used is 2μ. In this research, we will use the denominator μ.

Sometimes however, it is not easy to find optimal retention because there is incomplete information available to estimate the distribution of the total loss received by the insurance company. Therefore, an approximation is needed that can be used in order for the optimization of the VaR measure to be carried out. This approximation is called the distribution-free approximation.

Distribution-free approximation is one approximation that is used when the information about the distribution of a random variable is incomplete, that states the total loss received by the insurance company, e.g. there are only two first moments, and support of the total loss received by the insurance company. This approximation will use two principals, namely stochastic dominance order and stop-loss order. After these two principals are satisfied, then we can find an optimal retention according to a minimization of the VaR measure of a random variable, which states that the total cost must be prepared by the insurance company.

The rest of this paper is structured as follows. In Section 2, we will describe the method of this research and its underlying theory. In Section 3, we will describe the results of this research. In Section 4, we will explain the conclusions of this research. In the last section, we list the references that are used in this research.

2 METHOD

The method of the research is the study of literature. In this section, we will explain about a VaR risk measure based on the model of stop-loss reinsurance. After that, we will explain about how to get themaximum of the VaR risk measure of a random variable that states the parts of loss that were borne by the insurance company and the maximum stop-loss transform such that we can get optimal retention by optimization of the VaR risk measure.

2.1 *VaR risk measure based on model of Stop-Loss reinsurance*

Let X be a random variable that states the total loss that is received by the insurance company. X_I is a random variable that states the part of losses that were borne by the insurance company. X_R is a random variable that states the part of the losses borne by the reinsurance company. The relation between these three random variables is (Cai & Tan, 2007):

$$X = X_I + X_R \tag{1}$$

where

$$X_I = \left\{ \begin{matrix} X, X \le d \\ d, X > d \end{matrix} \right. = X \wedge d = \min\left\{ X, d \right\} \tag{2}$$

and

$$X_R = \left\{ \begin{matrix} 0, X \le d \\ X-d, X > d \end{matrix} \right. = \left(X - d \right)_+ = \max\left\{ 0, X - d \right\} \tag{3}$$

with $d > 0$.

In stop-loss reinsurance, the insurance company will bear the risk up to the retention limit, and transfer the risk exceeding the retention limit to the reinsurance company. Note that if the insurance company does not set a retention, then the insurance company will bear all of the risks that are received (no reinsurance). Otherwise, if the retention $d = 0$, then the insurance company will transfer all of the risks to the reinsurance company (full reinsurance).

After the insurance company joins *stop-loss* reinsurance, then the total cost that must be prepared by the insurance company (T) is the part of the loss borne by the insurance company (X_I) plus the reinsurance premium that must be paid to the reinsurance company ($\delta(d)$). The formula of T is:

$$T = X_I + \delta(d) \tag{4}$$

where $\delta(d) = (1+\rho)E[X_R]; \rho > 0$ is safety loading factor.

Since *stop-loss* reinsurance is based on the retention limit that is determined by the insurance company, then the insurance company needs to determine the optimal retention such that the insurance company can handle a big loss. One of the ways that can be used is by using VaR risk measure optimization.

The VaR risk measure of random variable X at a confidence level $1 - \alpha$ where $0 < \alpha < 1$ can be defined as follows (Cai & Tan, 2007):

$$VaR_\alpha(X) = \inf\{x : \Pr(X > x) \le \alpha\} \tag{5}$$

Based on Equation 5, we can define the VaR risk measure of random variables X_I and T as follows (Cai & Tan, 2007):

$$VaR_\alpha(d, X_I) = \inf\{x : \Pr(X_I > x) \le \alpha\} \tag{6}$$

$$VaR_\alpha(d, T) = \inf\{x : \Pr(T > x) \le \alpha\} \tag{7}$$

The objective of this research is to optimize the VaR risk measure of random variable T by minimizing the VaR risk measure of random variable T such that the optimal retention (d^*) will be found. Thus, Equation 7 will be (Cai & Tan, 2007):

$$VaR_\alpha(d^*, T) = \min_{0 \le d \le b}\{VaR_\alpha(d, X_I) + \delta(d)\} \tag{8}$$

However, to optimize the VaR risk measure of random variable T it is sometimes difficult because there is not enough information about the distribution of the total loss that is received by the insurance company, such that to find the optimal retention from Equation 8 is also difficult. Therefore, we need an approximation to estimate the distribution of the total loss that is received by the insurance company, so that the optimization VaR risk measure can be done. This approximation is namely the distribution-free approximation. This approximation uses two principals, namely stochastic dominance order and stop-loss order. Stochastic dominance order is used to get the maximum of the VaR risk measure of a random variable, which states the parts of loss that were borne by the insurance company. Stop-loss order is used to get the maximum stop-loss transform.

2.2 *Maximum of VaR risk measure of random variable that states the part of loss borne by the insurance company (T)*

Before explaining about the maximum of the VaR risk measure of random variable X_I, we will explain about the stochastic dominance order from a Chebyshev-Markov distribution random variable. Given a partial order between a random variable and some classes of random variables, we can construct random variables that are associated with this partial order. This partial order can be called stochastic dominance order for $X \in \mathcal{B}$, where $\mathcal{B}$ is a set that contains all non-negative random variables with mean μ, standard deviation σ, and support in interval $[0,b]$, where the value of b can be $+\infty$. Stochastic dominance order is an order where if $F_X(x) \le F_Y(x), \forall x \in \mathbb{R}$, then $Y \le_{st} X$ (Kaas et al., 2008). Let $F_*(x)$ and $F^*(x)$ be extremal Chebyshev-Markov distribution functions in set $\mathcal{B}$ that are solutions of an extremal moment problem (Hu et al., 2015):

$$S_*(x) := \min_{X \in \mathcal{B}}[S_X(x)] \tag{9}$$

$$S^*(x) := \max_{X \in \mathcal{B}}[S_X(x)] \tag{10}$$

where $S_*(x) = 1 - F_*(x)$ and $S^*(x) = 1 - F^*(x)$.

A random variable with distribution function $F_*(x)$ and $F^*(x)$ can be written as X_* and X^* respectively. Both of these random variables can be ordered in stochastic dominance order and satisfy the inequality:

$$X_* \leq_{st} X \leq_{st} X^*, \forall X \in \mathcal{B} \tag{11}$$

According to inequality Equation 11, the minimum and maximum of the VaR risk measure can be defined as follows (Hu et al., 2015):

$$\min_{X\in\mathcal{B}}\{VaR_\alpha(X)\} = VaR_\alpha(X_*) \tag{12}$$

$$\max_{X\in\mathcal{B}}\{VaR_\alpha(X)\} = VaR_\alpha(X^*) \tag{13}$$

From Equation 8, the maximum value of $VaR_\alpha(d, X_I)$ can be derived analytically as follows.

Proposition 2.1 The maximum value of $VaR_\alpha(d, X_I)$ for $X \in \mathcal{B}$ is:

Proof

To get the maximum value of $VaR_\alpha(d, X_f)$, follow these steps:

1. Find the distribution function of X^*. The distribution function of X^*can be found in the proof of Proposition 1 in Hu et al. (2015).
2. Based on Equation 5 and the definition of random variable X_I, we will get $\max_{X\in\mathcal{B}}\{VaR_\alpha(d, X_I)\} = VaR_\alpha(X^*) \wedge d$.
3. Analyze every condition in the distribution function of random variable X^* and pair with the condition in Proposition 2.1, whether it is satisfied or not. If there are two or more possibilities, choose the smallest one.
4. Finally, the result of pairing between the distribution function of random variable X^* and the condition in Proposition 2.1 will be $\max_{X\in\mathcal{B}}\{VaR_\alpha(d, X_I)\}$.

2.3 *Stop-loss transform*

Before explaining about stop-loss transform, we will explain about stop-loss order from a Chebyshev–Markov distribution random variable. Given a partial order between a random variable and some classes of random variables, we can construct random variables that are associated with this partial order. This partial order can be called *stop-loss order* for $X \in \mathcal{B}$, where $\mathcal{B}$ is a set that contains all non-negative random variables with mean μ, standard deviation σ,

Table 1. The maximum value of $VaR_\alpha(d, X_I)$ based on the condition (Hu et al., 2015).

Condition	$\max_{X\in\mathcal{B}}\{VaR_\alpha(d, X_I)\}$
$\alpha \leq \dfrac{\sigma^2}{\sigma^2 + (b-\mu)^2}$	d
$\dfrac{\sigma^2}{\sigma^2 + (b-\mu)^2} \leq \alpha \leq \dfrac{\mu^2}{\sigma^2 + \mu^2}$	$\left(\mu + \sqrt{\dfrac{1-\alpha}{\alpha}}\sigma\right) \wedge d$
$\alpha \geq \dfrac{\mu^2}{\sigma^2 + \mu^2}$	$\left(\mu + \dfrac{(1-\alpha)b\mu - \sigma^2}{\alpha b - \mu}\right) \wedge d$

and support in interval [0,b], where the value of b can be +∞. *Stop-loss order* is an order where if $\pi_X(x) = E[(X-x)_+] \le E[(Y-x)_+] = \pi_Y(x)$, then $X \le_{SL} Y$ (Kaas et al., 2008). Let the minimum and maximum of the stop-loss transform in set B be defined as follows (Hu et al., 2015):

$$\pi_l(d) = \min_{X \in \mathcal{B}} \{\pi_X(d)\} \tag{14}$$

$$\pi_u(d) = \max_{X \in \mathcal{B}} \{\pi_X(d)\} \tag{15}$$

where the stop-loss transform refers to $\pi_X(d) = E[(X-d)_+] = \int_d^\infty S_X(x)dx$ (Klugman et al., 2012) or can be written as $S_X(x) = -\frac{d}{dx}\pi_X(x)$, since $S_X(x) = 1 - F_X(x)$ can be defined as random variables X_l and X_u with distribution functions respectively as follows (Hu et al., 2015):

$$F_l(x) = 1 + \frac{d}{dx}\pi_l(x) \tag{16}$$

$$F_u(x) = 1 + \frac{d}{dx}\pi_u(x) \tag{17}$$

Random variables X_l and X_u can be ordered in *stop-loss order* and satisfy this inequality (Hu et al., 2015):

$$X_l \le_{SL} X \le_{SL} X_u, X \in \mathcal{B} \tag{18}$$

According to inequality Equation 18, the minimum and maximum of stop-loss transform can be defined as follows (Hu et al., 2015):

$$\min_{X \in \mathcal{B}} \{E[(X-d)_+]\} = E[(X_l - d)_+] \tag{19}$$

$$\max_{X \in \mathcal{B}} \{E[(X-d)_+]\} = E[(X_u - d)_+] \tag{20}$$

From Equation 8, $\max_{X \in \mathcal{B}}[\pi_X(d)]$ can be derived analytically as follows.

Proposition 2.2 The maximum of value of $\pi_X(d)$ for $X \in \mathcal{B}$ are shown in Table 2.

Table 2 The maximum value of $\pi_X(d)$ based on the condition (Hu et al., 2015).

Condition	$\max_{X \in \mathcal{B}}[\pi_X(d)]$
$0 \le d \le \frac{\sigma^2 + \mu^2}{\mu}$	$\mu\left(1 - \frac{\mu d}{\sigma^2 + \mu^2}\right)$
$\frac{\sigma^2 + \mu^2}{\mu} \le d \le \frac{b+\mu}{2} - \frac{\mu^2}{2(b-\mu)}$	$\sqrt{\frac{\sigma^2 + (d-\mu)^2}{2}} - \frac{d-\mu}{2}$
$\frac{b+\mu}{2} - \frac{\mu^2}{2(b-\mu)} \le d \le b$	$\frac{\sigma^2(b-d)}{\sigma^2 + (b-\mu)^2}$

Note that in the first row, we use a different denominator from that used by Hu et al. (2015) who used the denominator 2μ; in our research, we use μ because there is a miscalculation when we use the denominator 2μ.

3 RESULT AND DISCUSSION

In this section, we will explain how to get optimal retention if there is insufficient information available to estimate the distribution of the total loss received by the insurance company. At the end of this section will be given the example case that interprets this research.

3.1 *Optimal retention*

In the previous section, we have explained about the maximum of the VaR risk measure of a random variable, which states the part of loss borne by the insurance company (X_I) and the maximum *stop-loss* transform to get the VaR risk measure of random variable T. We have also explained that to get the optimal retention, then the VaR risk measure of random variable T must be minimum or can be written in Equation 8. Before obtaining the optimal retention, first we will define three subintervals and two notations respectively, to make it easier in find the optimal retention, as follows:

$$I_1 = \left[0, \frac{\sigma^2 + \mu^2}{\mu} \right]$$

$$I_2 = \left[\frac{\sigma^2 + \mu^2}{\mu}, \frac{b+\mu}{2} - \frac{\mu^2}{2(b-\mu)} \right]$$

$$I_3 = \left[\frac{b+\mu}{2} - \frac{\mu^2}{2(b-\mu)}, b \right]$$

$$\Delta_1 = \frac{\sigma^2 + \mu^2}{\mu^2}$$

$$\Delta_2 = \frac{\sigma^2 + (b-\mu)^2}{\sigma^2}$$

The optimal retention can be found with this equation:

$$d^* = \arg\min_{0 \le d \le b} \left\{ \max_{X \in \mathcal{B}} \left\{ VaR_\alpha(d, X_I) \right\} + (1+\rho) \max_{X \in \mathcal{B}} \left\{ \pi_X(d) \right\} \right\} \tag{21}$$

with objective function:

$$OBF(d) := \max_{X \in \mathcal{B}} \left\{ VaR_\alpha(d, X_I) \right\} + (1+\rho) \max_{X \in \mathcal{B}} \left\{ \pi_X(d) \right\} \tag{22}$$

For easier writing, $1 + \rho$ will be written in form $\bar{\rho}$.

The optimal retention can be found by the criteria in this theorem:

Theorem 3.1 From the optimization problem in Equation 8, the optimal retention can be found in three cases as shown in Table 3.

3.2 *Example case*

We will explain the example case according to this research. Suppose that an insurance company joins stop-loss reinsurance. This company has three recommendations for the reinsurance company that has safety loading value $\bar{\rho} = 2.2$. The insurance company only has information about the total loss received by the insurance company with mean $\mu = 500$, standard deviation $\sigma = 450$, and upper bound of $b = 1000$. With $\alpha = 0.05$, optimal retention d^* and $OBF(d^*)$ will be found.

To get the optimal retention d^* and $OBF(d^*)$, follow these steps:

Table 3. Criteria of optimal retention according to the case and condition (Hu et al., 2015).

Case	Condition	d^*	$OBF(d^*)$
$\alpha \le \dfrac{\sigma^2}{\sigma^2+(b-\mu)^2}$	$1 \le \bar{\rho} \le \Delta_1$	0	$\bar{\rho}\mu$
	$\bar{\rho} = \Delta_1$	Any number in I_1	$\mu + \dfrac{\sigma}{\mu}\sigma$
	$\Delta_1 \le \bar{\rho} \le \Delta_2$	$\mu + \dfrac{\sigma(\bar{\rho}-2)}{2\sqrt{\bar{\rho}-1}}$	$\mu + \sqrt{\bar{\rho}-1}\sigma$
	$\bar{\rho} = \Delta_2$	Any number in I_2	B
	$\bar{\rho} > \Delta_2$	B	b
$\dfrac{\sigma^2}{\sigma^2+(b-\mu)^2} \le \alpha \le \dfrac{\mu^2}{\sigma^2+\mu^2}$	$1 \le \bar{\rho} \le \Delta_1$	0	$\bar{\rho}\mu$
	$\bar{\rho} = \Delta_1$	Any number in I_1	$\mu + \dfrac{\sigma}{\mu}\sigma$
	$\Delta_1 \le \bar{\rho} \le \dfrac{1}{\alpha}$	$\mu + \dfrac{\sigma(\bar{\rho}-2)}{2\sqrt{\bar{\rho}-1}}$	$\mu + \sqrt{\bar{\rho}-1}\sigma$
	$\bar{\rho} \ge \dfrac{1}{\alpha}$	b	$\mu + \sqrt{\dfrac{1-\alpha}{\alpha}}\sigma$
$\alpha \ge \dfrac{\mu^2}{\sigma^2+\mu^2}$	$1 < \bar{\rho} < \Delta_1$	u^*	$\min\left\{\bar{\rho}\mu, \mu + \dfrac{(1-\alpha)b\mu-\sigma^2}{\alpha b-\mu}\right\}$
	$\bar{\rho} \ge \Delta_1$	b	$\mu + \dfrac{(1-\alpha)b\mu-\sigma^2}{\alpha b-\mu}$

$^*u = 0$ if $\bar{\rho}_\mu < \mu + \dfrac{(1-\alpha)b\mu-\sigma^2}{\alpha b-\mu}$ and $u = b$ for otherwise.

Table 4. The value of d^* and $OBF(d^*)$ according to the example case.

Condition	Δ_1	Δ_2	d^*	$OBF(d^*)$
$\alpha = 0.05 \le \dfrac{\sigma^2}{\sigma^2+(b-\mu)^2} = 0.448$	1.81	2.235	541.079	992.950

1. Check the value of α to determine the condition that satisfies Theorem 3.1.
2. Find the value of Δ_1 and Δ_2 to get the condition of $\bar{\rho}$ in Theorem 3.1.
3. Determine the value of d^* and $OBF(d^*)$ based on the condition of $\bar{\rho}$ in Theorem 3.1.

The value of d^* and $OBF(d^*)$ are summarized in Table 4.

4 CONCLUSION

Based on Section 3, we can conclude that optimal retention for stop-loss reinsurance can be found, although with only insufficient information. For the example, there are two first moments and support from the total loss that is received by the insurance company in interval [0, b], where b can has value $+\infty$. One of the ways is distribution-free approximation. With this approximation, we can conclude that optimal retention will depend on two first moments and the value of $\bar{\rho}$.

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Modeling structural breakpoints in volatility of Philippine Peso-US Dollar currency exchange rate

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ABSTRACT: This work presents a novel method to determine structural breakpoints in volatility of a time series. The proposed method, called the *breakpoint-search algorithm*, utilizes the log-likelihood function value derived from the fitted Generalized Auto-Regressive Conditional Heteroskedasticity (GARCH) model of the given data. In many time series models, volatility is approximated to be constant over a period of time or moving from one regime to another. In such cases, it is important to determine when shifts in volatility patterns occur, in order to capture the behavior of the data very well. The proposed model, together with the GARCH model, are used to identify periods of high and low volatility, and to assess the long-term volatility of the time series. To test the efficacy of the proposed algorithm, the method is applied to a real-world time series data, such as the Philippine Peso-US Dollar currency exchange rate. Empirical results agree with the events in Philippine history indicating periods of economic instability.

1 INTRODUCTION

One benchmark for gauging a country's economic performance is how its currency is valued against other currencies. For instance, we may compare how the Philippine Peso (PHP) trades against the US Dollar ($ or USD), given that the latter has been stable over the past three decades. The Philippine currency was trading at PHP8 per $1 back in 1980s, and by 1986 it was at PHP20 per $1. At the turn of the millennium, the currency was at PHP40 per $1, reaching a high of PHP55 in the mid-2000s, before stabilizing to low PHP40's per $1 as of 2015.

There are many factors that affect the movement of currency value. A country's government may devalue its currency in order to stimulate the economy by increasing exports and reducing imports. The currency may also depreciate due to external market forces, such as financial crashes, natural disasters, and political instability. As such, it is important that financial analysts, especially policy makers, must be able to understand and examine the behavioral patterns in a time series data such as stock price and currency exchange rate for them to have more accurate forecasts and in turn design monetary policies that minimize economic risks.

A widely-used indication of market movement is volatility (or variance), where low volatility indicates little movement in the time series data, whereas high volatility means a lot of movement in the data in a short span of time. Early assumptions about volatility is that it is constant, until the seminal paper of (Engle, 1982) that recognizes the non-constant behavior of volatility, or *heteroskedasticity* (Tsay, 2001), of a stochastic process.

Time series volatility, although non-constant, exhibit behavioral patterns that can be partitioned into groups of high and low. Accurately determining these patterns and the locations where they can be partitioned is especially important in forecasting stochastic processes such as stock proce and currency exchange rate. However, despite the many studies that model the nonconstant behavior of volatility, studies on how to automatically locate the partitions (or *breakpoints*, as will be formally defined in the next section) have not been given much attention yet.

In this paper, we present a novel method, called the *breakpoint-search algorithm*, that utilizes economic tools such as the Generalized Auto-Regressive Conditional Heteroskedasticity (GARCH) model to identify volatility breakpoints in the PHP-USD currency exchange rate. Determining breakpoints allows us to separate periods of high volatility and delineate baseline or long-term volatility, which are critical when modeling a process such as exchange rates, interest rates and stock prices. The calculated volatility breakpoints are then compared with historical events that affected the currency movement in the Philippines.

2 THE GARCH METHOD

The Generalized Autoregressive Conditional Heteroskedasticity or GARCH, is a forecasting method proposed by (Bollerslev, 1986, Bollerslev et al, 1992) that generalizes the ARCH model of Engle in 1982. The GARCH (*p, q*) models the return y_t

$$y_t = C + \epsilon_t, \tag{1}$$

and conditional variance σ_t^2 as

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}^2, \tag{2}$$

where C, ω, β_i and α_j are parameters (to be estimated), satisfying $\omega = 0$ and $\beta_i, \alpha_j \geq 0$. To ensure covariance stationarity, $\Sigma_{i=1}^{p} \beta_i + \Sigma_{j=1}^{q} \alpha_i < 1$. Setting $p = 1$, $q = 1$ leads to the GARCH(1,1) model (Engle et al, 2012), wherein (2) becomes

$$\sigma_t^2 = \omega + \beta \sigma_{t-1}^2 + \alpha \varepsilon_{t-1}^2, \tag{3}$$

where α is the weight of the lagged squared returns and β is the weight of the lagged variances. The long-run average variance is given by

$$\sigma_t'^2 = E\left[\varepsilon_t^2\right] = \frac{\omega}{1 - \beta - \alpha}, \tag{4}$$

with $\alpha + \beta < 1$. The parameters that best fit the data are estimated via maximum likelihood estimation (Lamoureux & Lastrapes, 1990). The Matlab® built-in function garchfit returns not only the GARCH parameters but also the optimized log-likelihood function (LLF) value. The LLF gives the likelihood of the GARCH-estimated parameters given a set of data (Myung, 2003). In the next section, we will see how the log-likelihood function value can be used in modeling time series volatility.

3 PROPOSED METHOD: BREAKPOINT SEARCH ALGORITHM

A *breakpoint* is a point in the time series where there is a large change in the parameters (Kapetanios & Tzavalis, 2004; Eizaguirre et al, 2003). As pointed out in the study of (He & Maheu, 2009), a change in the LLF values implies a change in the variance parameters. This was a good observation, however, there seems to be no study yet about the use of LLF values in modeling structural breakpoints in volatility. Hence, motivated by the studies of (He & Maheu, 2009; Rivero, 2012), we propose the following model in searching for the primary breakpoint in the volatility of a stochastic process:

$$max \Delta LLF = \max_{k \leq j \leq N-k} \left| l\left(\theta_k^j\right) + l\left(\theta_{j+1}^{N-k}\right) - l\left(\theta_k^{N-k}\right) \right| \tag{5}$$

where the breakpoint is in the interval $[k, N-k]$; $l(\theta_n^m)$ is the LLF of the sample data from $t = m, \ldots, n$; the set q_n^m contains the GARCH parameters α, β and ω that best fit the sample data from $t = m, \ldots, n$; N is the total number of data points; and k is the margin set around the breakpoints (and endpoints). The margin was used to prevent the algorithm from returning consecutive breakpoints, and instead grouped such breakpoints as part of volatility clusters. The secondary breakpoints were then determined conditional on the primary break. Given the primary break at $t = j \in [k, N-k]$, the secondary breakpoints were located by searching for max ΔLLF in the intervals $[k, j-k]$ and $[j+k, N-k]$. The proposed model then captures the actual dynamics of a stochastic process, as it can automatically locate where significant changes in the volatility happened.

4 RESULT AND DISCUSSION

The data set used was the daily PHP-USD exchange rate from 1985 to 2011, covering a period of 6,688 days, which is roughly 248 trading days per year. The plot of the data is given in Figure 1.

The returns series was first tested for the presence of correlation and heteroskedasticity. The Matlab® built-in functions lbqtest and archtest showed that the returns series exhibited no correlation and absence of homoskedasticity, respectively. This implied that the GARCH process can be used on the data set. The parameters obtained are given in Table 1, with $LLF = 25769.7$. These were used with the model given in (1) and (2) with $p = q = 1$.

The GARCH-fitted standard deviation of the log returns is given in Figure 2. The standard deviation of the returns series was also computed using a nonparametric approach. The Rolling Variance Method (Zivot & Wang, 2006) was used to compute the standard deviation of the data in a predefined window width which "rolled" from start to end of the data. The plot of the standard deviation given by the Rolling Variance is superimposed on the plot of the

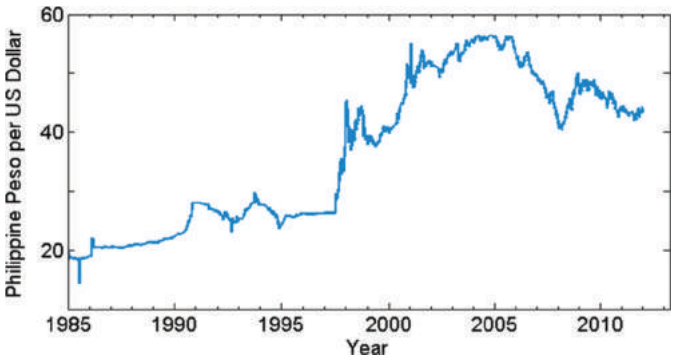

Figure 1. Peso-Dollar Exchange Rate from 1985 to 2011.

Table 1. GARCH-fitted parameters for the mean returns and conditional volatility of the log returns.

Parameter	Value	Standard error	T-Statistic
C	-3.5241×10^{-5}	6.9403×10^{-5}	–0.5078
ω	9.4660×10^{-6}	1.8883×10^{-7}	50.1285
α	0.22964	0.0102000	22.5138
β	0.53694	0.0091846	58.4606

GARCH-fitted standard deviation for comparison. The GARCH-fitted standard deviation was slightly higher than the rolling standard deviation, although both followed the same trend.

The breakpoint-search algorithm in the previous subsection was employed to obtain the volatility breaks in the PHP-USD exchange rate log-returns. The breakpoints obtained and the corresponding volatilities (sigma) are shown in Figure 3 and are summarized in Table 2.

From Table 2, there were only two periods when volatility was higher than the unconditional standard deviation $\sigma = 0.0066$: during the first interval, which corresponded to the

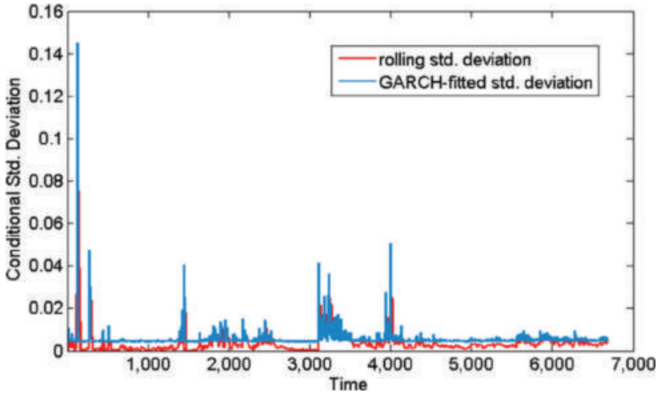

Figure 2. The rolling standard deviation (red) and the GARCH-fitted standard deviation (blue) of the data set.

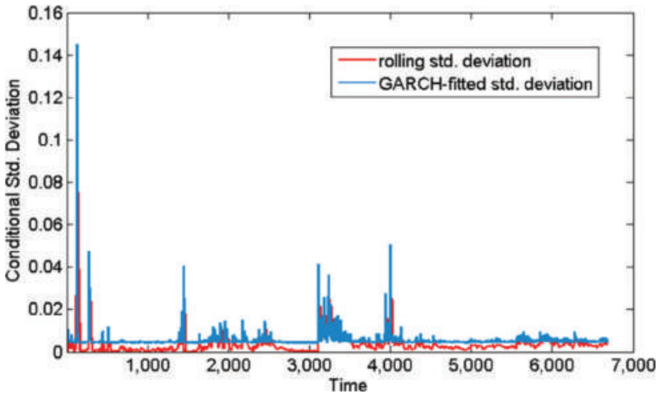

Figure 3. The GARCH-fitted volatility with breakpoints at t = 278, 652, 1450, 2709, 3114, 3510, 3996, 4858, and 5171. Unconditional standard deviation (green dashed line) has value 0.0066. Also shown are the rolling standard deviation (red) and the GARCH-fitted standard deviation (blue) of the data set.

Table 2. The unconditional volatilities for each subinterval.

Subinterval*	Sigma	Subinterval	Sigma
1–277	0.0210	3114–3509	0.0130
278–651	0.0057	3510–3995	0.0053
652–1449	0.0021	3996–4857	0.0047
1450–2708	0.0047	4858–5170	0.0021
2709–3113	0.0004	5171–6688	0.0038

*The time for the subinterval is in days, counted from January 1, 1985.

1985 until February 1986, when the People Power Revolution occurred, and during the sixth interval, from June 1997 to February 1999, when the country suffered from the effects of the Asian financial crisis. Note also that the lowest volatility occurred from December 1995 until the start of the Asian financial crisis. A baseline standard deviation for the PHP-USD exchange rate would be around 0.005 if those two periods were not considered, or an annualized volatility of 7.9%. Considering recent data, volatility has been stable over the past 6 years, with a sigma of 0.0038, or an annual volatility of 6%.

5 CONCLUSION

In this paper, we presented a novel method of determining structural breakpoints in volatility of an asset process such as stocks or currency exchange, thus identifying periods of high volatility and low volatility, and allowed us to separate short-term spikes in volatility that greatly affected the long-term volatility. The method utilized the Generalized Auto-Regressive Conditional Heteroskedasticity (GARCH) and was applied to the Philippine Peso-US Dollar currency exchange rate covering the period from 1985 to 2011. The results showed that there were two events in recent Philippine history when the country's economy underwent periods of instability: during the People's Power Revolution on February 1986 and during the Asian financial crisis from June 1997 to early 1999. Aside from those periods mentioned, the volatility has remained fairly stable over the past decade, with an annual volatility of 6% over the past 6 years. Note that this method may also be used for other time series, such as weather data.

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A Laplace transform dual reciprocity method for two-dimensional diffusion equation

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ABSTRACT: In this paper, a problem involving two-dimensional diffusion equation is considered. The problem may be solved numerically using a Laplace Transform Dual Rec-iprocity Method (LTDRM). To apply the method, the diffusion equation is transformed in-to an equation in Laplace space. The resulted equation is solved numerically following the technique of dual reciprocity element method. The LTDRM is tested on a problem involving diffusion equation. Results obtained are then compared to the corresponding analytic solutions to check the accuracy of the numerical solutions.

1 INTRODUCTION

Laplace transform dual reciprocity methods (LTDRM) have been employed by researchers to solve various problems numerically. Such researchers are Zhu, Satravaha and Lu (1994), Zhu and Satravaha (1996), Ang (2002), and Solekhudin and Ang (2015). Zhu, Satravaha and Lu solved linear diffusion equations (1994). Transient heat conduction problems involving nonlinear source terms have been solved by Zhu and Satravaha (1996). Ang (2002) solved two-dimensional microscale thermal problems. A time-dependent infiltration problem with root-water uptake was solved by Solekhudin and Ang (2015).

In this paper, An LTDRM is employed to solve a problem involving diffusion equation numerically. The diffusion problem considered in this paper is heat conduction. The method is tested through a problem with known analytic solution. Solutions obtained using the proposed method are then compared with the corresponding analytic solutions to investigate the accuracy of the method. In addition, the numerical results obtained are then observed to determine the effect of time to temperature.

2 BASIC EQUATIONS

One of diffusion problems is heat conduction. In this study, a heat conduction problem is considered. The governing equation that commonly used to model heat conduction is

$$\rho C_p \frac{\partial u}{\partial t} = k\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right), \tag{1}$$

where u is the temperature, ρ is the density, C_p is the heat capacity and k is the heat conductivity coefficient. Equation 1 may be rewritten as

$$\frac{\partial u}{\partial t} = K\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right), \tag{2}$$

where $K = \frac{k}{\rho C_p}$. In this study, we omit units of variables and constants in Equation 1.

In this paper, we consider an isotropic thin plate bounded by $0 \le x \le 1$ and $0 \le y \le 1$. Over the material, a heat conduction occurs. The heat conduction is governed by

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}, \tag{3}$$

subject to initial boundary conditions

$$u(x,y,0) = 10\sin(\pi x)\cos(\pi y), \tag{4}$$

$$u(x,y,t) = e^{-2\pi^2 t}\sin(\pi x), \quad \text{for } 0 \le x \le 1 \text{ and } y = 0, \tag{5}$$

$$u(x,y,t) = 0, \quad \text{for } 0 \le y \le 1 \text{ and } x = \tag{6}$$

$$u(x,y,t) = -e^{-2\pi^2 t}\sin(\pi x), \quad \text{for } 0 \le x \le 1 \text{ and } y = 1, \tag{7}$$

$$u(x,y,t) = 0, \quad \text{for } 0 \le y \le 1 \text{ and } x = 0. \tag{8}$$

A Laplace transform dual reciprocity method (LTDRM) is employed to solve the problem. To employ the method, we first represent Equation (3) into an integral equation. The integral equation is

$$\begin{aligned}
&\lambda(\xi,\eta)u(\xi,\eta,t) \\
&\quad = \iint_R \Phi(x,y;\xi,\eta)\frac{\partial u}{\partial t}dxdy \\
&\quad + \int_C \left\{ u\frac{\partial}{\partial n}[\Phi(x,y;\xi,\eta)] - \Phi(x,y;\xi,\eta)\frac{\partial u}{\partial n} \right\} ds(x,y),
\end{aligned} \tag{9}$$

where $\Phi(x,y,\xi,\eta)$ is the fundamental solution of two-dimensional Laplace equation, defined as

$$\Phi(x,y;\xi,\eta) = \frac{1}{2\pi}\ln\sqrt{(x-\xi)^2 + (x-\eta)^2}, \tag{10}$$

and

$$\lambda(\xi,\eta) = \begin{cases} 1/2, & (\xi,\eta) \text{ on smooth part of } C \\ 1, & (\xi,\eta) \in R \end{cases}. \tag{11}$$

Applying Laplace transform

$$u^*(x,y,s) = \int_0^\infty u(x,y,t)e^{-st}dt, \tag{12}$$

Subject to Initial condition (4), transform Equation (9) and Boundary conditions (5) – (8) into

$$\begin{aligned}
&\lambda(\xi,\eta)u^*(\xi,\eta,t) \\
&\quad = \iint_R \Phi(x,y;\xi,\eta)[su^* - 10\sin(\pi x)\cos(\pi y)]dxdy \\
&\quad + \int_C \left\{ u^*\frac{\partial}{\partial n}[\Phi(x,y,\xi,n)] - \Phi(x,y;\xi,n)\frac{\partial u^*}{\partial n} \right\} ds(x,y),
\end{aligned} \tag{13}$$

and

$$u^*(x,y,s) = \frac{\sin(\pi x)}{\pi^2 + s}, \qquad \text{for } 0 \le x \le 1 \text{ and } y = 0, \tag{14}$$

$$u^*(x,y,s) = 0, \qquad \text{for } 0 \le y \le 1 \text{ and } x = 1, \tag{15}$$

$$u^*(x,y,s) = -\frac{\sin(\pi x)}{\pi^2 + s}, \qquad \text{for } 0 \le x \le 1 \text{ and } y = 1, \tag{16}$$

$$u^*(x,y,s) = 0, \qquad \text{for } 0 \le y \le 1 \text{ and } x = 0. \tag{17}$$

Now, Equation (13) subject to Boundary conditions (14) – (17) may be solved numerically following the procedure of dual reciprocity boundary element method (DRBEM), which is also used by Solekhudin (2016, 2017). Reader may refer to Solekhudin and Ang (2013) for the detail of the method.

Using the LTDRM, numerical values of u^* may be obtained. To obtain values of u, an inverse of Laplace transform is needed. In this study, a numerical invers of Laplace transform is used. The numerical inverse of Laplace transform used is the Stehfest formula given by

$$u(x,y,t) \approx \frac{\ln 2}{t} \sum_{n=1}^{2P} \mu_n u^*(x,y,s_n), \tag{18}$$

where,

$$s_n = n\frac{\ln 2}{t}, \tag{19}$$

and

$$\mu_n = \sum_{k=[(n+1)/2]}^{\min(n,P)} \frac{k^P (2k)!}{(P-k)!k!(k-1)!(n-k)!(2k-n)!}. \tag{20}$$

Here, P is a positive integer.

3 RESULT AND DISCUSSION

In this section, some of results obtained from the application of the LTDRM described in the preceding section for solving the problem are presented. To apply the method, we set $N = 100$ and $M = 100$. To apply Stehfest formula, the positive number P is chosen to be 3. These value of M, N, and P are chosen such that absolute errors of the numerical solutions are less than 0.02. In addition, this value of P has been reported for a good accuracy and computational efficiency (Lobo, 2008). The numerical results obtained are then compared with the corresponding analytic solutions. The analytic solution of the problem is

$$u(x,y,t) = 10\sin(\pi x)\cos(\pi y)e^{(-2\pi^2 t)}. \tag{21}$$

Some of the results are presented in Tables 1–3 and Figure 1–2.

Tables 1–2 show numerical and corresponding analytical solutions, as well as absolute errors, at selected points, at $t = 0.1$, $t = 0.2$, and $t = 0.3$. Specifically, Table 1 shows results at five different points at $x = 0.1$. Values of u at five different points at $x = 0.5$ are shown in Table 2. At glance, the absolute errors of the numerical solutions are about less than 0.05. At any values of x, errors of numerical solutions decrease as y increases, and reach 0 at $y = 0.5$. For $y > 5$, errors increase as y increase. It seems that errors are symmetrical about line $y = 0.5$.

Table 1. The values of $u(0.1,y,t)$ at selected values of y and t.

	$t = 0.1$			$t = 0.2$			$t = 0.3$		
Point	Num.	Anal.	Error	Num.	Anal.	Error	Num.	Anal.	Error
(0.1, 0.10)	0.4166	0.4082	0.0084	0.0737	0.0567	0.0170	0.0113	0.0079	0.0034
(0.1, 0.25)	0.3096	0.3035	0.0061	0.0547	0.0422	0.0125	0.0084	0.0059	0.0025
(0.1, 0.50)	0	0	0	0	0	0	0	0	0
(0.1, 0.75)	–0.3096	–0.3035	0.0061	–0.0547	–0.0422	0.0125	–0.0084	–0.0059	0.0025
(0.1, 0.90)	–0.4166	–0.4082	0.0084	–0.0737	–0.0567	0.0170	–0.0113	–0.0079	0.0034

Table 2. The values of $u(0.5, y,t)$ at selected values of y and t.

	$t = 0.1$			$t = 0.2$			$t = 0.3$		
Point	Num.	Anal.	Error	Num.	Anal.	Error	Num.	Anal.	Error
(0.5, 0.10)	1.3481	1.3211	0.0270	0.2383	0.1835	0.0548	0.0367	0.0255	0.0106
(0.5, 0.25)	1.0023	0.9823	0.0200	0.1772	0.1364	0.0408	0.0273	0.0190	0.0083
(0.5, 0.50)	0	0	0	0	0	0	0	0	0
(0.5, 0.75)	–1.0023	–0.9823	0.0200	–0.1772	–0.1364	0.0408	–0.0273	–0.0190	0.0083
(0.5, 0.90)	–1.3481	–1.3211	0.0270	–0.2383	–0.1835	0.0548	–0.0367	–0.0255	0.0106

Table 3. Variation of u at some points as t increases.

	Points					
t	(0.1, 0.1)	(0.1, 0.25)	(0.1, 0.5)	(0.3, 0.1)	(0.3, 0.25)	(0.3, 0.5)
0.1	0.4166	0.3096	0	1.0907	0.8108	0
0.2	0.0737	0.0547	0	0.1928	0.1434	0
0.3	0.0113	0.0084	0	0.0297	0.0221	0
∞	0	0	0	0	0	0

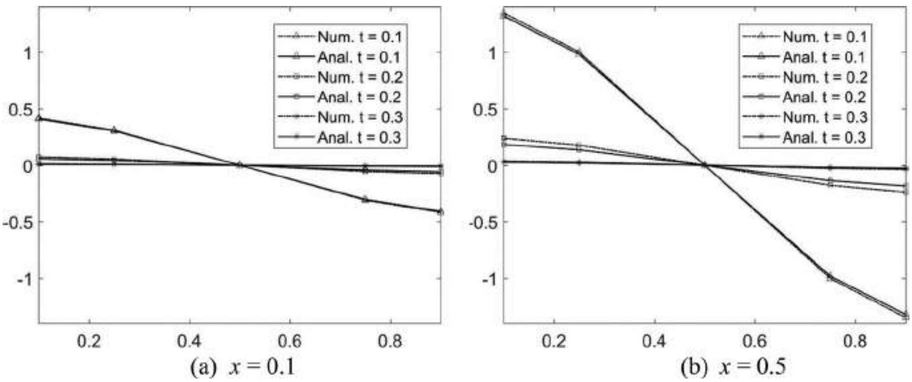

Figure 1. Numerical and analytical solutions of u at selected points and t.

It can be seen, for any value of selected values of y, numerical results in Table 1 give smaller errors than those in Table 2. This indicate that results at $x = 0.1$ may be better in terms of accuracy. From Table 1 and 2, solutions at $t = 3$ are more accurate than those at different values of t. Errors of the numerical solutions at $t = 0.2$ are about 5 times of errors of the

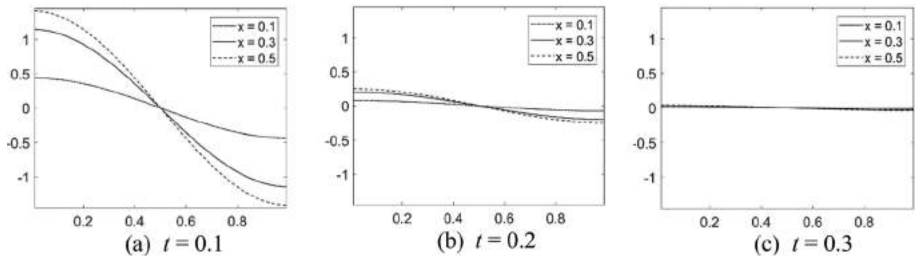

Figure 2. Graphs of u at selected values of x at $t = 0.1$, $t = 0.2$, and $t = 0.3$ along y-axis.

solutions at $t = 0.3$. At $t = 0.1$, errors of the numerical solutions are about 2.5 times of those at $t = 0.3$.

The numerical and corresponding solutions in Tables 1–2 are plotted in Figure 1. Figure 1(a) shows plot of analytical and corresponding numerical solutions at selected points for $x = 0.1$. Plot of analytical and corresponding numerical solutions at selected points for $x = 0.5$ is shown in Figure 1(b). From Figure 1, numerical solutions and the corresponding analytical solutions are in good agreement. As discussed before, absolute errors are about less than 0.05. Since the numerical solutions are in good agreement with the corresponding analytic solutions, we may observe the numerical solutions to determine effect of conduction time to temperature. To observe effect of conduction time to temperature, variations of u at some points as t increases is presented, as can be seen in Table 3.

Table 3 shows variations of u at six different points as t increases. Values of u decrease significantly from $t = 0.1$ to $t = 0.2$. The decrease in u gets much lower from $t = 0.2$ to $t = 0.3$. It can be seen that values of u at $t = 0.3$ are about 0.025 times than those at $t = 0.1$. As can be seen these values of u are less than 0.03. In other words, the distance between u and 0 is less than 0.03. These results indicate that values of u almost reach their convergence value at $t = 0.3$. Percentages of the decreases in u from a time level to another time level are about the same. From $t = 0.1$ to $t = 0.2$, the percentages of the decreases are about 82%. The percentages of the decreases in u are about 84% from $t = 2$ to $t = 3$. These results imply that at any locations the percentage of decrease may be about the same, except at $y = 0.5$. At $y = 0.5$, the value of u is 0.

Figure 2 shows graphs of u at $x = 0.1$, $x = 0.2$, and $x = 0.3$, at three different time levels. Specifically, Figure 2(a) shows graphs of u at $t = 0.1$. Graphs of u at $t = 0.2$ are shown in Figure 2(b). At $t = 0.3$, graphs of u are shown in Figure 2(c). It can be seen that highest value of u occurs at point (0.5, 0), and the lowest value of u is at point (0.5, 1). At $t = 0.1$, the graphs show that values of u vary greatly, especially at x = 0.5 as shown in Figure 2(a). The variation in the values of u decreases significantly at $t = 0.2$. There are almost no variation in the values of u at $t = 0.3$. These results indicate that the greatest variation in temperature occurs at the beginning of heat conduction process. The temperature almost reaches its convergent values, which is 0, at $t = 0.3$.

4 CONCLUDING REMARKS

A problem involving time-dependent heat conduction has been solved numerically by applying the Laplace transform to the boundary integral equation and the boundary conditions, and a dual reciprocity boundary element method to solve the resulting boundary integral equation. Solutions obtained are then inverted numerically using Stehfest formula to obtain the time-dependent values of temperature throughout an isotropic thin plate.

The results indicate that numerical solutions obtained using the LTDRM are in good agreement with the corresponding analytical solutions. The results illustrate that highest variation in temperature over the plate occurs at the beginning of heat conduction. Temperatures over the thin plate almost reach their convergence values at $t = 0.3$.

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Learning to innovate; the role of imitation on the innovation adoption process within innovation networks: Evidence from a developing country

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ABSTRACT: Innovating firms are faced with myriad challenges within their innovation network. The prevailing challenges rests on improving prediction mechanisms that hopefully will assure cost to benefit parity as well as improve on existing competitive advantages. We present an approach which looked at how firms learn to innovate within their innovation networks. We postulate that innovation is generated from a source; typically an academic or research institution, and has initial adopters based on identified direct investors. The adoption behaviour of early and later adopters we argue helps determine the adoption decision of other firms within the innovation network through their imitation linked adoption of the diffused innovation. Thus, a mathematical analysis was conducted and subsequently tested with data from an emerging economy in sub-Saharan West Africa. The results were presented with economic, firm sustainability and policy implications drawn. Our approach is promising, by virtue of its ability to closely determine realistic innovation adoption predictions within an innovation network.

1 INTRODUCTION

Economic growth and competitiveness are strongly dependent on regular innovation influx. As traditional industry-driven economies evolve into knowledge economies, the dependency on innovation as a major driver to sustain growth has become significantly important to policy developers, as they seek for efficient and effective tools to create, measure, diffuse and absorb innovation (Carayannis, Goletsis, & Grigoroudis, 2018).

Collaborations between industry and academia are reviewed as processes that incorporate multifaceted constructs that transcend organisational cultural boundaries, influenced by each partner's internal goals, motives and routines. Obviously, in such interactions, decision-making will be complex and strongly-affected by individual and organisational factors. Rajalo and Vadi (2017), explain that such industry-university collaborations tend to have three major attributes: such partnerships involve individuals with diverse professional backgrounds, are individually-centred and in most cases, not every individual in the entities involved is always part of the interactive partnership that develops and evolves. Based on this argument, we also posit that not all departments within organisations may be involved in such partnerships; at best the partnerships become restricted to the research, product development and marketing (information dissemination) arms of the partnering entities.

The strength of collaboration links between industry and university are critical in accelerating the pace of innovation generation and how this influences value chains and innovation adoption. Fischer, Schaeffer, and Vonortas (2018), studying the coevolution of universities in innovation partnerships, concluded that universities in modern times have become central agents in the innovation system and ensuing technological upgrades. Invariably, this leads to the expectation that academia is strategically positioned to influence innovation development, diffusion and evolution within an economic system.

Applying network theories, K. Chen, Zhang, Zhu, and Mu (2017); conducted an empirical study that showed the impact of inter-organisation collaborations on both research institutes and industries. They concluded that the performance of universities/research institutes was greatly affected by their "*positions in*" and "*strengths of collaboration*" networks that they develop with industry. They also found that the structure of the network influenced the impact that each entity had on the other. Another study, sought to explore how university-industry collaborations affected new product development, as well as the success of such products of innovation. The study observed that collaborations had an effect on the development of new products only when there was the conscious effort and ability, on the part of industry, to absorb the resulting innovation (Najafi-Tavani, Najafi-Tavani, Naudé, Oghazi, & Zeynaloo, 2018).

Thus university-industry collaborations become useful only when captains of industry evolve a preference and tolerance for external, knowledge-infused innovations. Another study also concluded that innovation diffusion and absorption, was driven by social contagion, or imitation. This was applicable so long as organisational leaders did not act as detractors of innovation and were willing participants in the absorption of diffused innovation within their collaborative networks (Borracci & Giorgi, 2018). Research advocates for authors to consider the attributes of innovation and its early evaluation, as a means to improving the translation of knowledge-linked innovation, to aid its eventual integration and industry buy-in (Cadarette et al., 2017).

Several research tools and paradigms have been used to study the impact of diffusion and imitative behaviours on the adoption of university-linked innovation. A recent study of Small and Medium Enterprises (SMEs), adopted a social network approach to study the SMEs' awareness of benefits available to them for being in innovation networks. The study observed that SMEs in innovation networks benefited from different actor-determined activities within the network, the focus of which was mostly technical, with adoption of innovation being contingent on competitors' rate of innovation adoption (Ioanid, Deselnicu, & Militaru, 2018).

Liang and Liu (2018), caution that the structure and composition of networks are critical in determining whether university—industry partnerships are co-beneficial, especially when governments are involved. Their study further shows that structural efficiency of networks in diffusing information is critical to the performance of innovation. Another study alludes to the importance of socio-economic characteristics of environments, which develops and diffuses innovation on the resultant impact on enterprise performance within and amongst network (Hossain, 2018).

Literature on the behavioural patterns of individual enterprises in innovation networks suggests that adoption and diffusion of research-linked innovations depend on communication and imitation among potential adopters (Makkonen, Johnston, & Javalgi, 2016). Using an epidemic diffusion model, Rode and Weber (2016), showed that imitation was a critical factor in the innovation adoption behaviours of German firms when technical innovation was involved, with localisation within the network being significantly important. Policy developers challenged with identifying the best fit of industry to university innovation collaborations that maximises benefits resort to interventions likely to yield more benefits, whilst minimizing cost. The logic being that imitation weakens the incentive for enterprises to innovate.

The aim then, is to eventually reduce cost of adoption whilst increasing the number of evolving innovation-linked partnerships in the network. This becomes more feasible when policy-makers introduce diversity in the innovation networks involving research and development partners (Cerqueti, Quaranta, & Ventura, 2016). Competitor imitation, therefore, provides the required incentive for firms to keep dipping into the innovation pool to ensure benefit maximisation. The structural integrity of industrial networks ensures that competitors are basically aware of innovation activities of each other, and this drives the formation, maintenance and sustenance of innovation partnerships with diverse research and innovation developing institutions; aka universities.

It appears that some critical factors influence innovation diffusion and eventual adoption in University-Industry networks. One main factor is the structure of the network of enterprise networks, as it determines efficiency of information flow within the network. Another factor is that imitation in the presence of diverse sources of innovation among competitors is heightened, reduces cost of adoption and eventually yields evolved innovations. Again, adoption is critically dependent on the individuals involved in the industry-university partnerships.

In this paper we first present summary literature review of studies that have adopted network analysis to identify individual influence on the network; based on this, we submit our proposed approach through a detailed methodology section. We then subject our proposed approach to empirical data from a developing country and report the results. Moreover, we provide a discursive analytics of the results and policy implications and finally conclude the paper with possible future directions.

2 LITERATURE REVIEW

2.1 *Individuals and spaces*

There is an ongoing debate that is critically assessing the conduciveness of *structural holes* (Burt, 2000) and or *network closure* (Coleman, 2000) to the role of innovations in generating social capital. Burt's argument focuses on the structural configuration of the network, whilst Coleman's was built on the quality of relationships between actors within the network and how these impact on innovation generation and diffusion. Some researchers have advised that both concepts should be considered as complementing of each other. The argument is that in the presence of strong ties, weak network architectures leverage the strength of strong ties in the creation of innovation. Thus by implication, innovation networks with weak architectures are significantly valueless without strong connections between nodes. On the contrary, strongly-connected innovation networks may generate value, however this is also dependent on the type of innovation network structure. The evidence then, suggests that open innovation will not work if closed innovation principles are pushed back (Rost, 2011).

The early 1990s saw an increased enriching of the dichotomy between vertical integration and market exchanges, through the identification of the existence of networks as a third form of organisations (Ceci & Iubatti, 2012). This dichotomisation was seen in works explaining industrial districts (Becattini, Cascini, & Nikulin, 2015; Giacomo, 1991) as facilitating a broader and faster diffusion of information in relation to innovating the industrial space.

The works of Inkpen and Tsang (2007), Burt and Celotto (1992), and Burt (2000) showed the impact of network-structure, individual-position within the network on innovation yields. Thus strong ties indicate a mutual alignment that facilitates unidirectional flow of information between actors within the network. Ceci and Iubatti (2012), reiterate that the multi-dimensional links that characterise innovation networks contribute beyond the social and economic development of the network, as they facilitate information-sharing, establishment of new relations, and, by extension, sub-networks within the main network. The researchers conclude that personal relationships between actors in a network help to establish trust, foster knowledge exchange and invariably network development.

Relationships in innovation partnerships are between professionals within the innovation space. Intensity, frequency and strength of interactions are, therefore, contingent on indicators or profession-linked trust and reputation. This was aptly captured by Granovetter (1985) when he argued that preference of interaction is influenced by individual reputations within the network.

The condition for interaction between actors in a network has always been contingent on proximity (closeness, distance) and accessibility (centrality) and similarities (clusters). The argument is that, all things being equal, proximity is a catalyst for establishing relationships between nodes within a network. This is due to the fact that the reciprocal closeness of nodes within the network space signals commonalities and mutually-benefiting bonds (Lissoni, 2001). In innovation-linked business spaces, the investment of firms in innovation generation is strongly contingent on the individual characteristics of knowledge generators, competition innovation adoption behavioural patterns, as well as the proximity of firms to both competitors and innovation partners.

2.2 *Network analysis*

Innovation research involving network principles adopt specific indicators to analysis measures such as cohesiveness, centralities and prestige, communities and structural equivalence. These help them to highlight the research phenomena under review within the network sphere.

Cohesion measures of the network, are considered by innovation researchers as an index of the systematic connectedness of any innovation interactive space. Some indicators of analysis under this general component are*, reciprocity, symmetry, distance, eccentricity, diameter, connectedness, reachability, density,* etc. This research shall use indicators such as density, clustering coefficients and average shortest distance in its analysis of the innovation-linked interactions within the partnership network.

Density: considered as the number of connections divided by the number of possible connections. A completely linked network has a density of 1. It is calculated by first determining the potential connections (pc) a network can have, expressed as

$$pc = \frac{n*(n-1)}{2} \tag{1}$$

Subsequently the density is deduced as: *actual connections/potential connection*

Average distance: The average or mean distance in a network is the average length of all shortest paths between all pairs of connected actors in the corresponding network. Since our research will adopt an undirected connection between actors, the formula we will use in calculating the average distance within our innovation network adopts a model presented by Barnes, Kalberg, Pan, and Leung (2016) and presented as

$$\bar{d} = \frac{\sum_{u \neq v}\left\{ d(u,v), \forall u,v \in V \right\}}{n \cdot (n-1)} \tag{2}$$

where:

$d =$ distance between two actors

u, $v =$ actors with a connection within a given network

$n =$ number of actors within a network within which u, v are actors

Clustering Coefficient: reflects the degree to which the nodes tend to cluster together and characterises the transitivity of interactions within the innovation space network. Specifically, the clustering coefficient of a node quantifies how close the node and its neighbours are to being a complete subgraph (clique) (Barnes et al., 2016). In this paper it is calculated as:

$$c_i = \frac{2\left|\left\{ e_{jk} : v_k \in N_i, e_{jk} \in E \right\}\right.}{k_i(k_i - 1)} \tag{3}$$

Let k_i be the number of vertices, $|N_i$, in the neighbourhood, N_i, of a node i, and E is the network

The network average clustering was calculated using the approach suggested by Watts and Strogatz (1998) as

$$\bar{C} = \frac{1}{n}\sum_{i=1}^{n} C_i \tag{4}$$

Centralities and Prestige analysis of networks helps to identify the influence factor of each actor within a system. The conceptualisation and applications of centrality and prestige indices in relation to network analyses are well covered in works by Knoke and Burt (1983), Knoke and Burt (1983) and Wasserman and Faust (1994); which we shall not elaborate in this paper. This paper engages centralities indices for the assessment of actor importance within the partnership network.

One of the indices of influence used was the *degree centrality* (*DC*) as it helps quantify the number of relations an actor has within the system, it signifies how active the actor is in relation to other actors. The *group degree centrality (GDC)* was calculated using the Freeman formula (Borgatti, 2005; Freeman, 1977, 1978; Opsahl, Agneessens, & Skvoretz, 2010; Opsahl, Vernet, Alnuaimi, & George, 2017).

$$GDC = \frac{\sum(\max DC' - DC')}{(N-1)\cdot(N-2)/(2\cdot N-1)} \tag{5}$$

where N is the number of actors within the network and DC' is the normalised degree centrality.

Another index we considered in our research was that of eigenvector centrality (EVC). The eigenvector is a measure of the relative influence of an actor in a network. It factors in the relative influence of the actors that an actor is connected to, thus a high index indicates that an actor is connected to similarly important actors (Cellerino & Sanguanini, 2018; Gould, Kenett, & Panterov, 2018). To calculate it, we assume that for a given graph $A = (V, E)$ with $|V|$ vertices, let $A = (h_{v,r})$ be its adjacency matrix such that $h_{v,t} = 1$ if v is linked to r; and 0 if otherwise. Thus the eigenvector centrality of actor v was defined as

$$y_v = \frac{1}{\lambda}\sum_{r\in M(v)} y_r = \frac{1}{\lambda}\sum_{r\in A} h_{v,r} y_r \tag{6}$$

Such that $M(v)$ is a set of neighbours of v and λ is a constant. This can subsequently be written as $\mathbf{A}\boldsymbol{x} = \lambda\boldsymbol{x}$.

Further, we analysed the network based on Closeness Centrality (CC) of actors. This index helps showcase how close each node is to all other nodes in the network. Thus a node is considered more central if it interacts with more actors and serves as a signal of its ability to access information through the grapevine of the network (Barnes et al., 2016). Given a node u in a network E with v connections of path lengths d, we calculate closeness centrality of u as

$$CC_u = \frac{1}{\sum_{v\in E} d(u,v)} \tag{7}$$

We can adopt the Freeman formula to calculate the group closeness centrality as

$$GCC = \frac{\sum(maxCC' - CC')}{(N-1)\cdot(N-2)/(2\cdot N-1)} \tag{8}$$

Given that information does flow through paths within a network, the information centrality of actors allows for the estimation of their influence on information flow, as well the information they transmit through their connections. In innovation networks, identifying the central people in information flow is essential to understanding how people communicate and coordinate, as well as who controls the information flow in the network (Amrit & Maat, 2013). Examples of works that show how information centrality is an important index can be found in (Knoben, Oerlemans, Krijkamp, & Provan, 2018; Rossi, Blake, Timmermann, Tonks, & Wermers, 2018; Sanchez-Cartas & Leon, 2018).

The centrality value of a node's information is an average of the information of all paths from that node. Since information is the inverse of the length of the path (reciprocal of the variance, according to the theory of statistical estimation), this measure is related to proximity. Then, the information in a path is the inverse of the length of the path. If there are two, or more connections between a pair of nodes containing some of the same incident nodes, the information is calculated using a matrix containing the number of incident nodes that share the connections and vice versa. The centrality of information for a node is given by.

$$\overline{IFC_i} = \overline{I_i} = \frac{n}{\sum_{j=1}^{n}\left(\frac{1}{I_{ij}}\right)} \tag{9}$$

where n is the number of nodes and I_{ij} the centrality of a path from node i to j.

Alternatively, it can be calculated using the symmetrized socio-matrix of $N \times N$ (e.g. A) such that.

$$A_i i = 1 + d_i$$

Conditionally, $A_i j = 1$ if $(i, j) = 0$. Then, $A_i j = w_{ij}$ if $(i, j) = w_{ij}$. Next compute the inverse matrix of A, for instance D, using LU decomposition approach (Bunch & Hopcroft, 1974; Golub & Van Loan, 1996). Given that Matrix A is diagonally strong and invertible, it is possible to compute D (Barnes et al., 2016). This allows for the information centrality of a node to be computed by

$$IFC_i = I_i = \frac{IC_i - 1}{D_{ii} + \frac{T - 2R}{N}} \tag{10}$$

where T is the trace of matrix D (the sum of diagonal elements) and R is the sum of the elements of any row (since all rows of D have the same sum). Note that in this case, information centrality has a minimum value, but no maximum.

3 RESEARCH DESIGN AND METHODOLOGY

The research builds on empirically testing a numerically-determined argument hinged on innovation diffusion conditions and how this eventually affects innovation adoption within university-industry partnership networks. Thus, we start by developing the numerical argument, and then the empirical testing of this argument.

3.1 *Modelling arguments*

3.1.1 *Preamble*

The preamble to our numerically deduced argument for innovation adoption is encapsulated in Figure 1, in which universities engage in research aimed at resolving and addressing observed real-world conditions. This results in the creation of knowledge and technical innovations, as through diffusion mechanisms, captains of industry become aware of new knowledge and patents (technical innovation). The economic viability of the new innovation, the presence of *innovators*, and *early adopters* of said innovation and prior adoption history; influence current adoption decision-making within industries. Adopted innovation is subjected to market conditions, which determine its continued adoption or rejection. It is important to note that not all innovation generated is adopted and not every industry that becomes aware of innovation, given the influencing factors, decides to adopt said innovation. Knowing this, we can start our numerical modelling of innovation adoption probabilities.

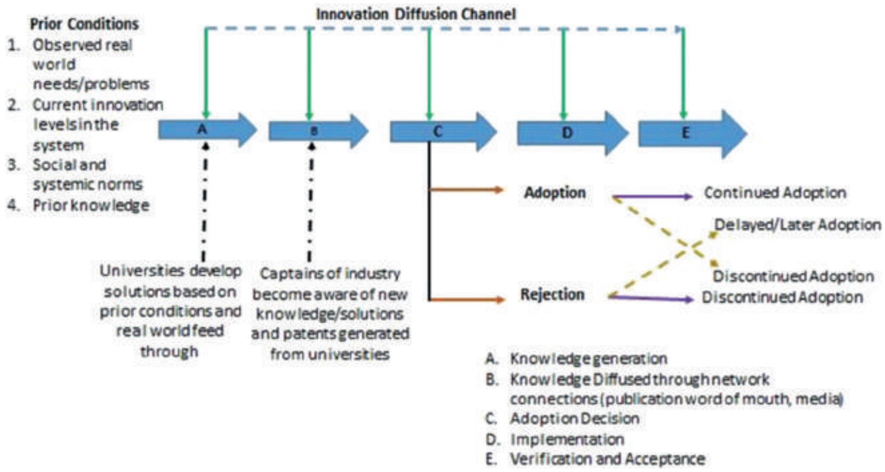

Figure 1. Modified Rogers (2010) innovation diffusion model.

3.2 *Adoption probabilities of diffused innovation in university-industry partnership networks*

Our modelling argument is based on the assumption that, a company (C_i) is a member of an industry network $C(i, j)$, that can structurally be complex and allows diversity of memberships, as well as freedom of connection. Moreover, there is a knowledge generation institution R_i in a knowledge network $R(i, j)$, whose research activities produce technical (l) and knowledge (w) innovations which diffuse to the industrial network of $C(i, j)$ when there is at least one connection between two nodes of C and R. Knowledge innovations are basically research publications, whereas technical innovations tend to be linked to patents.

Inferentially, the diffusion of innovation probability from research networks to industrial networks when there is a connection can be estimated, using the maximum likelihood approach in addition to the theory of epidemiology spread (Anita & Capasso, 2017; Bertotti, Brunner, & Modanese, 2016; Kenrad & Masters, 2019; Mahajan & Peterson, 1985) and its adaptation to diffusion principles. As proposed by Bass (1969), the spread of innovation is a differential equation of the form

$$\frac{dN(t)}{dt} = g(t)(m - N(t)) \tag{11}$$

where

$N(t)$ = the cumulative number of innovation adopters in a system at time t as a signal of diffused innovation

m = maximal limit of potential adopters within the system after which adoption no longer yields cost-benefit parity.

$g(t)$ = the rate of diffusion of innovation within that system and our innovation coefficient.

According to Kijek and Kijek (2018); **(1)** satisfies the condition that the rate of innovation diffusion is a function of potential adopters who could, but have not adopted innovation and the diffusion rate at time of interest. In the same vein, the likelihood that such individuals will adopt innovation over a marginal time frame is reflected in $g(t)$, so long as there is a connection between C_i and R_i. They further argue that the value of $g(t)$ depends on the characteristics and types of innovation, strength of diffusion channels, time and structure of the network within which the innovation is being diffused.

Summing the argument of Kijek and Kijek (2018) and referencing the Bass diffusion model in relation to some influencing conditions it is safe to consider the following:

External: $(g(t) = p)$,
Internal: $(g(t) = qN(t))$ and
Mixed: $(g(t) = p + \frac{q}{m}N(t))$

In this model, we consider ***p*** and ***q/m*** as the innovation and imitation coefficients. The innovation parameter relates to external influences, such as advertising and the imitation coefficient corresponds to internal effects like word-of-mouth. The subsequent derivatives of external, internal and mixed influences on diffusion of innovation in an innovation network based on **(1)** is well known. However, given that in industry-linked innovation networks, awareness of competitor space and actions is a critical factor to the lifespan of industrial actors, a new model for estimating the internal influence conditions of adoption is being proposed to account for imitation of competitor adoption behaviours. The Mansfeld (1961) model allows for factoring in the influence of imitation from and by competitors to influence the internal conditions of innovation adoption. Imitation is a reflection of the interactions between prior adopters and current potential adoptees and can be expressed as.

$$\frac{dN(t)}{dt} = qN(t)(m - N(t)) \tag{12}$$

where;
$N(t)$ = cumulative number of potential adopters at time t
m = maximal adoption ceiling
q = coefficient of imitation.

Subsequently, a mixed influence model for determining adoption probabilities can be extrapolated given the same parameters as a differential equation of a first order that satisfies.

$$\frac{dN(t)}{dt} = \left(p + \frac{q}{m}N(t)\right)(m - N(t)) \tag{13}$$

This allows for the diffusion model to be restated in the Bass-model with a fractional adoption by the total potential adopters. Thus when the fraction of adopters is assumed to be a coefficient of potentials to the maximal ceiling $F(t) = N(t)/m$ then the Bass-model considering fractional adoption becomes.

$$\frac{dF(t)}{dt} = (p + qF(t))(1 - F(t)) \tag{14}$$

It is well documented that innovation systems are characteristically dynamic, thus adoption ceilings cannot always be considered as constants and must incorporate dynamism. Adopting a model developed by Sharif and Ramanathan (1981; 1982) and reiterated by Kijek and Kijek (2018), to account for the dynamic conditions of adopters, it is necessary to then adopt an exponential model to determine potential numbers. This can be expressed in reference to parameters in **(1)** as.

$$m(t) = m_o e^{g(t)} \qquad \text{where} \qquad m_o = m(0) \tag{15}$$

Thus by solving the conditional dynamics of (5) in relation to (3), the complex dynamic model for determining innovation adopters amongst enterprises in an industrial network can be deduced as.

$$N(t) = m_o e^{g(t)} \left(\frac{\frac{\partial_1 - \partial_2}{2} - \partial_3 \frac{\partial_1 - \partial_2}{2} e^{-\partial_1 t}}{q + q\partial_3 e^{-\partial_1 t}} \right) \tag{16}$$

The satisfying conditions for (6) are $0 < N_0 = N(t=0) \leq m_o = m(t=0)$; where $\partial_1 = \sqrt{(g+p-q)^2 + 4pq}, \partial_2 = g+p-q$ and subsequently $\partial_3 = \left(\frac{\frac{\partial_1-\partial_2}{2} - \frac{qN_0}{m_0}}{\frac{\partial_1-\partial_2}{2} + \frac{qN_0}{m_0}} \right)$

4 EMPIRICAL TEST

4.1 *Data collection method*

We have made some critical deductions based on university industry-linked networks and how these influence adoption rate and its direct impact on technical innovation production and diffusion. To test this we collected data based on a nationally funded research centre in a university in a sub-Saharan African country. We also collected data on the industries that have been cited in institutional documents and publications as:

Having entered into funding of research/students agreement through Memorandum of Understandings

Adopted techniques and products published or patented by the centre

The sampling structure of the data is presented in Table 1 below. The focal period was from 2014 to 2018.

4.1.1 *Network development*

4.1.1.1 *Industry network*

Using our data, we developed an industrial network that focused on commonality of products or market niches between industries, where each enterprise was considered as having a weight based on its contribution to the *total funding portfolio*, to the Centre. Inter-enterprise connectivity was unweighted, thus all links between enterprises were maintained at a weight of 1.

4.2 *Co-author network*

We collected data based on co-author data from a research centre in a sub-Saharan African country and developed a co-author network to establish relationship between authors. Using a K-core analysis we showcase the core levels of research-linked interactions within the research Centre. All lead authors were observed to be in the same core group.

4.3 *Partnership network*

Using data from the two networks, we developed a network symbolising the partnership network of academia-industry. All lead authors in the Research Centre had authored a research with all other lead authors at the centre. The connection weight was determined based on the number of co-authored research, which authors had with each other. The proportional influence of lead authors on the total authored research at the centre was considered as their proportionate influence on knowledge generation in the network. This was used to determine the link strength between authors and enterprises that were funding their research. A similar approach was used to determine the proportionate contribution of enterprises on research activities of the researcher at the Centre.

Table 1. Sampling structure for data collection.

Information source	Methodology	Institutions	Sample size
publication	Co-author classification	Research Centre	Authored researchers in the Centre
patents	University-Industry product analysis	Select SMEs	SME Industry Network
Memorandum of Understandings	University-Industry partnerships		

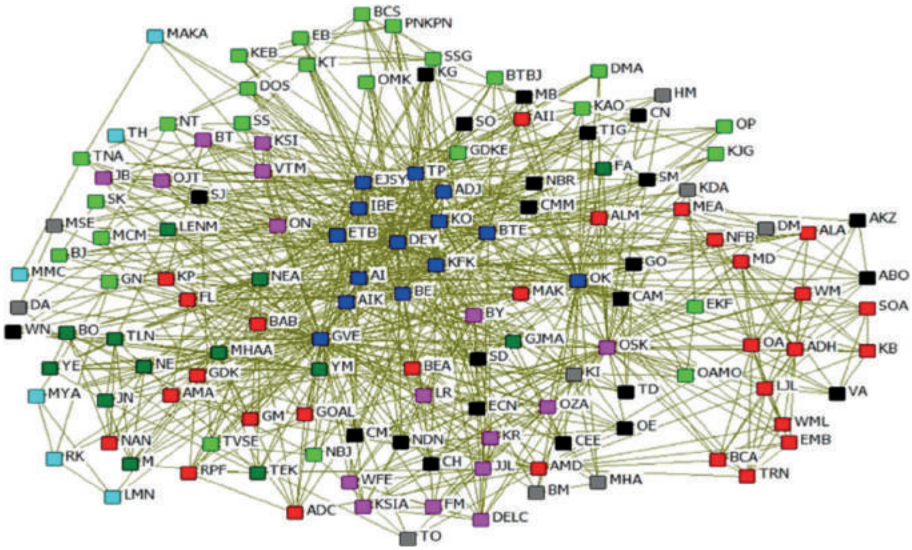

Figure 2. Co-author network of research centre.

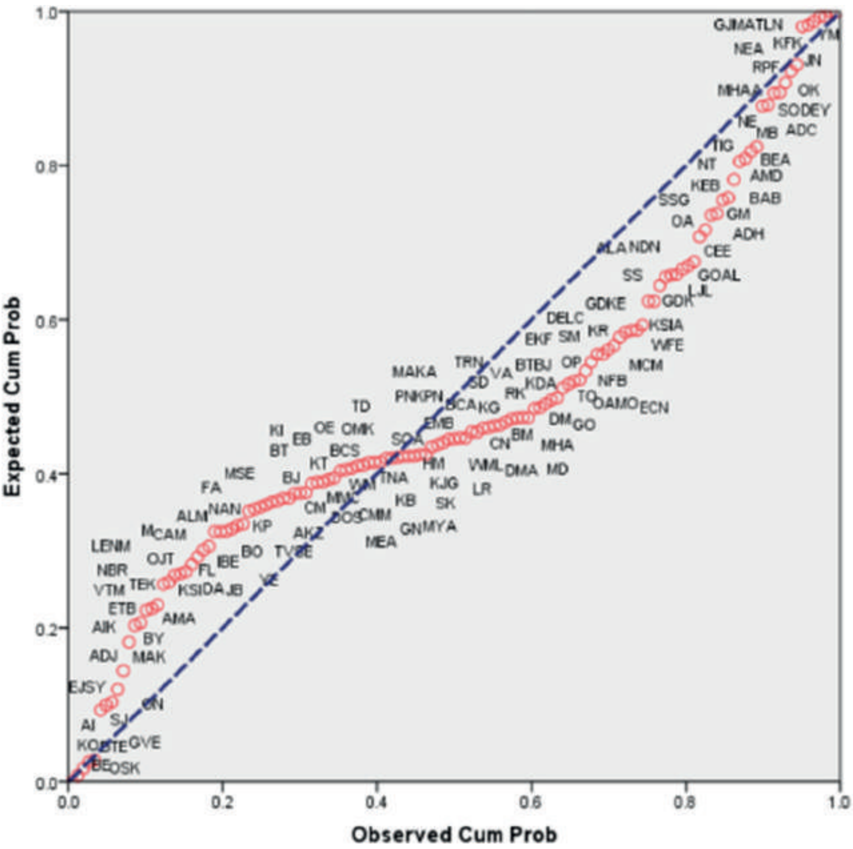

Figure 3. Normal plot of standardised residuals for authors.

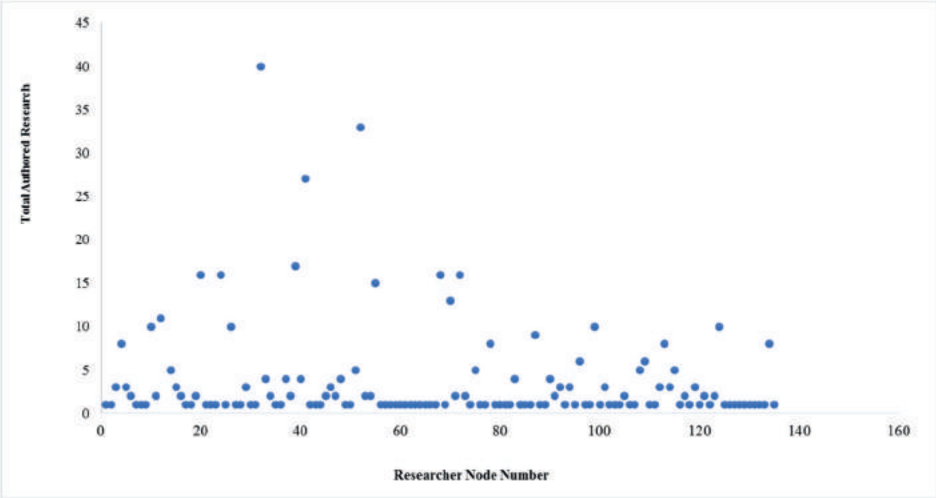

Figure 4. Scatter plot of authored research papers.

Table 2. Researcher influence on authored research.

Node	Total number of connections	Actual number of publications involved in	Years involved					Proportionate contribution to knowledge generation
			2014	2015	2016	2017	2018	
ADJ	47	16	4	6	12	15	10	6
AIK	52	13	1	3	4	2	3	5
AI	43	11	1	3	2	1	4	4
BTE	50	10	0	3	5	0	2	4
BE	95	14	0	2	3	4	4	6
DEY	148	34	8	12	4	6	4	13
EJSY	55	14	2	5	2	2	3	6
ETB	57	10	0	4	3	1	2	4
GVE	189	47	6	7	12	10	12	19
IBE	61	12	1	3	0	4	4	5
KFK	76	15	1	3	2	5	4	6
KO	55	20	2	5	6	3	4	8
OK	137	23	3	4	5	4	7	9
TP	75	15	2	1	5	3	4	6
Total	1140	254	31	61	65	60	67	100

4.4 *Industry portfolio contribution*

We begin by assuming that the funding portfolio of a research centre in a developing country is a set of contributions from diverse sources represented by $T = (T_1, T_2, T_{3,} \quad T_n \mid n\ is\ a\ funding\ source)$. Then each source's proportionate contribution to the set of $T\ portfolio$ can be estimated as

$$\frac{T_i}{\sum T_i}$$

Let *private sector contributions* (s) be a subset of T represented by $T_n = (s_{11}, s_{12}, s_{13}, \quad s_{1n} \mid n\ is\ a\ private\ sector\ enterprise\ contributing\ to\ funding\ source\ T_n\ in\ T)$.

Then each enterprise's proportionate contribution to the sub-funding source can be considered as

$$v_{in} = \frac{s_{in}}{\sum s_{in}}$$

but $\sum s_{in} = T_i$, then,

$$\sum s_{in} = \frac{s_{in}}{v_{in}}$$

which denotes that

$$T_i = \frac{s_{in}}{v_{in}}$$

Table 3. Normalised seights of industrial partners.

Enterprises	USD ($)	Proportionate influence on research through funding	
		Normalised	%
Ent1	11250854	0.678	67.813
Ent2	98460	0.006	0.593
Ent3	151481	0.009	0.913
Ent4	1625270	0.098	9.796
Ent5	373032	0.022	2.248
Ent6	502961	0.030	3.032
Ent7	196630	0.012	1.185
Ent8	735000	0.044	4.430
Ent9	311360	0.019	1.877
Ent10	150000	0.009	0.904
Ent11	267372	0.016	1.612
Ent12	195000	0.012	1.175
Ent13	133686	0.008	0.806
Ent14	600000	0.036	3.616
Industry	**16591106**	**0.541**	**54.144**
Government	**14051691**	**0.459**	**45.856**
Total Portfolio	**30642797**	**1.00**	**100**

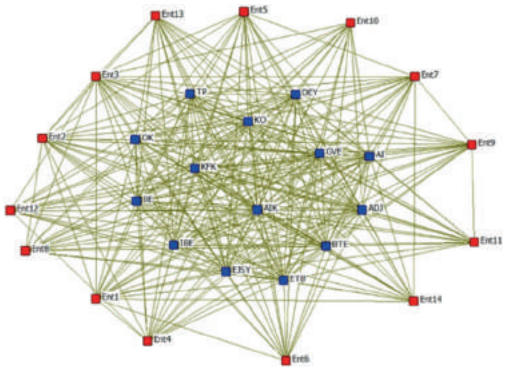

Figure 5. Academia-industry partnership network.

By substitution then, the proportionate contribution of an enterprise (s_{in}) that contributes to the industrial component (T_i) of a Research Centre's total funding portfolio (T) can be written as.

$$\frac{\frac{s_{in}}{v_{in}}}{\sum T_i} = \frac{s_{in}}{v_{in}.\sum T_i} = \frac{s_{in}}{v_{in}.T}$$

Expressing the proportionate contributions as a percentage form helps showcase the impact of each enterprise's contribution to the total funding portfolio of the Research Centre.

Figure 5, shows when enterprises within an industrial space with proportionate influence on research, through funding, are connected to the research centre through its lead authors. Industry is represented by its members (enterprise nodes—red) whilst the Research Centre is represented by its lead authors (blue nodes).

5 RESULTS AND ANALYSIS OF PARTNERSHIP NETWORK

Actor importance in systems are critical in determining their influence on the system and the phenomena to which it relates. Network research focuses on control of actors on networks as a factor of their influence. Several identification criteria has been proposed to determine how critical an actor in a network is, comparative to other actors. The proposed approach, tends to be characteristic-restricted and explains only a specific aspect of the actors' influence. Some of these influence indicators are degree, and centrality coefficients, however, actor influence on a system is subject to multi-factor attributes. Yang and Xie (2016), recommend a relatively comprehensive and effective method of evaluation node importance in social networks, by using the multi-objective decision method. Their idea recommends for, network studies to consider each node as being affected by different indicators that help determine the influence it has on the network, thus the sum coefficient of the individual indicators will serve as the representative coefficient of the nodes likely influence on the network. Thus, multi-attribute analyses of nodes helps to systematically evaluate and develop, as closely as possible, a general character assessment of actors in networks (Malczewski, 2018).

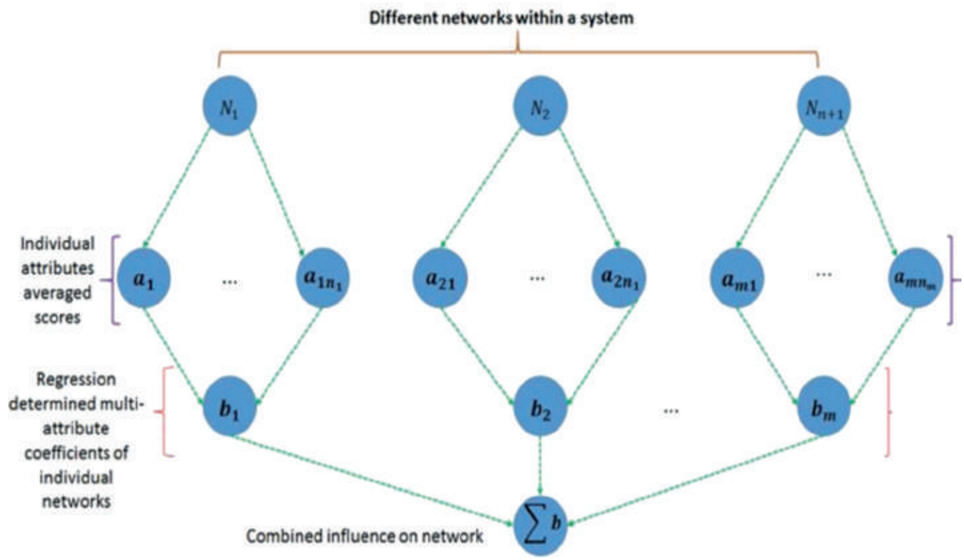

Figure 6. Proposed multi-attribute regression model.

Using this approach, we hypothesised that average coefficients of these indicators help reflect the interactive influence of individual networks in relation to other networks, when they are considered to be interactive in a larger system. Using regression models, we can then extract the coefficients of individuals in a network when they are considered as being involved in sub-systems of a larger system. This hypothesis is presented in Figure 6.

Using our data (Table 6) from our innovation network and proposed regression model, a multi-attribute assessment of institutional networks was used to determine the individual institutional influence in the university-industry partnership networks (Table 4). In developing countries, we can assume that government contribution is enshrined in the work of researchers in national research networks, especially when they are subject to national funding policies. Furthermore, industrial networks reflect national policies and governmental controls that foster economic growth and development within such systems. In this vein, we can consider the partnership networks as a triple helix relationship involving Research Institutions (or Universities), Industry and Government.

Table 4. Implications on innovation generation and adoption (Beta Coefficients).

		Unstandardized coefficients		Standardized coefficients
Condition		B	t-Stat	Beta
Innovation	Co-Author (Generation)	5.811	7.209	0.657
	Industry (Adopters)	3.214	7.656	0.342

a. Dependent variable: Partnership.

Table 5. Analysis of variance.

Network		Sum of squares	df	Mean square	F	Sig.
Partnership	Regression	173538.682	2	86769.341	5710.781	.000[b]
	Residual	75.970	5	15.194		
	Total	173614.652	7			

Table 6. Multi-attribute results of network—averages.

Network	Average degree centrality of network (*DC'*)	Max degree of nodes	Density of the network (*D*)	Average shortest length of network	Average clustering coefficient (*CCC*)	Average eigenvector centrality (*EVC'*)	Average information centrality (*IFC'*)	Closeness centrality
University	0.071	51	1.06593	1.01099	0.991	0.266	0.071	0.851
Industry	0.071	48	0.758242	1.31868	0.676	0.264	0.071	0.763
Partnership	0.036	446	0.753968	1.28307	0.838	0.166	0.036	0.820

Table 7. Results of regression analysis.

					Change statistics					
Network	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
Partnership	0.998[a]	0.999	0.999	3.71712	0.999	5710.781	2	5	0.000	1.219

a. Dependent variable: Partnership; b. Predictors: (Constant), Industry, Co-Author.

5.1 *Multi-attribute analysis of partnership*

Using our proposed multi-attribute regression model, we conducted an analysis of how the partnership influences innovation generation and adoption; using the same attributes used in the simulated condition and results are presented below.

5.2 *Model tests*

We started by arguing about the impact of individuals in networks and how their ability to learn to adopt innovation is linked to the structure and quality of interaction they develop within innovation spaces help determine their innovation adoption decisions. We continued to suggest the numerical conditions of some critical factors that influence innovation adoption. In this section we subject our numerical assumptions to an empirical situation in a developing country. The results are presented in the proceeding sections.

5.3 *Imitation*

Building on the (Mansfeld (1961)) model we deduced the competitor imitation-linked adoption contingency (Figure 7) as being a mix of internal and external forces-linked adoption (Figure 8) to the situation of fractional adoption of innovation (Figure 9).

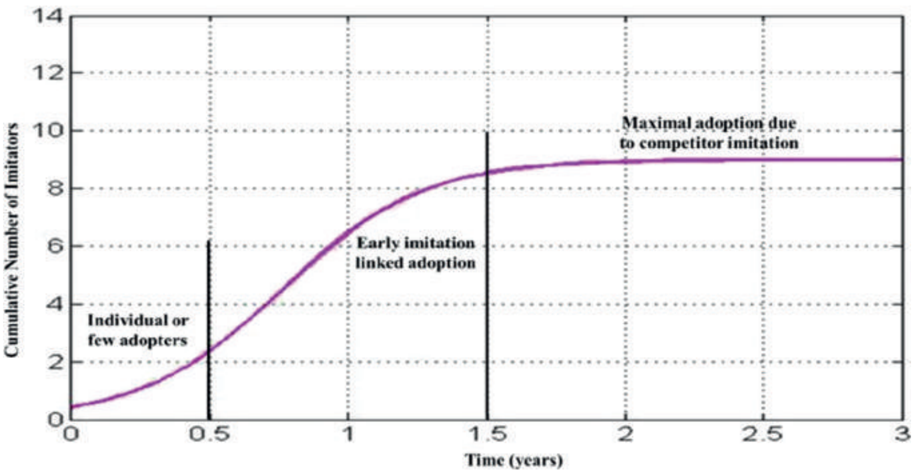

Figure 7. Competitor imitation-linked adoption—internal force.

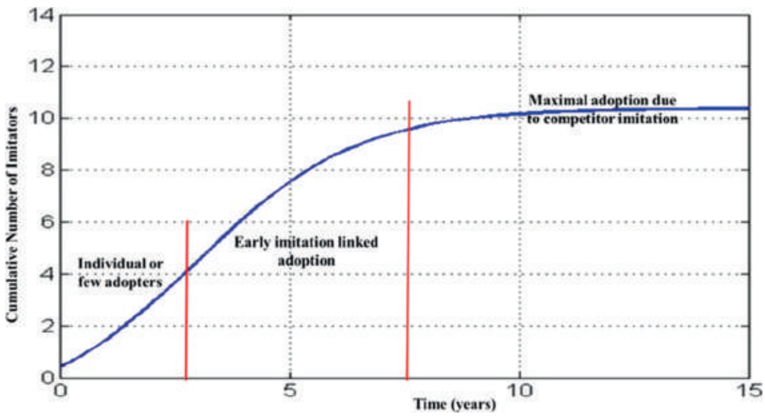

Figure 8. Competitor imitation linked adoption—mixed forces.

In Figure 7, the internal forces of imitation-linked adoption institutes a rapid decay of the adoption process. In the initial phase of adoption, where few enterprises are adopting the innovation diffused from the research centre, firms enjoy low imitation. Competitors observe and cash in on the innovation with increasing imitation-linked adoption such that by the second year of the innovation, the maximal adoption ceiling has been obtained. Firms in the network at this point require reintroduction of diffusion and will thus be seeking for new partnerships, or sources of imitation. This lends credence to our argument that as firms observe their competition imitate their innovation decisions, the drive to retain competitive advantage sets the learning conditions for smooth innovation adoption. This affirms the Dodd (1955) assumptions of imitation-linked adoption of innovation.

In Figure 8, we considered the situation where prior adopters and the source of innovation generation can and does influence the adoption behaviour of other firms within the network. In such cases, as explained by Ceci and Iubatti (2012), personal relations and trust-based interactions between innovation adopters and generators are critical in determining adoption behaviours within innovation networks. From Figure 9, it can be deduced that mixed forces tend to prolong the innovation adoption span, with the maximal ceiling being obtained close

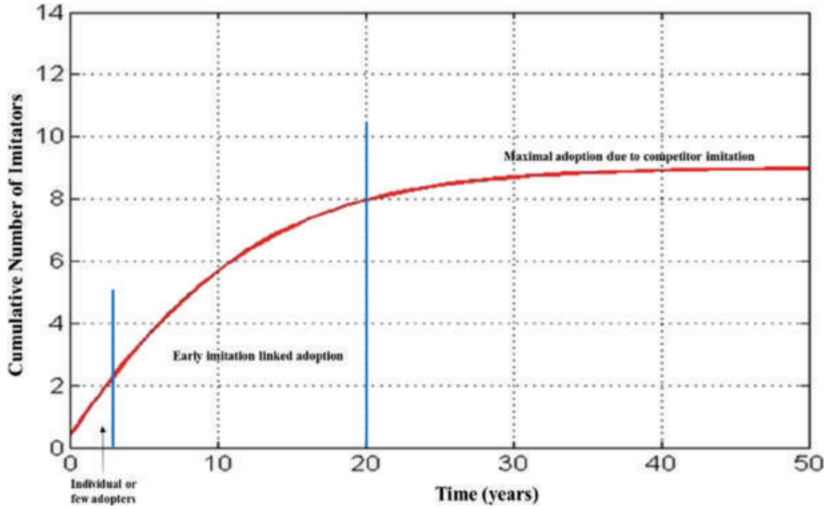

Figure 9. Competitor imitation-linked adoption—fractional adoption.

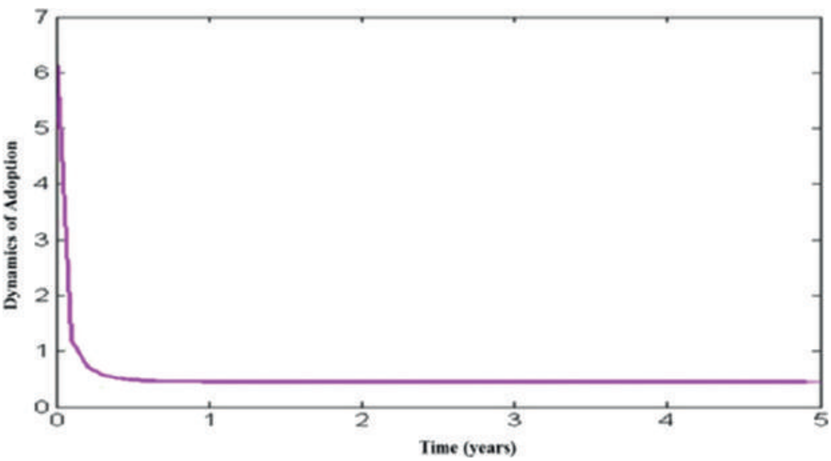

Figure 10. Dynamics of adoption—internal forces determined.

to year 10. Thus firms who have diverse sources and reasons to innovate tend to take longer in innovating. In such cases, prior history, may dictate or explain the impact of competitively imitating firms influence on their innovation pools.

There are situations in which irrespective of the forces at play, structure of interaction, as well as quality of the interaction, only a fractional number of the potential adopters actually adopt diffused innovation at a time. Figure 9 shows that in such situations, the adoption process has a longer life span, even though initial adopters are few in the early years.

5.4 *Dynamics of adoption*

In this section, the arguments of Sharif and Ramanathan (1981; 1982) as reiterated by Kijek and Kijek (2018), were tested. Similar to the imitation conditions, we tested these arguments

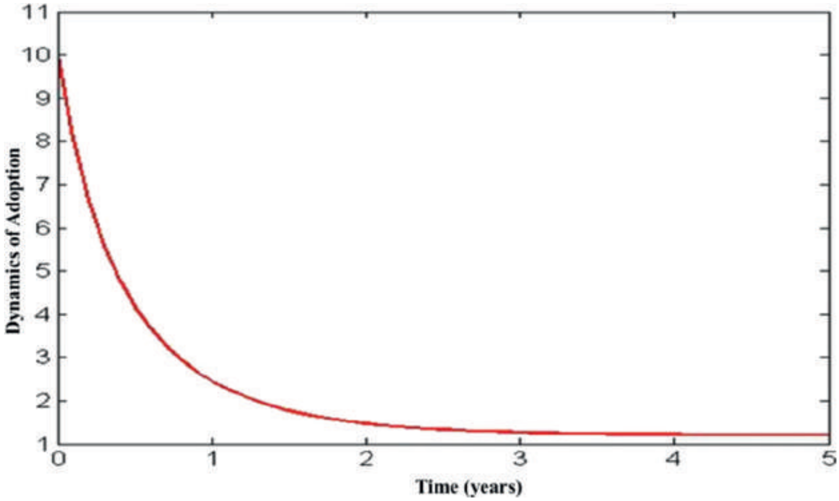

Figure 11. Dynamics of adoption—external forces determined.

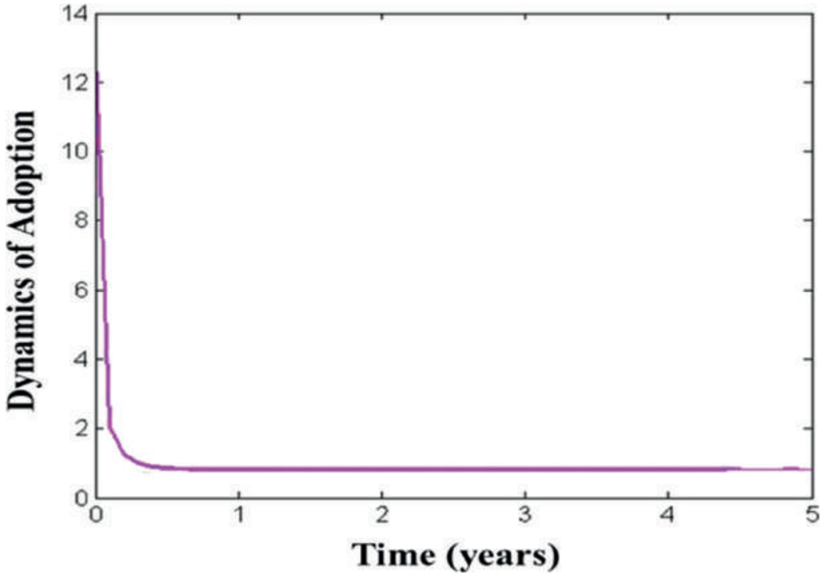

Figure 12. Dynamics of adoption—mixed forces determined.

on three levels, when internal (Figure 10), external (Figure 12) and mixed forces are responsible for dynamically influencing innovation adoption. The assumption is that initially diffused innovation is immediately adopted based on the forces at play.

The results of the dynamic analysis shows that in situations where the internal forces (initial adopters ≥6) and mixed forces (initial adopters ≥12) are at play, there is rapid exponential decay of adoption behaviour of enterprises within the partnership network. When enterprises within the partnership network base their adoption dynamics on their assessment of the source of innovation only, and not on the adoption behaviour of competitors, or both, the decay is slow (Figure 12).

6 DISCUSSION: IMPLICATIONS OF THE RESULTS

According to research, strategic innovation decisions by firms focus on either product, process, or both. Product innovation is more likely to have enforced licensure protection whilst process, even if licenced, is less likely to be enforced (Brouwer & Kleinknecht, 1999). Thus, process-based innovation tends to adopt secrecy as a measure of preventing imitation-linked economic fallouts (J.-Y. Chen & Dimitrov, 2017).

Process innovation is, therefore, susceptible to imitation; firms seeking to prevent this, whilst adopting secrecy, may offload components of the process via a shared licensed approach as suggested by Chen and Dimitrov (2017), since this allows other enterprises within the network to partially imitate the adopters' innovations, whilst he activates patents to enhance the revenue of the innovation, or deter the competitors from imitating his strategic investments. Thus in our network, given the level of competition and the lack of diversity in the innovation source, enterprises that ignore the potential of process imitation reduce their profit potential from their adopted innovation and are likely to lose competitive advantage.

Completive advantage and licensing conditions notwithstanding, the adoption of innovation as a process and its resulting products are strongly-linked to the efficiencies of the adopter's research and development systems. Diffusion by nature moves from higher levels to lower levels. Thus initially, imitation may be beneficial and require support (Collins, 2015), however as observed in the situation where competitor imitation is the only driving force for the adoption of innovation, the process and its benefits are short-lived (Figure 11) and the benefiting ceilings attained faster (Figure 8).

Further, we observed that our results provides evidence to prior research that argues that research and development spill-overs. Have a correlation to competitor-linked innovation imitation (Figure 8), this becomes much more apparent when innovation sources provide the incentive to enhance original innovation adoption (Cappelli, Czarnitzki, & Kraft, 2014). Dynamically, when a fraction of the industrial network adopts innovation from research networks, with their adoption providing spoils for less-endowed firms to imitate, the presence of researchers provides the needed catalyst to sustain the innovation system as observed in Figures 10 and 12. In such situations, sanctioned spills and resulting innovation discussions amongst researchers and competitors, serve as vital sources of knowledge for reseeding the innovation system through its generation source (Bi, Sarpong, Botchie, & Rao-Nicholson, 2017; Sarpong, AbdRazak, Alexander, & Meissner, 2015).

Studies of innovation diffusion tend to model the strategies of adopters as they seek to maximise their benefits, through their invested adoption behaviours. Enterprises in competitive innovation networks review strategies based on their proportionate contributions to the generated innovation (Tsakas, 2017). These reviews tend to include uncertainty of benefits and the reversibility of their adoption choices, which further influence neighbour interaction within competitive innovation networks and how this influences competitor innovation behaviour.

We initially set a preamble by modifying the Rogers model of innovation adoption within and amongst firms, tapping from a common source of innovation. The results indicate that in situations where only inter-firm interactions are responsible for adoption of diffused innovation, the innovation process has a shorter lifespan. The process has a longer span when fractional adoption is taking place. These indicate that imitation within firms tend to cut down on the duration for turning innovation into marketable products. Firms in such situations avoid competitor-observed mistakes, thus shortening the process.

In reviewing the dynamics of innovation adoption, it is clear that when firms build strong relationships with sources of innovation and consider initial adoption only on the quality and structure of their innovation sources, the process decays slowly and that innovation has a longer span within the network.

7 CONCLUSION

Imitation and subsequent dynamics of adoption conditions are critical when firms are considering partnering innovation sources as partners in the innovation space, as these will determine the length of the innovation process for firms. Firms, in developing innovation partnerships may shorten the innovation process if they imitate innovation adopted by competitors in the same space and if they share a common source of innovation. Fractionally-adopted innovation may result in prolonged processes which may not yield desired results. The study then concludes that given a common source, imitation and adoption dynamics are critical in determining the process span of innovation. We admit that we based our analysis on the average results of our partnership network; in future works we plan to apply a similar approach to review the dynamic impact of national policies and how this changes the landscape of innovation sources. Further, the source of innovation may be expanded beyond one source, this will help highlight partnership behaviour characteristics of firms and how these influence the innovation adoption process.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Analysis of the causes of unemployment in DKI Jakarta using panel data regression

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ABSTRACT: DKI Jakarta is the capital city of Indonesia, so that the high unemployment rate in Jakarta must be overcome. Unemployment can cause complex economic and social problems. This study aims to analyze the effect of the number of vacancies, gross regional domestic product, provincial minimum wages, inflation rates, and population growth rates on the number of unemployed people in DKI Jakarta from 2008–2017. The data in this study are secondary data obtained from the Central Statistics Agency (BPS) publications from 2008–2017. The data analysis technique used is the panel data regression method. Based on the results of the analysis obtained, it is shown that the provincial minimum wage variable has a significant effect on the Open Unemployment Rate (OUR) in DKI Jakarta at $\alpha = 0.05$ with an R^2 of 78.18%.

1 INTRODUCTION

DKI Jakarta is the capital of the country and the largest city in Indonesia, with a land area of 661.52 km^2 and a population in 2017 reaching 10,374,235 people. DKI Jakarta is the city with the highest population density in Indonesia, reaching 15,663 people/km^2. DKI Jakarta only has a subdivision in the form of five administrative cities, namely the city of Central Jakarta, the city of East Jakarta, the city of West Jakarta, the city of North Jakarta, and the city of South Jakarta, and one administrative district, Kepulauan Seribu. Economic growth in DKI Jakarta is quite high because it is supported by the trade, services, property, creative industries and finance sectors. This has resulted in a large need for labor in DKI Jakarta. However, a large number of employment opportunities in DKI Jakarta, as well as the imbalance of economic development in DKI Jakarta and other regions, have resulted in many residents coming from outside Jakarta to look for work in Jakarta. This condition makes DKI Jakarta have a potentially high number of unemployed people. According to data from the Central Bureau of Statistics, unemployment in the six regions in Jakarta, namely the Thousand Islands, South Jakarta, East Jakarta, Central Jakarta, West Jakarta, and North Jakarta, always increases from year to year (BPS, 2018).

The results of previous studies indicate that unemployment in a region is influenced by macroeconomic factors in the region. For example, by applying multiple linear regression analysis, Setiawan (2013) concluded that unemployment in the city of Magelang was largely due to inflation and population dependence, and a small portion due to the Gross Regional Domestic Product (GRDP) and city minimum wages. Chen et al. (2017), using time series data regression analysis, found that unemployment in China is largely due to Gross Domestic Product (GDP) growth and population numbers, and a small part is caused by inflation and foreign investment. In addition, they also found that the factors in macroeconomics as causes of unemployment in each region could vary.

Unemployment is a situation where a person does not work, or has been looking for work for approximately four weeks beforehand (Kaufman & Hotchkiss, 1999). The factors that are thought to cause high unemployment rates are economic factors, the number of vacancies, and population factors. Economic factors that affect the high unemployment include the rate of inflation, the rate of GDRP (Gross Regional Domestic Product), and the minimum wage (regional minimum wage). The number of job openings is assumed to influence the number of unemployed because the number of job openings is not comparable to the number of job seekers. Moreover, the number of job openings in Indonesia cannot accommodate all graduates every year. Population factors include the rate of population growth. It is assumed, with increasing population growth, that the number of unemployed is increasing.

Based on the above review, to model the unemployment rate in DKI Jakarta, a combination of unemployment data for each city/administrative district of DKI Jakarta is observed repeatedly every time period so that it becomes a panel data. The advantages of using panel data include providing more information, having considerable variability, controlling the heterogeneity of locations, and reducing collinearity between independent variables. According to Gujarati (2009), there are three models in panel data regression, namely the combined model (Pooled Least Squares), the Fixed Effect Model, and the Random Effect Model. The combined model parameters are estimated using the least squares method (Ordinary Least Squares), the fixed effect model using the Least Squares Dummy Variable (LSDV) method, while the random effect model uses the Generalized Least Squares (GLS) method. The random influence model assumes that the influence of location is a random variable that is inserted into the model as a side form (Judge et al., 1980).

2 METHOD

2.1 *Data*

The data used in this study is secondary data obtained from the Central Statistics Agency (BPS). The data used is panel data, with the independent variable used in this study being the percentage of open unemployment in six districts/cities in DKI Jakarta from 2008–2017. The independent variables used are factors that are thought to influence the unemployment rate in a macro area. The independent variable is the number of vacancies (X_1), the percentage of gross regional domestic product rate (X_2), the provincial minimum wage (X_3), the percentage of inflation rate (X_4), and the population density (X_5).

2.2 *Data analysis method*

The data analysis method used is panel data regression. Panel data regression is different from the usual regression model because panel data regression considers the location and time dimensions in the model. The general form of panel data regression according to Baltagi (2005) is:

$$y_{it} = \beta_{0+}\, x'_{it}\ \ \beta +_{it} \tag{1}$$

where $i = 1, \ldots, N;\ t = 1, \ldots, T$ with i units across locations and t time series units. To estimate the parameters of a panel data regression model, the method to be used depends on assumptions about intercept, slope, and error constants. Judging from the various assumptions and their constituents, the panel data regression model consists of a pooled regression model, a fixed effect model, and a random effect model.

2.2.1 *Combined model*

The combined model in panel data regression does not pay attention to the effect of location and time, or in other words, this model has the same form as linear regression. The form of the combined model equation or Common Effect Model (CEM) is:

$$y_{it} = \beta_{0+}\ \beta X'_{it} + \varepsilon_{it} \tag{2}$$

where the assumption is $\varepsilon_{it} \sim N(0,\sigma^2)$.

Estimating the combined model parameters according to the nature of the data can use one of the following methods: Ordinary Least Squares (OLS), Weighted Least Squares (WLS), Seemingly Uncorrelated Regression (SUR), or Feasible Generalized Least Squares (FGLS).

2.2.2 *Fixed effect model*

In the influence model, there are still different models between locations. The assumption used is that the constants ($\boldsymbol{\beta}_0$) vary between locations, but the slope is constant ($\boldsymbol{\beta}_k$). To explain the difference in intercepts ($\boldsymbol{\beta}_{0i}$) in individual units, dummy variables can be used. The general form of panel data regression models with fixed effects models are as follows:

$$\mathrm{Y_{it}} = \sum\nolimits_{j=1}^{j} \beta_{0j}\mathrm{D_{jt}} + \sum\nolimits_{k=1}^{k} \beta_k \mathrm{X_{kit}} + \varepsilon_{it} \tag{3}$$

with D_{jt} worth 0 or 1. According to Gujarati (2009), the dummy variable will be 1 if $j = i$ and value 0 if $j \neq i$. The assumption in this model is $\varepsilon_{it} \sim N(0,\sigma_\varepsilon^2)$. Estimating the influence model parameters remains adjusted for the nature of the data, can use one of the following methods: OLS, WLS, and SUR).

2.2.3 *Random effect model*

The random influence model is based on the assumption that the constants (β_0) or the influence of location are random variables that are included in the model as a side form (Judge et al., 1980). This random influence model no longer uses dummy variables as in the fixed influence model, but uses systems that are thought to have relationships between locations. The random effect model equation is written as follows:

$$\mathrm{Y_{it}} = \beta_{0i} + \sum\nolimits_{k=1}^{k} \beta_k \mathrm{X_{kit}} + \varepsilon_{it} \tag{4}$$

where β_{0i} is fixed. Assume that β_{0i} is a random variable with mean β_0, so that it has the form:

$$\beta_{0i} = \beta_0 + \mu_i \beta_{0i} = \beta_0 + \mu_i \tag{5}$$

$$\mathrm{Y_{it}} = \beta_0 + \mu_i + \sum\nolimits_{k=1}^{k} \beta_k \mathrm{X_{kit}} + \varepsilon_{it} \tag{6}$$

$$\mathrm{Y_{it}} = \beta_0 + \sum\nolimits_{k=1}^{k} \beta_k \mathrm{X_{kit}} + \mu_i + \varepsilon_{it} \tag{7}$$

where the component is a characteristic of a random observation of a fixed unit of all i. Assume u_i and ε_{it} are mutually independent. Parameters of random influence models are estimated using generalized least squares (Baltagi, 2005).

2.2.4 *Chow test*

The Chow test is a hypothesis testing between the combined model and the fixed influence model. The testing procedure is as follows:

Hypotheses:

H_0: $\beta_{01} = \ldots = \beta_{0N} = 0$ (Combined Model)

H_1: There is at least one $\beta_{0i} \neq 0$ (Fixed Influence Model)

The test statistics used are as follows:

$$\mathrm{F_{hit}} = \frac{(\mathrm{SSE_{CM}} - \mathrm{SSE_{FIM}})/(\mathrm{N}-1)}{\mathrm{SSE_{FIM}}/(\mathrm{NT}-\mathrm{N}-\mathrm{K})} \tag{8}$$

with

SSE_{CM} = Sum square error on the combined model;

SSE_{FIM} = Sum square error in the fixed influence model.

Reject H_0 if $F_{hit} > F_{(N-1,NT-N-K)}$ or if the p-value is smaller than the real level of 5% (Baltagi, 2005).

2.2.5 *Hausman test*

The Hausman test is a hypothesis testing between random influence models and fixed influence models. The testing procedure is as follows:

Hypotheses:

H_0: Correlation (X_{it}, ε_{it}) = 0 (Random Effect Model)

H_1: Correlation (X_{it}, ε_{it}) ≠ 0 (Fixed Effect Model)

The test statistics used are as follows:

$$W = \left(b_{FEM} - b_{REM} \right)' \, [var(b_{FEM} - b_{REM})]^{-1} (b_{FEM} - b_{REM}) \tag{9}$$

with

b_{FEM} = vector predictor of fixed effect model parameters;

b_{REM} = vector estimator of random effect model parameters.

If $W > \chi^2_{\alpha(k)}$ follows a chi-squared distribution with free degrees k, or p-value < α determined, then reject the initial hypothesis so that the chosen model is a fixed effect model.

In selecting the best model with the Hausman test, it is assumed that the cross-section category is greater than the number of independent variables.

2.2.6 *Classic assumption test*

The classic assumption test is a normal test, multicollinearity test, or homoscedasticity test.

2.2.7 *Test parameter significance*

To test the significance of the parameters, a simultaneous test, and a partial test are carried out as follows:

2.2.7.1 *Simultaneous test*

The aim of this test is to test whether independent variables together have an influence on non-independent variables. The F test is formulated as follows:

$$F = \frac{R^2/(N + K - 1)}{(1 - R^2)/(NT - N - K)} \tag{10}$$

If $F_{hitung} \geq F_{N+K-1,\ NT-N-K}$ then the independent variable has a significant effect.

2.2.7.2 *Partial test*

The aim of this test is to see the effect of individual independent variables on non-independent variables, if other independent variables are considered constant.

3 RESULTS AND DISCUSSION

3.1 *Open unemployment*

The Central Statistics Agency (BPS) formulates the Open Unemployment Rate (OUR), which represents the number of unemployed in a region. Open unemployment is part of the workforce that does not work or is looking for work (both for those who have never worked at all or who have worked), or are preparing a business, those who are not looking for work because they feel it is impossible to get a job and those who already have jobs but have not yet started work (BPS, 2018). The formulation of the open unemployment rate is:

$$OUR = \frac{\text{number of unemployed}}{\text{number of workforce}} \quad 100\% \tag{11}$$

3.2 *Estimation of data panel regression*

The estimation results of the DKI Jakarta open unemployment rate with panel data regression are shown in the following model:

Combined Model

$$\widehat{y_{it}} = 14.972 - 0.0172\ X_{1it} + 0.0127\ X_{2it} - 0.2326\ X_{3it} - 0.0252\ X_{4it} - 0.8020\ X_{5it} \quad (12)$$

with the value of $R^2 = 74.24\%$.

Fixed Effect Model

Estimated results:

$$\widehat{y_{it}} = a_i - 0.0065\ X_{1it} + 0.0273\ X_{2it} - 0.2348\ X_{3it} - 0.0276\ X_{4it} - 0.7256\ X_{5it} \quad (13)$$

with the value of $R^2 = 78.18\%$, $\sigma_u = 0.6056$, $\sigma_e = 1.1345$.

Random Effect Model

Estimated results:

$$\widehat{y_{it}} = a_{it} + 14.903 - 0.0092\ X_{1it} + 0.0174\ X_{2it} - 0.2343\ X_{3it} - 0.0268\ X_{4it} - 0.7517\ X_{5it} \quad (14)$$

with the value of $R^2 = 78.17\%$, $\sigma_u = 0.8611$, $\sigma_e = 1.1345$.

Figures 1, 2 and 3 show the comparison between the estimated charts and the combined model, fixed influence model, and random influence model, respectively:

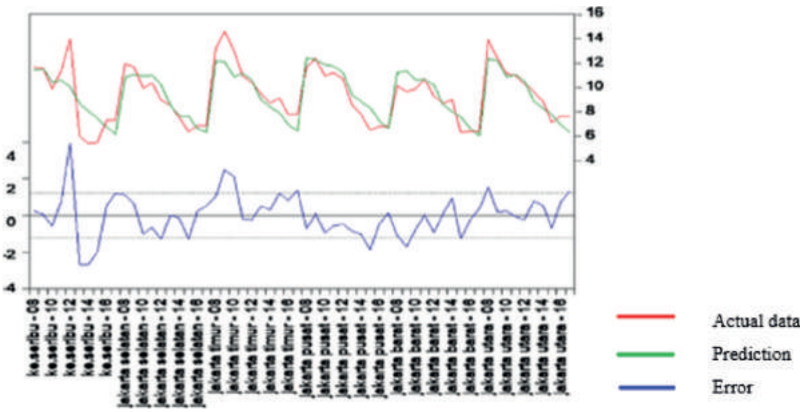

Figure 1. Combined model charts.

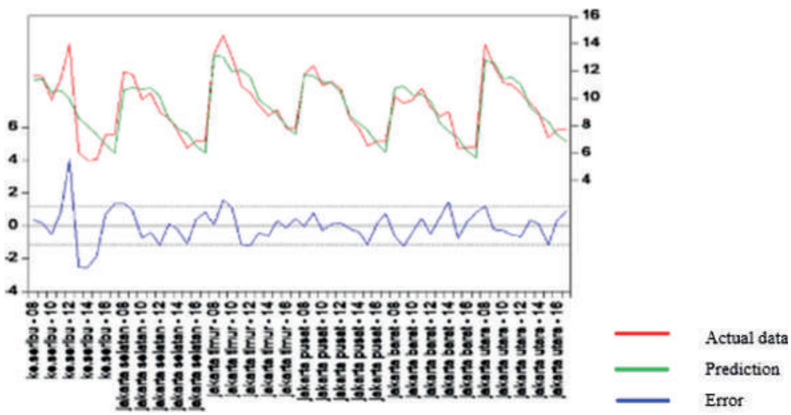

Figure 2. Fixed influence effect model chart.

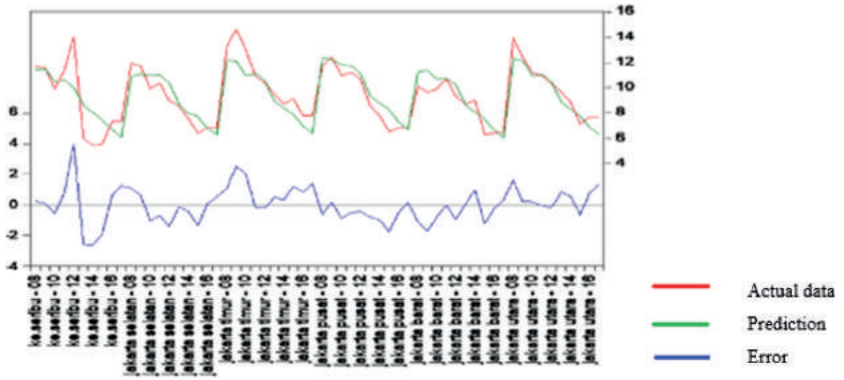

Figure 3. Random influence effect model chart.

3.3 *Test assumption*

There is no multicollinearity because there is no value VIF > 10. Applying a normality test using the Shapiro–Wilk (W) test, the non-free unemployment variable has a value of W = 0.973 with p-value = 0.208 > 0.05. Therefore the normal data assumption is met. A heteroscedasticity test using the Breusch–Pagan test obtained chi-squared value = 0.06 or p-value = 0.8078. Therefore the assumption of homoscedasticity is fulfilled, or in the other words the data is homogeneous.

3.4 *Selection of the best models*

The Chow test will be used to choose between the combined model and the fixed influence model, while the Hausman test will be used to choose between the fixed influence model and the random influence model.

- Selection of Fixed Effect Models and Combined Models with Chow Test
  The results of the analysis with the Chow test obtained p-value = 0.0275 so that the chosen model is a fixed influence model.
- Selection of Fixed Effect Models and Random Effect Models with Hausman Test
  The results of the analysis with the Hausman test obtained a value of W = 0.06 or p-value = 1 > a, so the random influence model is chosen.
- Final Estimation of Data Panel Regression Model
  The best model chosen to model DKI Jakarta open unemployment is a random effect model, as follows:

$$\widehat{y_{it}} = 14.903 - 0.0092\, X_{1itr} + 0.0174\, X_{2it} - 0.2343\, X_{3it} - 0.0268\, X_{4it} - 0.7517\, X_{5it} \quad (15)$$

with the value of $R^2 = 78.17\%$, $\sigma_u = 0.8611$, $\sigma_e = 1.1345$.

3.5 *Parameter significance test*

Simultaneous Test (Test F)

Based on the results of panel data regression, the analysis obtained an F count of 31.12 with p-value = 0.000. So it can be concluded that the variable number of vacancies, GDP rate, provincial minimum wage, inflation, and population growth rates jointly affect the open unemployment rate in DKI Jakarta.

Partial Test (t Test)

Based on the results of panel data regression, the value of t_{hitung} was obtained for the provincial minimum wage variable and the intercept constant was −11.69 and 1.125 with

p-value = 0.000. So it can be concluded that the provincial minimum wage variable affects the open unemployment rate in DKI Jakarta significantly.

4 CONCLUSION

From the results of this study, it can be concluded that:

- There are differences in results from previous studies regarding the factors that cause open unemployment in a region. In this study, open unemployment in DKI Jakarta is influenced by the number of vacancies, the gross regional domestic product rate, the provincial minimum wage, inflation, and the rate of population growth together. In addition, it was found that only the provincial minimum wage variable had a significant effect on the open unemployment rate in DKI Jakarta at $\alpha = 0.05$ with an R^2 of 78.18%.
- The limitation in this study is that it is difficult to obtain complete data for a long period of time with complete variables, based on the results with R^2 of 78.18%, which means that there are still 21.82% of factors affecting the open unemployment rate beyond the factors formed in this model.

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Developing Predict-Observe-Explain worksheets on elementary school mathematics subject

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ABSTRACT: This study aimed to develop Predict-Observe-Explain worksheets on elementary school mathematics subjects in plane material. The approach in this study used a mixed method with Research and Development (R&D) methodology. Data collection instruments were validation questionnaire instruments, teacher response questionnaire instruments, and concept comprehension test instruments, which have been calculated through validity and reliability tests. Data analysis techniques used the data analysis of validity, data analysis of practicality, and data analysis of product effectiveness of a difference test of mathematical concepts comprehension through paired sample t-test. The results showed that the validation of Predict-Observe-Explain worksheets on elementary school mathematics subjects amounted to 81.9% and had very good criteria. Practical results from the teacher response amounted to 83.1% and had very good practicality criteria. The results of the effectiveness test contained differences in mathematical concepts comprehension before and after the use of Predict-Observe-Explain worksheets were 50.73 and 74.41. The conclusion of this study was that the development of Predict-Observe-Explain worksheets on elementary school mathematics subjects of was valid and practical, and could improve the students' mathematical concept comprehension.

1 INTRODUCTION

Mathematics is a basic science that has an important role in the process of human life. In everyday life, we are not separated from mathematics, neither for the small things, nor in the development of sophisticated technology. The importance of mathematics in life therefore means that learning mathematics must be taught to children from an early age, including elementary school students.

The core competency of the knowledge dimension of elementary school students is factual comprehension and conceptual knowledge by observing, asking, and trying, based on curiosity about themselves, God's creatures and their activities, and objects found at home, at school, and in playgrounds (Permendikbud, 2013, p. 8). These core competencies also apply to mathematical subjects. These competencies can be achieved if the factors that support learning can be optimally fulfilled. One of the supporting factors of learning is the use of creative students' worksheets. This refers to Mustikan's (2013, p. 1) opinion, stating the supporting factors of learning, namely teacher creativity with various teaching methods and approaches, teaching materials used, and student activities as being central to learning. Anggara (2015) found that interesting teaching materials can increase the students' curiosity and interest in learning.

The students' worksheet is one type of teaching material, and its construction must be considered in order to improve the students' conceptual understanding. Based on unstructured observations at Bogosari 1 Public Elementary School, Guntur Subdistrict, Demak Regency, information was obtained that the students' worksheets used by the teachers only contained questions for students to answer. This has an impact on the activities of students, who tend to be passive during learning, so that the understanding of the students' concepts is also not good. Based on the initial survey giving questions to 20 students and analyzed based on conceptual understanding, it can be seen that the average students' understanding of the concept of plane material was only 55% in the unfavorable category.

Considering the above problems, we need a solution in the form of students' worksheets that not only contain questions, but can also motivate students and construct the students' knowledge independently so that the conceptual understanding of mathematics is better. The development of the students' worksheet, combined with the Predict-Observe-Explain model, can be used as an alternative solution to the problem. This is because the development of the students' worksheet based on Predict-Observe-Explain will adopt the components in the model.

The Predict-Observe-Explain model is a learning model based on constructivist theory that can be seen from the constituent components of the Predict-Observe-Explain model. The Predict component invites students to guess the possibility that will occur, the Observe component invites students to make observations through practice or demonstration, and the Explain component invites students to explain the results of the practice or demonstration and match the expectations of the Predict component. So the product of developing a students' worksheet based on Predict-Observe-Explain also reflects constructive learning.

The plan to develop such a Predict-Observe-Explain students' worksheet is also based on relevant similar researches. For instance, Restami et al. (2013) found that there is an effect of interaction between Predict-Observe-Explain learning models and learning styles on understanding physics concepts and scientific attitude. Abdillah et al. (2017) found that the application of X-Presser learning models assisted by the students' worksheet is more effective in improving scientific process skills and understanding the concepts of elementary students. Fitriani et al. (2018) found that there is an influence of the Predict-Observe-Explain Worksheet (POEW) learning model on understanding physical concepts in terms of student gender.

Based on the background described above, the formulation of the problem in this study is: (1) Is the Predict-Observe-Explain worksheet on elementary school mathematics subjects in plane material criteria valid? (2) Is the Predict-Observe-Explain worksheet on elementary school mathematics subjects in plane material criteria practical? /(3) Is there a difference in the average comprehension of mathematical concepts before and after being taught with a students' Predict-Observe-Explain worksheet?

2 METHOD

The approach in this study used a mixed method approach with Research and Development (R&D) research methodology. This methodology is used because it is suitable for answering problems and needs in the field, which requires worksheets that can motivate students, and construct the students' knowledge independently so that the conceptual understanding of mathematics is better. Products produced by development research must be valid, practical, and effective in their use. The research procedure consists of potential and problem stages, data collection, product design, product validation, design revision, suitability testing, product revision, product testing, and product revision.

The trial design was carried out through a time-series design quasi-experimental type methodology. The design of this study was quasi-experimental without using experimental and control classes, but only with four pretests, and four post-tests, and then comparing them. The trial subjects in this study were the fourth-grade students of SD Negeri Bogosari 1, Guntur Subdistrict, Demak Regency, 2017/2018 school year. There were 20 students. Figure 1 represents the time-series design quasi-experimental type methodology.

Sample	Pretest	Treatment	Post-test
RC	$O_1\ O_2\ O_3\ O_4$	X	$O_5\ O_6\ O_7\ O_8$

Figure 1. Time-series design quasi-experimental type.

$$P = \frac{\sum X_i}{\sum X_j} \times 100\,\%$$

Figure 2. Validity and/or practical data analysis techniques.

Data types and data collection instruments used in this study are validity data of product development with instrument validation questionnaire, product practicality data development with teacher response questionnaire instrument, and conceptual comprehension data with conceptual comprehension test instruments. Before being used, it must be ensured that the three instruments are valid and reliable by calculating their validity and reliability tests.

Data analysis techniques consist of validity data analysis and practicality data analysis using the following formula:

Information:
P = percentage;
ΣX_i = number of answers to expert judgment/teacher response;
ΣX_j = maximum score.

The data analysis of the conceptual comprehension consists of two steps: assumption test and hypothesis test. The assumption test used the normality test as a condition to test the hypothesis. Whereas, after the data was normally distributed, the next step was to test the hypothesis to find out the differences in the students' conceptual comprehension before and after the use of a Predict-Observe-Explain based students' worksheet. The statistical technique used to test the hypothesis was the paired sample t-test technique.

3 RESULTS AND DISCUSSION

3.1 *Form of Predict-Observe-Explain worksheet*

The developed Predict-Observe-Explain students' worksheet is included in the worksheets of practicum students, containing procedures or work steps for their completion. The components of the students' worksheets based on Predict-Observe-Explain consist of:

a. the initial section, consisting of a cover, instructions for using the students' worksheet, and a table of contents.
b. the core part, consisting of the title of the material, objectives, tools and materials, predicts components, observes components, and explains components.
c. the final section, consisting of items and references.

The students' worksheet based on Predict-Observe-Explain was a learning support based on constructivist theory, which can be seen from the constituent components of the Predict-Observe-Explain model. The Predict component invited students to guess the possibility that will occur, the Observe component invited students to make observations through practice or demonstration, and the Explain component invited students to explain the results of the practice or demonstration and match the expectations of the Predict component. Figures 3 to 6 illustrate the parts of the students' worksheet based on Predict-Observe-Explain.

3.2 *The validity of the Predict-Observe-Explain worksheet on elementary school mathematics subjects in plane material*

The validity of the Predict-Observe-Explain students' worksheet was obtained from the assessment made by three mathematicians on product development. The results of the expert assessment were used as a reference to determine the validity of product development. The minimum validity criteria so that development products can be used are $70 \leq P < 80$, or minimal good criteria. The results of the validity of worksheets based on Predict-Observe-Explain can be seen in Table 1.

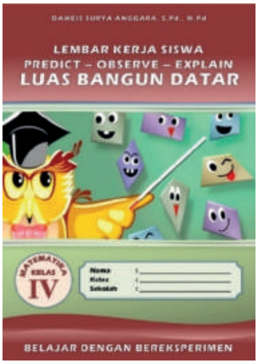
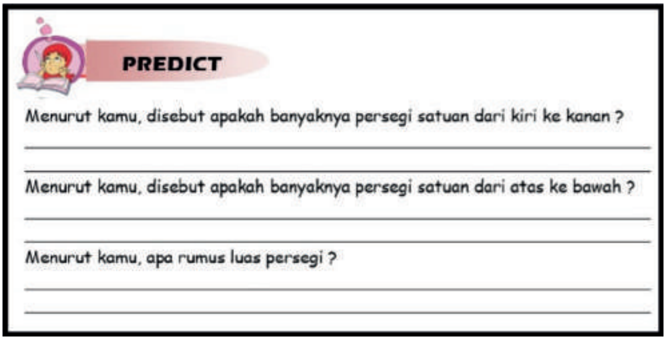


Figure 3. Cover of a Predict-Observe-Explain worksheet.


PREDICT

Menurut kamu, disebut apakah banyaknya persegi satuan dari kiri ke kanan ?

Menurut kamu, disebut apakah banyaknya persegi satuan dari atas ke bawah ?

Menurut kamu, apa rumus luas persegi ?

Figure 4. Predict components of a Predict-Observe-Explain worksheet.


OBSERVE

Untuk membuktikan perkiraanmu, lakukanlah percobaan berikut!

1. Potonglah kertas berpetak dengan menggunakan gunting sesuai dengan tabel berikut.

NO.	BANGUN
1.	
2.	
3.	

Figure 5. Observe components of a Predict-Observe-Explain worksheet.

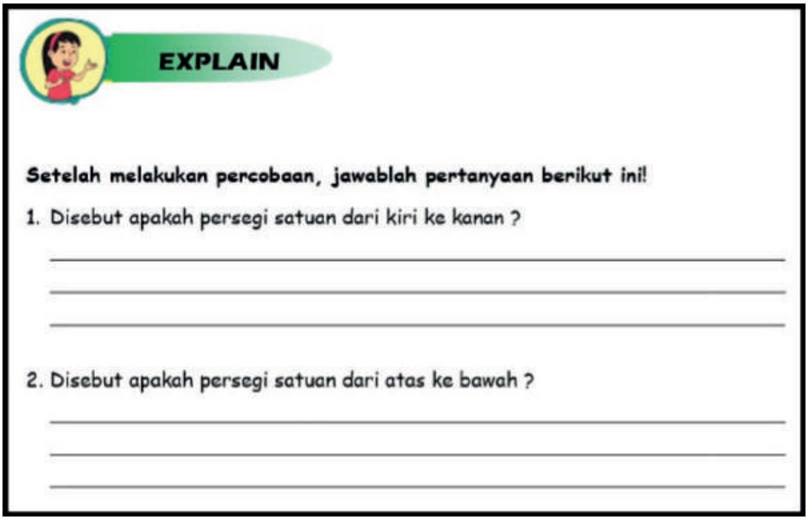


Figure 6. Explain components of a Predict-Observe-Explain worksheet.

Based on the mathematicians' assessment of the development products shown in Table 1, it can be concluded that the development product in the form of Predict-Observe-Explain-based students' worksheets on elementary mathematics in flat-building material has a percentage of 81.9% with excellent validity criteria, and can be used in practical tests.

The content aspect of the students' worksheet was in accordance with the Predict-Observe-Explain component. Examples of the language aspects were the use of punctuation, that capital letters are in accordance with enhanced spelling, and that sentences were in accordance with the level of cognitive development of students. Appearance aspects were those such as cover, color, and clarity of letters are clear and attract students in learning. Prastowo (2012, p. 139) proposed a variety of formats, such as utilizing physical appearance in teaching materials, which can provide a stimulus to students. The images provided can support and clarify material. They are vital because besides clarifying the description, they can also add to the attraction and reduce the boredom of students who are learning the material. The impact aspect of use has been designed to improve the understanding of mathematical concepts.

3.3 *Practicality of Predict-Observe-Explain worksheet on elementary school mathematics subjects in plane material*

The practicality of the students' worksheet based on Predict-Observe-Explain was obtained from the teachers' responses to the use of the development products. The results of the respondents were used as a reference to determine the product development criteria. There was minimum practicality criteria so that development products can be used are $70 \leq P < 80$, or minimal good criteria. Table 2 presents the results of the teachers' responses to the use of development products.

Based on the Table of the mathematicians' assessments of the development products above, it can be concluded that the development product in the form of Predict-Observe-Explain students' worksheet on elementary school mathematics subjects in plane material has a percentage of 83.1% with very good practicality criteria, and can be used in effective tests.

The content aspect of the students' worksheet was in accordance with the Predict-Observe-Explain component to facilitate students in understanding the concept of knowledge. Language aspects were easy to understand, and a structured display and pictures were very interesting for students when learning. The impact aspect of use has been designed to facilitate students in active learning so that the understanding of mathematical concepts can

Table 1. Results of expert assessment of product development.

No	Aspect	Evaluator 1	2	3	∑ Score
1	Fill in	27	30	28	85
2	Language	16	13	14	43
3	Display	12	11	11	34
4	Impact of use	4	5	4	13
Earnings score					**175**
Maximum score (5 × 14 statements × 3 validators)					**210**
Percentage					**81.9%**
Validity criteria					**Very good**

Table 2. Results of teachers' responses to product use development.

No	Aspect	Evaluator 1	2	3	∑ Score
1	Fill in	22	24	21	67
2	Language	16	15	13	44
3	Display	14	14	11	39
4	Impact of use	13	12	12	37
Earnings score					**187**
Maximum score (5 × 14 statements × 3 validators)					**225**
Percentage					**83.1%**
Practicality criteria					**Very good**

improve. This was in accordance with the findings of Stoffels (2005), which states that learning needs to use special worksheets in accordance with teaching materials and learning processes, based on practicum in order to run optimally.

3.4 *The difference in average comprehension of mathematical concepts before and after being taught with Predict-Observe-Explain worksheets*

Indicators of comprehension concepts were measured from the students' answers in the worksheet and the tests given after the experiment. The students' answers were then analyzed based on the indicators of conceptual understanding. The indicators of comprehension concepts are as follows: 1) the ability of students to restate a concept; 2) the ability of students to distinguish examples and non-examples; 3) the ability of students to present concepts in various forms of mathematical representation; 4) the students' ability to solve problems based on related concepts.

Before calculating the difference in average comprehension of mathematical concepts before being taught with a student-based worksheet Predict-Observe-Explain, it was necessary to test assumptions in the form of data normality tests. This is in accordance with the opinion of Anggara and Anwar (2017), that before conducting a paired sample t-test, there is a test of assumptions that must be met, namely the normality test. Data normality test results show that $0.200 > 0.05$, so that the sample data is normally distributed.

After the results of the normality test were known, the students' comprehension data was calculated using paired sample t-test to determine whether or not there was a difference in the average comprehension of mathematical concepts before and after being taught with students' worksheets, based on Predict-Observe-Explain. The results of the analysis are shown in Table 3.

Table 3. Effective test data results.

Paired samples statistics				
	Mean	N	Std. deviation	Std. error mean
Pair 1 comprehension concept (Pretest)	50.7350	20	18.51967	4.14112
comprehension concept (Posttest)	74.4125	20	18.01002	4.02716

Paired samples test								
	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std.error mean	Lower	Upper	t	Df	Sig. (2-tailed)
Pair 1 comprehension concept (Pretest) – comprehension concept (Posttest)	–23.67750	3.94986	0.88322	–25.52609	–21.82891	–26.808	19	0.000

Based on the output of the paired sample's statistics, a comprehension was obtained of the concept of empirical pretest of 50.7350, and a comprehension of the empirical post-test concept of 74.4125. As for the output of the paired sample's test, the sign value is $0.000 < 0.05$, so there is a difference in the average comprehension of mathematical concepts before and after being taught with students' worksheets based on Predict-Observe-Explain. So it can be concluded that the comprehension mathematical concept was better when learning using the students' worksheets based on Predict-Observe-Explain. This situation was because when learning, students construct their knowledge through the phases of Predict, Observe and Explain. When in the Predict phase, students actively predict answers to questions based on previous experience. In the Observe phase, students actively prove predictions of answers through experiments. As for the Explain phase, students actively test the knowledge that has been acquired during the Observe phase. This method allowed students to understand the concept of knowledge.

This was in accordance with the opinion of Restami et al. (2013, p. 3) that Predict-Observe-Explain learning models can include ways that can be used by a teacher to help students in improving their understanding of concepts, as well as psychomotor skills. In addition, Anisa et al. (2013, p. 17) stated that in the Predict-Observe-Explain learning model students are directed and invited to find their own concepts of knowledge from observations through demonstration and experimental methods. Coştu et al. (2012) found that Predict-Observe-Explain learning strategies can help students to achieve better conceptual comprehension and enable students to maintain new conceptions in long-term memory.

4 CONCLUSION

Based on the results of the study and discussion, conclusions obtained about the development of the students' worksheets based on Predict-Observe-Explain on elementary school mathematics subjects in plane material are valid and practical, and can improve the students' conceptual comprehension. The validity of the students' worksheets based on Predict-Observe-Explain in mathematical subjects of elementary school material in plane materials has a percentage of 81.9% with very good validity criteria. The practicality of students' worksheets based on Predict-Observe-Explain in mathematics subjects in elementary school in plane material has a percentage of 83.1% with very good practicality criteria.

There was a difference in the average comprehension of mathematical concepts before and after being taught with Predict-Observe-Explain based students' worksheets. This was reinforced by the comprehension of the concept of empirical pretest of 50.7350 and the comprehension of the empirical post-test concept of 74.4125. So, the average comprehension of the students' mathematical concepts in plane material after applying Predict-Observe-Explain based students' worksheets has increased by 23.6775 or 46% from before.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Categorizing environmental knowledge using a classification table based on median score

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ABSTRACT: Environmental knowledge classifications are important in order to know how many people are environmentally friendly, and have environmental awareness, so that sustainable life can work well. This study aims to determine which person (population) is categorized as having a high or low level of knowledge about the environment, and determines factors that are significant to the need to care about the environment. The data used is secondary data obtained from the Environment Caring Attitude Survey (ECAS), conducted by Statistics-Indonesia (BPS). The analytical method used a table of classification of median scores as critical points for distinguishing categories of environmental knowledge, and binary logistic regression to determine environmental care behavioral factors. The analysis shows that 67.8% of the population are well-informed about the environment, and that the classification of residence, gender, age, education, employment status, household income, information facilities, sources of information, and socialization/training significantly affects knowledge about environmental awareness behaviors in Indonesia. Therefore, it is recommended that the government must pay attention to the availability of education and the implementation of education/training related to the environment (environmental education).

1 INTRODUCTION

Environmental damage, such as water pollution, air pollution, and deforestation, is widespread in Indonesia. River water in Indonesia is generally polluted, air quality is worsening, and forest performances are being damaged (KLH, 201a). Indonesia used the Environmental Performance Index (EPI) for measuring the environmental performance in Indonesia. The EPI was developed and adopted by Virginia Commonwealth University (VCU). It basically measures trends in the quality or environmental conditions of water, air, land media, toxic pollutant loads, biodiversity (i.e. breeding of birds), and population growth (Sumargo, 2018). The EPI in Indonesia decreased from 65.76 in 2011 to 63.96 in 2012, and became 63.20 in 2013, thus indicating the environmental quality was deteriorating from 2011 to 201b3 (KLH, 2015). Environmental issues are commonly caused by a complicated interaction between humans and the environment.

Some studies show a reciprocal relationship exists between humans and the environment (i.e. man affects the environment and the environment affects human behavior) (Kollmuss & Agyeman, 2002; Kitzmuller, 2013; Frick et al., 2004). However, the environmental awareness in Indonesia remains low (Kutanegara, 2014). The lack of knowledge about the environment is one of the major factors, resulting in low environmental awareness and concerns (Fransson & Gärling, 1999; Mifsud, 2011).

Every individual should have knowledge about the environment to preserve it in the long term. Communities with this type of knowledge can realize the importance of the environment and strive to preserve it (Iskandar, 2013). Knowledge can be regarded as a basic capital to be more concerned about the environment, as knowledge is a collection of information that is held by a person as an incentive to behave and act (Kutanegara, 2014). Understanding the environment means comprehending the elements or aspects of life shaped by the environment (Arjana, 2012). Knowledge about the relationships among the types of environment is important to alleviate environmental problems, and it can be obtained in an integrated and comprehensive manner (Slamet, 1994).

Knowledge comprises of the facts gathered by a study, observation, or experience and the conclusions drawn based on these facts (Aune, 2008). Many demographic variables, such as gender and age (Koivisto, 2008; Iniesta-Arandia et al, 2015; Birhanu, 2013; (Díaz-siefer, Neaman, Salgado, & Celis-diez, 2015) can affect an individual's knowledge. Educational level is an important variable that influences knowledge about the environment (Birhanu, 2013; Aminrad et al, 2011). Another important factor is the source of information (BPS, 2013a). Kowledge about the environment can be obtained from counseling or training. By following environment counseling or training, individuals can enhance their knowledge and change their behavior to become environment friendly (Kollmus & Agyeman, 2002; Kitzmuller, 2013; Dverden & Witt, 2010; Liefländer, 2015; Zsóka et al., 2013; Vaughan et al., 2003). Economic conditions or income can also affect a person's knowledge (Mamady, 2016; Digby, 2013; Lyons & Breakwell, 1994). There are few studies using the variables partially-there has been limited use of consistency.

The way in which knowledge about the environment is developed and organized (i.e. the processes of environmental cognition) is also considered, and affective and evaluative dependents as mediators of behavior are discussed. Finally, cognitive, affective, and behavioral responses to the environment can all be incorporated in the concept of attitude.

This study aims to describe and investigate the behaviors of environmental awareness and concern, especially demographic, and socio-economic factors. Dummy and numerical variables are used, namely: residence classification (Huddart-Kennedy, Beckley, McFarlane, & Nadeau, 2009), age (Rebolj & Devetak, 2000), gender (Zafeiroudi & Hatzigeorgiadis, 2014), education level (Rodrigues, 2014), information source (CÔRTES et al., 2016), information facility, counseling or training (Cushman, 1971), work status, and income (Power & Elster, 2005).

2 METHOD

This study covers the entire territory of Indonesia, and the unit of analysis is the Indonesian population aged more than 15 years old. The researchers used secondary data obtained from the Environment Caring Attitude Survey (ECAS) in 2013, conducted by Statistics-Indonesia (BPS). ECAS 2013 is the first survey conducted by BPS to gather information on caring behaviors related to the environment using a household approach. ECAS aims to obtain data describing the behavior of households toward the environment, whether friendly or destructive behavior, which directly and indirectly affects the environment.

The population sample used in ECAS comprised of 75,000 households in Indonesia that were interviewed, and data on 70,406 households were obtained. Conversely in this study, the

Table 1. Environmental knowledge classifications.

Category	Measurement	Range
High knowledge	$X \geq$ median	7–11
Low knowledge	X < median	0–6

Note: X = Score of environmental knowledge by respondent.

target population comprised of the population of those aged 15 years and above that was obtained from a household sample in ECAS: in this sample, only one person in every household could be the informant (BPS, 2013b).

Categorizing population with environmental knowledge principles based on variables: burning garbage pollutes the air; waste disposal; waste containing chemicals; motor vehicle fumes; waste of water; water catchment area; save electricity; using public transportation; maintenance of motorized vehicles; alternative energy (sunlight); save fuel. Each question is assigned a value of 0 for those who answered incorrectly or did not know, and a value of 1 for those who answered correctly. In this study, knowledge is divided into two classifications, namely high knowledge and low knowledge. A person is categorized as having low knowledge if they can answer correctly up to six questions, and is categorized as having high knowledge if they can answer correctly between seven and 11 questions. This classification is based on a two-level categorization that divides variables into two categories (Azwar, 2007).

The analytical method used was the binary logistic regression analysis. Binary logistic regression analysis (Hosmer et al., 2013) was adopted to check for whether there could be a significant effect between the independent variables and the dependent variable. The variables used consisted of nine independent variables and one dependent variable. The independent variables were residence classification, gender, age, education, work status, household income, information facility, information source, and education/training. Respondents have been asked about their environmental knowledge by way of answering true (code 1) or false (code 0) to 11 questions about environmental caring behavior that are about: (1) burning garbage pollutes the air; (2) plastic waste, food waste, paper waste, and other waste do not need to be sorted before disposal; (3) waste containing chemicals (such as spray cans, batteries, light bulbs, and insecticides) are preferably buried; (4) motor vehicle fumes cause the earth to warm up; (5) allowing water to flow unused has the opportunity to cause wastage of water; (6) households need to provide water catchment areas; (7) saving electricity means saving fuel; (8) using public transport when traveling means saving fuel; (9) doing motor vehicle maintenance has nothing to do with maintaining the environment; (10) sunlight can be a source of alternative electrical energy; (11) closing the pot when cooking can save fuel. The dependent variable used was knowledge about the behaviors of environmental concern. Respondents who correctly answered 0–6 questions were considered to have low knowledge, and those who correctly answered 7–11 questions were considered to have high knowledge.

Binary logistic regression analysis (Hosmer et al., 2013) is used for checking a significant effect between the independent variables and the dependent variable. Variables used environmental knowledge as the dependent variable and the eight independent variables were sex, age, education, job status, income, information facilities, source of information, and training. A binary-scale dependent variable was split into categories denoted by Y = 1 (success), and Y = 0 (failed). The average value is $E(Y|x)$, where Y is the dependent variable, and x is the independent variable, which is formulated as follows:

$$E(Y/x) = \beta_0 + \beta_1 x, \qquad -\infty \leq x \leq +\infty \tag{1}$$

The average value is $\left[0 \leq E(Y/x) \leq 1\right]$ or $E(Y|x) = \pi(x)$. The logistic regression model used is:

$$\pi(x) = \frac{\exp(\beta_0 + \beta_1 x_1 + \ldots + \beta k x_k)}{1 + \exp(\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k)} \tag{2}$$

with β_k = the parameter value; $j = 0, 1, \ldots, k$, and k is the number of variables. The formula logit transformation of $\pi(x)$ is as follows:

$$g(x) = \ln\left[\frac{\pi(x)}{1 - \pi(x)}\right] \tag{3a}$$

$$g(x) = \ln\left[\exp(\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k)\right] \tag{3b}$$

$$g(x) = \beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k \tag{3c}$$

Logit $g(x)$ values are between $-\infty$ and $+\infty$.

2.1 *Parameter estimation*

The parameter estimation used the Maximum Likelihood Estimation (MLE) method, which is the method that generates parameter values by maximizing the odds of the data being observed by using a function called the likelihood function. If Y is 0 or 1, then $\pi(x)$ means the probability that Y equals 1, with condition x denoted as $P(Y=1|x)$. While $1 - \pi(x)$ means a conditional probability that Y equals 0 when x is denoted as $P(Y=0|x)$. The pair (x_i, y_i), where $y_i = 1$, the contribution to the likelihood function is $\pi(x_i)$, and for the pair where $y_i = 0$, the contribution to the likelihood function is $1 - \pi(x_i)$, where the value $\pi(x_i)$ of $\pi(x)$ is calculated at x_i. The function of the pair (x_i, y_i) follows the following Bernoulli distribution (Hosmer et al., 2013):

$$f(yi, \pi(xi)) = \pi(xi)^{yi}\left[1 - \pi(xi)\right]^{1-yi} \tag{4}$$

Because the observations are assumed to be independent, the likelihood function is expressed as follows:

$$I(\beta) = \Pi_{i=1}^{n} \pi(xi)^{yi}\left[1 - \pi(xi)\right]^{1-yi} \tag{5a}$$

$$= \left\{\prod_{i=1}^{n}[1 - \pi(xi)]\right\}\left\{\prod_{i=1}^{n}\left[\frac{\pi(xi)}{(1 - \pi(xi))}\right]^{y_i}\right\} \tag{5b}$$

$$= \left\{\prod_{i=1}^{n}[1 - \pi(xi)]\right\}\left\{\prod_{i=1}^{n}\exp\left[y_i \ln\left(\frac{\pi(xi)}{(1 - \pi(xi))}\right)\right]\right\} \tag{5c}$$

$$= \left\{\prod_{i=1}^{n}\frac{1}{1 + \exp\left(\beta_0 + \beta_1 x_{1i} + \ldots + \beta_k x_{ki}\right)}\right\} \tag{5d}$$

$$= \prod_{i=1}^{n}\left[\exp[yi(\beta_0 + \beta_1 x_{1i} + \ldots + \beta_k x_{ki})]\right] \tag{5e}$$

Mathematically, it would be easier to use ln of the following functions:

$$L(\beta) = \ln\left[I(\beta)\right] \tag{6a}$$

$$= Ln\left\{\prod_{i=1}^{n}\frac{\exp\left(y_i\left(\beta_0 + \beta_1 x_{1i} + \ldots + \beta_k x_{ki}\right)\right)}{1 + \exp\left(\beta_0 + \beta_1 x_{1i} + \ldots + \beta_k x_{ki}\right)}\right\} \tag{6b}$$

$$= \sum_{i=1}^{n} yi(\beta_0 + \beta_1 x_{1i} + \ldots + \beta_k x_{ki}) - \sum_{i=1}^{n}(1 + (\exp(\beta_0 + \beta_1 x_{1i} + \ldots + \beta_k x_{ki})) \tag{6c}$$

$$= \left[\beta_0 \sum_{i=1}^{n} y_i + \beta 1 \sum_{i=1}^{n} x_{1i} y_i + \ldots + \beta_k \sum_{i=1}^{n} x_{ki} y_i\right] - \sum_{i=1}^{n}\ln(1 + (\exp(\beta_0 + \beta_1 x_{1i} + \ldots + \beta_p x_{pi}) \tag{6d}$$

$$= \sum_{j=0}^{k}\beta_j \sum_{i=1}^{n} x_{ij} y_i - \sum_{j=1}^{n}\ln\left[1 + \exp\left(\sum_{j=0}^{k}\beta_j x_{ij}\right)\right] \tag{6e}$$

To obtain the value of β which maximizes $L(\beta)$ it is decreased to with the equation equal to zero. The likelihood equation is as follows:

$$\sum_{i=1}^{n}[y_i - \pi(x_i)] = 0 \tag{7}$$

$$\sum_{i=1}^{n} xi[y_i - \pi(x_i)] = 0 \tag{8}$$

In logistic regression, Equations 7 and 8 are not linear with β_0 and β_1, so to obtain their value requires complicated iterations. The calculation of this iteration is done by using computer programming logistic graduation (Hosmer et al., 2013).

2.2 *Parameter significance testing*

The hypotheses used are:

H_0: $\beta_1 = \beta_2 = \beta_3 = \ldots = \beta_k = 0$ (there is no significant influence of independent variables simultaneously on dependent variables);

H_1: Minimum there is one $\beta_j \neq 0$ (there is at least one independent variable that has a significant effect on dependent variables)

with $j = 1, 2, \ldots, k$; k = number of independent variables. The test statistics are as follows:

$$G = -2\ln\left[\frac{L_0}{L_1}\right] \tag{9}$$

where L_0 = likelihood value of the model without independent variables, and L_1 = likelihood value of the model with independent variables.

The G-test statistic follows the chi-squared (χ^2) distribution for decision-making:

i. if the value of $G > \chi^2_{(k,\alpha)}$ or p-value $< \alpha$, then reject H_0;
ii. if the value of $G \leq \chi^2_{(k,\alpha)}$ or p-value $\geq \alpha$, then fail to reject H_0.

2.3 *Goodness of fit test model*

The next test is the model conformity test to examine the difference between the results obtained from the model and the observed results in the observational data. To check the suitability of the model, Hosmer et al. (2013) test statistics were used.

The hypotheses used in this test are:

H_0: Model is a fit (no difference in yield between observation and prediction result of the model);

H_1: Model is not a fit (there is a difference of result between observation and prediction result of the model).

Test statistics to be used are:

$$\hat{C} = \sum_{k=1}^{g}\frac{\left(o_k - n_k^1\bar{\pi}_k\right)^2}{n_k^1\bar{\pi}_k(1-\bar{\pi}_k)} \tag{10}$$

where

g = number of groups
$o_k = \sum_{j=1}^{c_k} y_j$ = number of response variable values in group k
n'_k = number of subjects in group k
$\bar{\pi}_k = \sum_{j=1}^{c_k} \frac{m_j \bar{\pi}_j}{n'_k}$ = average probability estimation of group k
ck = the number combinations of explanatory variables in the kth group
m_j = Number of subjects with c_k combination of explanatory variables.

Statistic $\hat{C}$ follows the distribution of chi-squared (χ^2) with (g-2) degrees of freedom. Therefore, the basis of decision-making is:

i. Jika $\hat{C} > \chi^2_{(g-2,\alpha)}$ or p-value < α, then reject H_0;

ii. Jika $\hat{C} \leq \chi^2_{(g-2,\alpha)}$ or p-value ≥ α, then fail to reject H_0.

The fit conformity test model is expected to obtain a failed outcome, to deny H_0 in order to conclude that the model formed fits or that there is no difference between the observed and predicted results.

2.4 *Odds ratio (Trend ratio)*

The relationship of independent variables to the dependent variable can be proved by the odds ratio. When x = 1, the odds is defined as $\frac{\pi(1)}{1-\pi(1)}$ and when x = 0, the odds is defined as $\frac{\pi(0)}{1-\pi(0)}$. The odds ratio, denoted by OR, is θ. The odds ratio for x = 1 and the odds ratio for x = 0 are expressed in the equation:

$$\theta = \frac{\pi(1)/1-\pi(1)}{\pi(0)/1-\pi(0)} \tag{11}$$

Based on Table 2, the value of the odds ratio (θ) can be obtained via the following formulae:

$$\theta = \frac{\pi(1)/1-\pi(1)}{\pi(0)/1-\pi(0)} \tag{12a}$$

$$\theta = \frac{\left[\frac{\exp(\beta_0+\beta_j)}{1+\exp(\beta_0+\beta_j)}\right]\left[\frac{1}{1+\exp(\beta_0)}\right]}{\left[\frac{\exp(\beta_0)}{1+\exp(\beta_0)}\right]\left[\frac{1}{1+\exp(\beta_0+\beta_j)}\right]} \tag{12b}$$

$$\theta = \left[\frac{\exp(\beta_0+\beta_j)}{\exp(\beta_0)}\right] \tag{12c}$$

$$\theta = \left[\exp(\beta_0+\beta_j-\beta_0\right] \tag{12d}$$

$$\theta = \exp(\beta_j) \tag{12e}$$

Table 2. Opportunity value in binary logistic regression model.

		Independent variable (X)	
		x = 1	x = 0
(1)	(2)	(3)	(4)
Dependent variable (Y)	y = 1	$\pi(1) = \frac{\exp(\beta_0+\beta_j)}{1+\exp(\beta_0+\beta_j)}$	$\pi(0) = \frac{\exp(\beta_0)}{1+\exp(\beta_0)}$
	y = 0	$1-\pi(1) = \frac{1}{1+\exp(\beta_0+\beta_j)}$	$1-\pi(0) = \frac{1}{1+\exp(\beta_0)}$
Total		1,0	1,0

Source: Hosmer et al. (2013).

In binary logistic regression the independent variable consists of two categories, that is, encoded with 0 (reference categories) and 1. Then, the interpretation of the coefficient on that variable depends on the magnitude θ, that is, the risk of occurrence of event $y = 1$ in the category $x = 1$ is $\exp(\beta_j)$ at times when the risk of occurrence of event $y = 1$ in the category $x = 0$. Meanwhile, if the independent variable is continuous scale, it can be interpreted that every increase of unit C in the independent variable will cause the risk of occurrence of $y = 1$ equal $\exp(C, \beta_j)$ more frequently.

2.5 *Binary logistic regression model*

The equation of binary logistic regression: g(D) = β0 D1 + β2 D2 + β3 X3 + β4 D4 + β5 D5 + β6 D61 + β7 D62 + β8 D63 + β9 D64 + β10 D65 + β11 D7 + β12 D81 + β13 D82 + β14 D9

Notes: Dependent variables: g(D) = 1 – high; 0 – low for environmental knowledge variables. Independent variables: D1 = dummy variable of residence classification (1 – rural; 2 – urban); D2 = dummy variable of gender (1 – female; 2 – male); X3 = variable of age (numeric); D4 = dummy variable of education level (1 < junior high school; 2 > junior high school); D5 = dummy variable of work status (1 – no; 2 – yes); dummy variable of income (IDR), D61 = <500,000; D62 = 500,000–1 million; D63 = 1.1–2.5 million; D64 = 2.6–5 million; D65 = 5.1–10 million; D7 = dummy variable of information facility (1 – no; 2 – yes); D81 = dummy variable of source of information otherwise media; D82 = dummy variable of source of information mass media; D9 = dummy variable of source of information counseling or training (1 – no; 2 – yes). The value of the odds ratio in the binary logistic regression is used to indicate the comparison between two dummies independent variables.

3 RESULTS AND DISCUSSION

According to ECAS data in 2013, about 60.3% of people aged 15 and older have high knowledge about the behaviors of environmental concern. This percentage is already high as more than half of the population has high knowledge. Nevertheless, 39.7% still have low knowledge.

Table 3 shows the frequency distribution of demographic and socio-economic characteristics. The percentage of population with a better knowledge of environmental caring behavior in urban areas (72.7%) is bigger than for those living in rural areas (51.3%). On the contrary, for knowledge about the behavior of environmental awareness that is not high: in rural areas (48.7%) it is bigger than in urban areas 27.3%). The percentage of the population of male sex (61.8%) who have better knowledge of environmental care behavior is almost the same relative to women (59%), equally over 50%. The percentage of the population with a better knowledge about environmental behavior in secondary education (81.2%) is larger than those with a basic education (51%). The percentage of working people who have high knowledge of environmental caring behavior (61%) is greater than among those who do not work (59.2%).

The percentage of people who have high knowledge increases with the increase in household income. Conversely, the percentage of people who have low knowledge decreases with the increase in household income (IDR). The highest percentage of residents who have high knowledge exists in the population group with a household income of >10 million rupiah (IDR), and the highest percentage of residents who have low knowledge is found in the population group with a household income < 500 thousand rupiah (IDR). People with information facilities (65.7%) have greater knowledge than those who do not (37.1%). The opposite case is found in people with low knowledge. The population group that received information from both the mass media and other media (70.7%) have a larger percentage of knowledge of environmental care than those who received information from mass media (62.6%) or other media (42.9%). The total percentage of the population who participated in the socialization/training (81.5%) have a larger knowledge than those who did not (18.5%).

Table 3. Demographic and socio-economic characteristics.

Variable	High knowledge (%)	Low knowledge (%)
Residence		
Rural	51.3	48.7
Urban	72.7	27.3
Gender		
Male	61.8	38.2
Female	59.0	41.0
Education		
Primary	51.0	49.0
Secondary	81.2	18.8
Work Status		
Employed	61.0	39.0
Unemployed	59.2	40.8
Household Income		
<500 thousand rupiah	40.0	60.0
500 thousand – 1 million rupiah	51.4	48.6
1.1–2.5 million rupiah	63.6	36.4
2.6–5 million rupiah	77.4	22.6
5.1–10 million rupiah	86.9	13.1
>10 million rupiah	91.2	8.8
Facilities		
Yes	65.7	34.3
No	37.1	62.9
Sources		
Mass Media	62.6	37.4
Other Media	42.9	57.1
Both Media	70.7	29.3
Socialization/Training		
Yes	81.5	59.4
No	18.5	40.6

All the independent variables significantly affect knowledge about the behaviors of environmental concern (Table 4). People who live in urban areas have 1.6 times better knowledge about the behaviors of environmental concern than those who live in rural areas. The difference between urban and rural residents is not large. People who live in urban areas have more access to various sources of information than rural residents, thereby increasing their knowledge (Blum, 1987; Rickison, 2001). Despite having fewer resources, the rural population usually upholds the values of local knowledge in preserving nature, and in doing so also increases their knowledge. Local knowledge is all forms of knowledge, beliefs, understanding, insights, customs, and ethics that guide human behavior in life in ecological communities. An understanding of local knowledge is an important asset in the management of natural resources and the preservation of the environment (Ariyanto et al, 2014). Communities adapt to the environment by developing environmental knowledge (ideas, norms, customs, and cultural values) so that it becomes knowledge for the society (Kutanegara, 2014).

Better educated populations have 2.2 times better knowledge about the behaviors of environmental concern than less-educated populations. People with high education have greater knowledge, including that about the behaviors of environmental concern (Tikka et al., 2000; Rickison, 2001).

The tendency of high knowledge about the behaviors of environmental concern increases along with the increase in household income. People with a household income of >10 million rupiah have 3.9 times better knowledge about the behaviors of environmental concern than those with a household income <500 thousand rupiah. Income does not directly influence a

Table 4. Regression binary output.

Variable	Odds ratio	P-value
Residence		
Urban	1.645	0.000
Rural	Reference	Reference
Gender		
Male	1.215	0.000
Female	Reference	Reference
Age	0.991	0.000
Education		
Primary	2.227	0.000
Secondary	Reference	Reference
Work Status		
Employed	1.089	0.000
Unemployed	Reference	Reference
Household Income (IDR)		
<500 thousand	Reference	Reference
500 thousand–1 million	1.109	0.000
1.1–2.5 million	1.370	0.000
2.6–5 million	1.881	0.000
5.1–10 million	2.931	0.000
>10 million	3.924	0.000
Facilities		
Yes	1.561	0.000
No	Reference	Reference
Sources		
Mass Media	1.337	0.000
Other Media	Reference	Reference
Both Media	1.746	0.000
Socialization/Training		
Yes	2.041	0.000
No	Reference	Reference

person's knowledge. People who earn sufficiently can obtain facilities or buy resources, thus indirectly increasing their knowledge (Lyons & Breakwell, 1994).

People with information facilities have 1.5 times better knowledge about the behaviors of environmental concern than those without. Ease of obtaining information can help individuals acquire new knowledge. Therefore, through information facilities, people can have better knowledge than those with no access to information facilities (Mubarak, 2007).

Residents with access to information from mass media and other media have 1.3 times better knowledge about the behaviors of environmental concern than those who receive information from mass media only, and have 1.7 times better knowledge than those who receive information through other media only. The presentation of information by mass media can be conducted quickly, and information can be disseminated to many people simultaneously. Media other than the mass media in this study includes people or scientific books that can provide detailed information: erroneous information can be confirmed directly by the recipient of the information. Therefore, people who obtain information from the combination of these media sources have more knowledge about the behaviors of environmental care than those who receive information from one media type only (Rickison, 2001). People should not only know about the behaviors of environmental concern but should also have correct knowledge related to them.

Residents who have followed socialization/training in the last three years have two times better knowledge about the behaviors of environmental concern than those who have not. The provision of short-term socialization/training offers high knowledge of the behaviors of environmental concern. The reason is that with the development of the condition of the population and technology, the environment also changes and thus conservation efforts must also be continuously adjusted.

According to the odds ratio results in regression binary output, it can be stated that men have 1.2 times better knowledge about environmental care behavior than women (reference). In other words, a high knowledge of environmental concerns between men and women is relatively similar. This finding corrects the claim that men have better environmental knowledge than women (Birhanu, 2013; Daleo, 1999, Demilew, 2007; Getaye, 2007; Arcury & Christianson, 1993; Coyle, 2005; White, 2006; Arbuthnot, 1977; Anderson et al., 2007; Ewert & Baker, 2001; Tikka et al., 2000).

4 CONCLUSIONS

This study shows that the Indonesians who have high environmental knowledge about environmental concern are more than half of the population aged 15 years and older. The remaining 40% have low knowledge about environmental concern. The classifications of residence, gender, age, education, work status, household income, information facilities, resources, and socialization/training significantly affect knowledge about environmental concern. The odds ratio indicates that the population with the following characteristics is likely to be knowledgeable about environmental concern: living in urban areas, having an educational level of junior high school and above, a household income (IDR) > 10 million rupiah, the mass media and other media, and follows socialization/training.

The comparison of residents with high environmental knowledge is 1.5 times that of people who are knowledgeable about the poor environment. Rural people (male and female) and communities with a low economic status (< 2.5 million IDR) are expected to increase their accessibility of information related to the environment. The less-educated population should continue to increase their knowledge about the environment, especially through socialization and training. Moreover the intensity and scope of socialization/training related to the environment should be increased.

Therefore, it is recommended that the government must pay attention to the availability of education and the implementation of education/training related to the environment (environmental education).

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Mathematics pre-service teachers' anticipation of students' responses: A case study of lesson study for pre-service teachers

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ABSTRACT: Anticipating students' responses is an important element in planning a lesson. This involves teachers' knowledge of the mathematics taught and knowledge of the students. This paper discusses pre-service teachers' anticipation of students' responses in a lesson study context. The lesson study was embedded in a teaching practice program at one university in Jakarta. It was conducted at two lower secondary schools in Jakarta, involving seven pre-service teachers, three mentor teachers, and two university lecturers. The researcher took the role of the knowledgeable other in the lesson study. Using case study methodology, data were collected through written test, video of the lesson study meetings, and interviews. The findings showed that the pre-service teachers' anticipation of students' responses was vague and lacked details. In making the anticipation, the pre-service teachers considered students' previous learning and characteristics. In teachings, having the anticipation of students' responses did not help the pre-service teachers to handle contingent moments. The pre-service teachers needed handy prompts to respond to students' questions. The pre-service teachers found that anticipating students' responses was difficult but rewarding. Despite the extra detailed work, anticipating students' responses helped the pre-service teachers plan the lesson better and improved their confidence.

1 INTRODUCTION

Anticipating students' responses is an important element in teaching and has been a focus in teacher education research. For example, Vale et al. (2018) argued that anticipating students' responses allows teachers to notice and attend to different students' mathematical strategies and misconceptions. Focusing on students' strategies and misconceptions while planning a lesson could help teachers develop tasks that fit to the students' needs. As pointed out by Ball et al. (2008) that the anticipation of students' responses helps teachers in selecting or designing proper mathematical tasks.

Attempts at helping teachers or pre-service teachers develop their skills in anticipating students' responses have been done in recent years. For example, Llinares et al. (2016) developed a learning environment where pre-service teachers were asked to anticipate students' responses on the classification of quadrilaterals. They found that the pre-service teachers' learning was supported by the structured learning environment where the pre-service teachers had the opportunity to discuss students' responses. From this point of view, lesson studies with its cycles of planning, research lessons, and post-lesson discussions (Leavy & Hourigan 2018) can be a promising means that provides pre-service teachers with such structured learning environment.

Lesson study aims to get insights about teaching and learning based on an understanding of students' mathematical thinking (Corcoran & Pepperell 2011), hence observing lessons is the core element of the lesson study process. Anticipating students' responses and discussing students' potential difficulties are important aspects in the planning (Corcoran & Pepperell 2011). In line with this, Fernandez et al. (2003) argued that lesson study encourages teachers to use a researcher's perspective, that is when observing and collecting evidence of students' learning to get insights about the students' learning.

While numerous studies have shown that lesson study supports pre-service teachers' focus on students thinking (Cajkler & Wood 2016; Sims & Walsh 2009), focus on how pre-service teachers anticipate students' responses, how it helps them build their understanding of the mathematics and the students' learning, and how it influences the teaching have not been explored in the literature. This study focuses on the pre-service teachers' anticipation of students' responses in a lesson study context. It asks a research question—how do pre-service teachers anticipate students' responses in a lesson study?

2 METHOD

This study examines the pre-service teachers' anticipation of students' responses while they are participating in lesson study. The research methodology used is case study. The lesson study was embedded in a teaching practicum program at one university in Jakarta, Indonesia. Teaching practicum is a compulsory component in the four-year teacher education program in Indonesia. It is offered to third-year pre-service teachers who have passed a number of mathematical and pedagogical units.

The lesson study was conducted in one lower secondary school—SMP D involving three pre-service teachers (Diana, Raya, Ida), one mentor teacher (Nur), and one university lecturer (Siti). Names are pseudonyms. They formed a lesson study group, and the researcher (Meili) was the knowledgeable other in the lesson study.

The lesson study group conducted two lesson study cycles. In each cycle, the group had one planning meeting in which the pre-service teachers, mentor teachers and if available, the university lecturer decided which topic to teach and planned the lesson. Next, one pre-service teacher taught the lesson in one classroom while the other members of the group observed the lesson. This was followed immediately by a post-lesson discussion where the lead teacher reflected on their teaching and together with the observers and the knowledgeable other discussed evidence of students' learning. The research lesson and post-lesson discussion were repeated for the second and third pre-service teachers. The second and third pre-service teachers taught the same lesson in different classrooms.

This paper discusses the data from the first lesson study cycle. In this cycle, the lesson study group taught about Linear Equation. This cycle was selected because it showed evidence of the pre-service teachers' anticipation of students' responses. Data were collected through video recording of lesson study meetings, and individual interviews. All lesson studies meeting (i.e. planning, research lessons, and post-lesson discussions) were videotaped. The individual interviews were conducted after the implementation of lesson study.

Only video vignettes that show the evidence of the pre-service teachers' anticipation of students' responses were selected for further analysis. These vignettes were transcribed and then coded by using an inductive approach. An inductive approach allows compelling themes to emerge from the data (Thomas 2006).

3 RESULT AND DISCUSSION

This study focuses on the pre-service teachers' anticipating students' responses while participating in lesson study. The key findings of this study are presented as follows.

3.1 *Anticipating students' responses in the planning*

In the planning, the group decided to teach Linear Equation. They discussed a way to introduce the concept of equivalence in an equation by using a balance model. The focus of the discussion was about how students would make sense of the balance model and transform it into an equation. The pre-service teachers would start the lesson by giving the students a

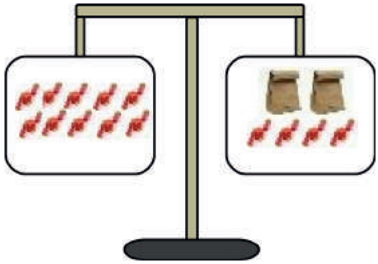

Figure 1. Balance model discussed in the planning.

problem (Fig. 1), students would be asked to find the number of candies in each bag. The pre-service teachers were asked by the knowledgeable other to anticipate students' responses to the balance problem. Their predictions were vague. They did not include students' reasoning processes when solving the problem. In particular, they did not assume that each bag should contain the same number of candies.

Raya : Prediction 1: student don't do anything
Prediction 2 : students take away four from each side.
Ida : First, we ask them why they take away four from both sides, and how is the balance position after they took away four from both sides?
Prediction 3 : they move the candies to the other side, but the balance stays equal.

The group continued the discussion with developing problems for students' exercises. They wanted to move forward from the balance model to equations. They planned to give the students a word problem – "*A number is multiplied by two then added to one. The result is 13. Find the number!*". The knowledgeable other—Meili prompted the pre-service teachers to anticipate the students' responses to the problem.

Meili : Think of the possibilities of students' answers!
Raya : Possibility 1: students might not understand at all.
Ida : Students might ask what number is that? Even number, odd number, or?
Nur : Tell them that it's their job to figure it out.
Ida : Possibility 3: students guess the number.
Raya : Tell them to check their answer, put the number in the equation and see if the answer is correct.
Nur : It's very unlikely they do the changing side, they're likely to do guess and check.
Raya : They write the equation but wrong, $3x = 13$.
"reread the problem there's a key word there "then" that means another mathematical operation".

In this excerpt, with no details on students' reasoning, the pre-service teachers again made obscure predictions. The pre-service teachers' predictions suggested their assumption of the level of students' mathematical competences. For example, possibility 1: *students might not understand at all*, likely refers to the lower achievers who do not show any effort at all to understand the problem. Whereas possibility 3: "*guess and check*" might be based on the pre-service teachers' assumption of the average students. Possibility 2: "*students might ask if it is an odd or an even number*" suggested that the pre-service teachers considered the students' behavior in their prediction. While odd or even numbers are not relevant to the problem, the pre-service teachers used a behavior lens for this prediction. The pre-service teachers often noticed that students mentioned random ideas before thinking of the problem.

Even though their predictions were still very vague, in this excerpt the pre-service teachers provided prompts for the students. Raya included the prompts corresponding to the Possibility 3. This could have been triggered by the feedback from the mentor teacher—Nur.

In responding to the odd or even numbers, Nur suggested that the pre-service teachers encourage the students to find it out for themselves.

Anticipating students' responses was a new practice for the pre-service teachers. With little or no teaching experience, it can be a challenge for the pre-service teachers. The interview data revealed the pre-service teachers' difficulties when anticipating students' responses. Diana and Ida commented on the difficulties of incorporating detailed predictions. Raya said that it was difficult to put herself into the students' heads.

I categorized the students, high achiever, middle and low achievers. I usually predicted the mistakes of the calculation but could not really predict the misconceptions. It is difficult to put myself in their head. What happened in the actual lessons was often different from what I predicted. (Raya, Interview).

3.2 *Anticipating students' responses in the teaching*

In the first research lesson, Ida—the lead teacher had a difficulty in responding to unanticipated students' responses. The pre-service teachers did not anticipate that students would have difficulties in transforming the balance model into a linear equation when working on the balance model. For example, one student—Nuri misunderstood the x as two bags of candies instead of the number of candies in one bag.

Ida : Yes, you may use x. x equals to what?
Nuri : x equals two bags of candies.
Ida : x is two bags of candies, and then how is the equation? Can you write it down?
Nuri : [writing $x = $ *2 bags of candies*]
Ida : You said it is balanced. Discuss this with your group. What does it mean? Why do you use x to represent 2 bags of candies?
Nuri : I don't know.

Ida did not anticipate students would use x to represent two bags of candies, and she was not prepared with appropriate prompts either. This shows that even though the pre-service teachers predicted students' responses, in the actual lesson, those predictions might not happen.

Following the first research lesson, the lesson study group discussed evidence of students' learning in the post-lesson discussion. They observed that moving from a balance model to the linear equation was not a simple process for the students. Learning from this, the second lead teacher—Raya made some changes in her lesson. She prompted the students to attend to the equivalence of the two sides of the balance.

Raya : Look at the position of the balance. Are they equal or any side is heavier than the other?
Students : The same.
Raya : Look at the right side of the balance. What's in there?
Students : 4 candies and 2 bags
Raya : What's in the left?
Students : …
Raya : So far do you understand? You will be asked to write the equation. Just like the previous example, $10 + 2s = 50$. This is called the equation. Now from the picture here, you are asked to change it into an equation.

This excerpt shows Raya emphasizes the equivalence and the intended students' responses—transforming the balance into an equation. This indicates that she had anticipated students' unawareness of the instruction might have caused students' difficulties in writing the equation. This finding suggests that observing lesson and discussing evidence of students' learning helped the pre-service teacher to better anticipate students' responses.

However, the students in this class also had the same difficulty as the previous class—they could not transform the balance model into a linear equation. The mentor teacher provided evidence of students' difficulties in the post-lesson discussion.

Nur : I think many students haven't grasped the meaning of equation, left side is equal to right side. Dira, she's one of the high achievers in the classroom. She wrote:

left side: $2x + 3 = \ldots$

She should have continued the right side with $x + 8$. But instead she wrote it underneath.

$2x + 3 =$

$1x + 8 =$

Then she was confused, she didn't know what to do because she has two equal signs. This indicates that she hasn't understood the concept of right side = left side.

The mentor teacher—Nur provided a very detailed description of students' thinking. She noticed that students did not understand the idea of equivalence and the use of equal sign. Even though Raya has anticipated that students would have difficulties transforming the balance model into the linear equation, she did not have handy prompts to help students with this difficulty. This finding showed that having the anticipation of students' responses without proper prompts did not help the pre-service teachers in the lesson. This suggests that in anticipating students' responses, pre-service teachers need more than just predicting students' responses, they also need to prepare handy prompts.

Even though the pre-service teachers' anticipations of students' responses do not always occur in the actual lessons, the interview revealed that the anticipating students' responses made the pre-service teachers more confident when teaching. Diana said, "the prediction makes us more prepared when students ask questions". Raya said that predicting students' responses helped her provide more appropriate support for students.

3.3 *Discussion*

In this study, anticipating students' responses was most prominent in the planning. The findings showed that initially, the pre-service teachers only considered students' prior mathematical learning and behavior for their prediction of students' responses. Their predictions of students' responses were vague and did not include students' reasoning or misconceptions. The pre-service teachers' anticipation of students' responses in this study lacked depth and detail. Meyer & Wilkerson (2011) found that teachers needed to spend a significant amount of time to produce detailed anticipation of students' responses, which includes discussing possible areas, which are difficult for students and predicting the students' questions and responses that may arise from the task. In this study, the lack of depth and detail in the pre-service teachers' anticipations of students' responses might have been attributed to the limited time spent on discussing such issues in the planning.

It should be noted that anticipating students' responses was a new practice for the pre-service teachers. Given that the pre-service teachers had little prior knowledge and experience in anticipating students' responses, this study confirms an earlier study of the pre-service teachers' lack of teaching experience, which hindered them in addressing students' common misconceptions and in predicting students' responses (Burroughs & Luebeck 2010). Despite the challenges, this study showed that anticipating students' responses helped the pre-service teachers became more prepared and more confident. This is consistent with earlier studies that found that the pre-service teachers grew self-confidence from participating in lesson study (Cajkler & Wood 2016; Corcoran 2011; Lamb 2015).

Llinares et al. (2016) found that pre-service teachers' participation in a structured environment provides them with an opportunity to discuss and recognize different students' responses. This study found that lesson study provides the pre-service teachers with a structured environment through the planning, research lessons, and post-lesson discussions. The structure of the lesson study cycles, provide opportunities to anticipate students' responses, observe actual students' learning, and discuss the evidence of students' learning.

Moreover, Llinares et al. (2016) suggested that recognizing students' understanding of the mathematical topic helps pre-service teachers to better anticipate students' responses. Given that pre-service teachers have no or little teaching experience, in a teaching practicum context, pre-service teachers might not be provided with a detailed information about the students' mathematical ability. However, this study found that with the help from the mentor teachers in lesson study, the pre-service teachers were better informed about the students' mathematical ability. The mentor teachers' comments triggered the pre-service teachers to incorporate prompts with the predictions. The prompts from the knowledgeable other stimulated the pre-service teachers to provide more detailed anticipations. This study is consistent with the literature that show that support from the mentor teachers and the knowledgeable other, helped the pre-service teachers develop the anticipating students' responses (Corcoran 2011, Chichibu 2016).

4 CONCLUSION

This study investigated the pre-service teachers' anticipation of students thinking while participating in lesson study. Anticipating students' responses was a new practice for the pre-service teachers in this study. The findings show that with little or no teaching experience, anticipating students' responses is difficult for the pre-service teachers. Their anticipations were vague and did not incorporate the students' mathematical reasoning.

Moreover, while anticipating students' responses, the pre-service teachers took into account students' prior mathematical learning and students' behavior. However, the students' responses cannot always be anticipated. This study found that even though the pre-service teachers have anticipated students' responses, in the actual lesson, students might respond differently. In such cases, the pre-service teachers had to deal with contingent moments. Moreover, responding to students' unanticipated difficulties was challenging for the pre-service teachers. This suggests that the pre-service teachers need to prepare prompts along with their anticipation of students' responses. While anticipating students' responses was difficult for the pre-service teachers, it was a rewarding practice. The pre-service teachers felt more confident in the classroom when they have anticipated the students' responses.

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Complex evolution of innovation partnerships: Policy influence, research generation and innovation adoption in a developing country

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ABSTRACT: Appreciating the dynamics of policies on innovation partnership networks is critical to policy developers and effectors. We adopt a time series data to develop a set of dynamic networks that reflect the structure and quality of innovation relations that develop and fizzle-out as specific reforms are applied to innovation partnerships. Industry-specific policies are also considered in relation to the period under consideration. Using specifically selected attributes of the networks we examine the variations as a means of extrapolating the impact of policies on the innovation network. The degree of change in the gradient of structural holes of the networks per period was used to showcase how individuals within the network are being impacted by the policies over time. The evidence shows that the structure and individual attributes have a direct impact on the innovation networks ability to generate research or commit to research funding. These findings indicate that national policies effect the evolution of innovation networks while influencing the desired aims of partnership formation in such evolving systems.

1 INTRODUCTION

Firm connections are critical in determining access to financial resources (Claessens, Feijen, and Laeven (2008); L. Liu, Liu, Tian, & Wang, 2018) subsidization regimes, favourable tax, and borrowing policies. These invariably positions firms to optimize their performance. Emphatically connections to high-level government influenced actors have been reported as having a positive influence on firm innovation performance and strategic partnership decisions (Li, Meng, Wang, & Zhou, 2008; Tsai, Zhang, & Zhao, 2018). The consensus in the literature is that, the process and structure of research and development networks have become more complex and dynamic. Kim and Park (2009), argue that irrespective of these complexities, the static review of collaboration network by researchers should make way for approaches that see these networks as dynamic, and growing. The argument is premised on the fact that seeing collaboration networks as static restricts the ability of researchers and the methods they employ to thoroughly explore knowledge generation and diffusion within the network over prolonged periods with dynamism and variation. Considering that there is marginal research in recent times on the relationship between evolving collaboration network structures and how this impacts the performance of knowledge creation, we focused our research on an evolving collaboration network and how this affects two major aspects of innovation; generation and adoption. We hope to use policy introduction from national actors as the motivating condition that sets the evolution pace whilst reviewing its impact on innovation generation and funding commitments. This selection logic is informed by the locality of the research, where government commitment is a necessary signal of policy success or failure.

Our paper is therefore presented under five major sections. An introduction, that provides a brief view on the network studies in innovation spaces is covered in section one. We conduct a brief literature assessment of how innovation network structure and actor attributes impact the innovation generation through the evolutionary process in section two. In section three, using empirical data from an emerging/developing economy, we showcased the relationship and structural evolution of an innovation network that employs system level and individual level changes to assess how research output and research funding within a policy implementing timeline is affected. We discuss our observations in relation to policy implications and draw a conclusion in the final section.

2 GOVERNMENT PUSHED POLICY AND INNOVATION PARTNERSHIPS

2.1 *Government policy and firm innovativeness*

The translation of knowledge into economic activity has become recognized as a core function of research and academic institutions. The era where the primary ideological justification of research and academic institutions was to pursue the endless frontiers of basic research is long gone (Etzkowitz & Leydesdorff, 1997). The current drive of researchers is to contextualize research in an applicable paradigm through transdisciplinary collaborations. This results in a more reflexive research collaboration that conforms to varying criteria of quality. This new mode of research activity is not meant to eradicate the ideological component, but to complement it (Hessels & van Lente, 2008).

Thus, the institutionalization of the research-based university has created the necessary conditions for the current trans-institutional connections that involve government and industry. This collaboration network has been defined as the Triple Helix Relation (Etzkowitz, 2002). Collaboration networks are heterogeneous which allows for free radicals, it has structure and boundaries which adopt varying assessment criteria; independently adopted and adapted by its actors on clearly distinct paths of decision making (Kogut, 2000; Matt, Gaunand, Joly, & Colinet, 2017). The value of research linked collaboration within this network is found in its ability to admit, modify and regenerate (Clement, Shipilov, & Galunic, 2018) ideas from the various actors in producing new knowledge (Perry-Smith & Mannucci, 2017). Notably, this network at the molecular level does not dissolve existing communication and collaboration paths within the individual subnetworks of industry, government, and co-authors (research institutions); it rather enhances it.

Categorically, whereas industry and academia are responsible for conjoint innovation creation and adoption, the government provides the requisite policy regulation that facilitates their interaction. Literature supports the view that innovation on the one hand and regulation on the other, form the main pillars for national policies on sustainable development (Fabrizi, Guarini, & Meliciani, 2018). The emphasis of studies on innovation collaborations is skewed towards industry-university interactions in subsets of formal disciplines. The focus of these studies has been on the motivating, process, costs, risks associated with such collaborations and how this impacts knowledge production and or innovation generation.

National governments serve as a major index for measuring innovation capacity of institutional actors in a system through government policy interventions in relation to research and development (Clarke, Chelliah, & Pattinson, 2018). This is critical when market forces cannot incentivize the production of knowledge and innovation. It is worth noting the level of impact of policy interventions on innovation systems vary in relation to the political, social and economic systems that develop and implement them. As succinctly put by Wang (2018) policy interventions range from direct; actively influencing industry innovation interactions to facilitative through the creation of enabling environments that assist in innovation generation and adoption by industry. Wang's research concluded that government innovation policies, when directed at the ego-nets of indigenous industries, helps to effectively improve their innovation performance.

Government policies are therefore the enabling catalyst that continuously regulates and structures innovation activities. Contextually, national agencies are to institute reforms and policies that facilitate the interaction of actors within the innovation networks of a country, with a special focus on business and education. One such direct policy would be for governments to invest in science, basic research, aimed at versatile technologies which would invariably yield further innovation. Thus national policies aimed at fostering the development and sustainability of innovation networks must involve the right mix of direct and indirect policy instruments, such as tax cuts, direct research funds, and grants as well as favourable public-private partnership regulations. Towards this end, Von Lohmann (2017) argues for the importance of regulatory agencies to activate reforms that prevents industrial activities that may undermine competition, fair use and dissemination of technology as well as assuring intellectual property within innovation.

Such reforms may, to a greater extent, foster the generation, diffusion, and adoption of innovation through network connections, however, they require strong political leadership, institutional efforts, and clearly defined policy instruments that are well understood by all stakeholders in the innovation partnership (Innovation, 2007).

Given the dynamic evolutionary conditions of innovation environments; industrial enterprises and their partners are increasingly having to diversify their innovation sources and adoption strategies to ensure profitability (Abdu & Jibir, 2017). There is in-depth analysis in the literature on how government policies help support the development, deployment, and adoption of innovation. Sustainability studies on innovation partnerships have resulted in a paradigm shift of innovation discussions to include non-technological innovations, such as novel environmentally-oriented business models and practices (Hannon, Foxon, & Gale, 2015; Rosenfeld, 2017; Tigabu, Berkhout, & van Beukering, 2015).

Evidence also suggests that aside government-linked policies, other factors are critical in the innovativeness of firms. An example is reported by Xu, Tihanyi, and Hitt (2017); that suggested that increased government presence, where higher fiscal powers were controlled by government yielded negative correlation to a firms innovativeness. Further, Abdu and Jibir (2017) observed that firm age, location, type, and industrial sector positively influenced the innovativeness of firms. However, these factors have a direct correlation to the firms' ability to invest in research and development, which in turn signals the firms' readiness to innovate. Other studies that reviewed the role of national policies on firm innovativeness provides evidence that government enterprises in government supported systems were positively moderated by national policies on their Research and Development (R&D) intensity as a measure of innovation performance (Cruz-Castro, Holl, Rama, & Sanz-Menéndez, 2018; He, Wang, Wang, & Wang, 2018). Yi, Hong, Chung Hsu, and Wang (2017), report a study that also showed that region-specific marketization and industry-specific institutional policies enhanced the innovation-enhancing effect of state-regulated innovation systems. In such instances, even weak firms in emerging market economies are able to innovate despite weak internal capacities to adopt the innovation.

2.2 *The contextual case of policy linked innovation partnership networks*

As institutions develop network relations and form innovation partnerships, it incorporates adaptive changes which support the diffusion of information, however, the structure of the network that evolves out of this growth influences the evolutionary dynamics as well as the flow of innovation.

Research suggests that the appreciation of the structural influence on innovation diffusion within dynamic networks must be explored at the system level as it helps provide clarity to policy developers on best intervention conditions for growing and evolving networks (M. Gibbons et al., 1994). An approach was published by Liang and Liu (2018), which uses the network structure in relation to attributes of actors in a network to determine their contribution to innovation performance within the network. Building on the Liang and Liu (2018) approach, our research reviewed some structural characteristics in relation to individual institutional attributes within an evolving and dynamic innovation network and how this relates to funding and research output when the network evolution is contingent on the introduction of a national policy targeted at the source of innovation. The idea is to observe the structural and relational changes that emerges within the innovation network based on the introduction of a government pushed policy. The underpinning conceptual logic of our research is presented in Figure 1.

The argument presented in Figure 1 is premised on the condition that policy introductions set the motivating conditions for partnership formation, strengthening or fracturing of partnership networks. Our research considers this as the signal of the evolutionary impact of the policy on the innovation network. Institutions, therefore, engage in hedging-related partnerships, with projected benefits through direct and indirect ties. Considering that transitive flow of information is related to innovation diffusion, fund transient impacts, policy linked partnerships; when established partnerships yield desired results, the resultant effect is expected to be a dynamically evolving self-sustaining network of partnerships that generate innovation. This concept is tested on the innovation partnership network within an emerging economies landscape.

Research and institutional policies in emerging and developing economies tend to be strongly influenced by national government politics. The non-secession of control of institutions that generate knowledge vis-à-vis the industrial partnerships they establish provide unique conditions that allow policy to be one of the critical factors that influence, growth, dynamics, and evolution of such systems. The control of research institutions in such environments builds on prior history, where they have provided the requisite knowledge, motivation, and logic for which political stability has been observed or lost (Effah & Bernardin, 2008).

Our research draws evidence from Ghana, an emerging economy. A country, which post-independence, has rolled out several education policies that have had the diverse impact on the higher education landscape (for an in-depth analysis of this see Adu-Gyamfi, Donkoh, and Addo (2016)) with varying results. This paper shall not concern itself on reviewing the policy history of Ghana, what is important is that each policy introduction dynamically influences the innovation network hinged on research and invariably affects funding for research. Such observed changes in innovation networks are not unique to an emerging economy like Ghana; for example, Radas and Božić (2009) report a study on SME networks in Croatia and how policy influenced their reaction to innovation

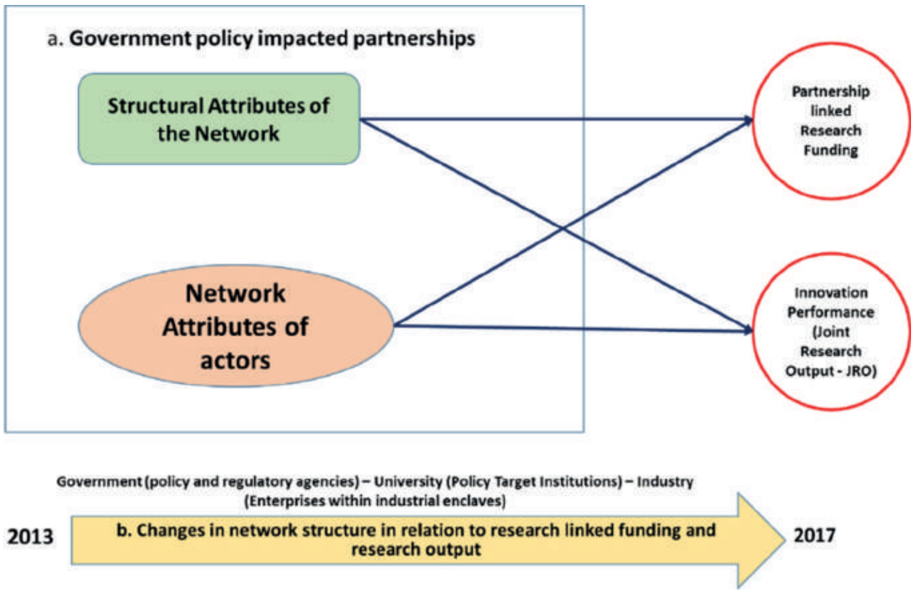

Figure 1. Research concept.

adoption and related activities. The study observed that SMEs in an innovation network whose innovation adoption activities are facilitated by policy, evolve to overcome adoption obstacles along the evolutionary trajectory of their innovation networks. Mandell (1999), also report in a study that, resource scarcity in relation to restrictive public policies provide the motivating conditions for firms to innovate methods that help optimize innovation adoption in relation to desired benefits. The study suggests that this is not unique to emerging economies with their accompanying myriad resource challenges, as it is reflective in the developed economies like the United States where industries seek efficient and effective collaborations with research institutions in the face of government policies as a means of achieving innovation benefiting partnerships. It is worth noting that research indicates that these collaborations, do not rely on government controls to achieve change. Change in such systems is a product of the dynamic partnerships that evolve allowing government policies to be substituted with collaborations that provide partners with equal and equitable access to innovation. Recent studies that have focused on individuals within policy based networks suggest that as key actors in a policy network develop policy linked preferential linkages in line with policy-based implementation activities they provide the requisite motivation for new actors to join the network (Biemans, 2018; Hakansson, 2015; Koliba, Meek, Zia, & Mills, 2018). The policy impacted actions of key actors; perceived to be relatively static; can be considered as *uncertainty reducing*, especially when rapidly changing political environments are involved.

3 METHODOLOGY AND DATA

3.1 *Measures of analysis*

3.1.1 *Dependent*

The network linked innovation studies have adopted patent count (Dang & Motohashi, 2015; Lindman & Söderholm, 2016), funding size (R. Liu & Rammer, 2016; Plank & Doblinger, 2018), research count and other critical variables to assess the impact of changes within the network on innovation. We reviewed the unique situation of the data landscape and opted to measure two dependent variables. The first variable focuses on the proportionate contribution of industry or private sources to research funds of higher education institutions in the period(s) of interest. The second focuses on research output of higher education institutions in relation to the policy timelines under consideration. Research output is a strong signal of knowledge stock which heralds the deposit rate in the innovation bank.

3.1.2 *Independent*

The authors considered various actor attributes that could be measured in a network as having an impact on the structure and dynamics of connectivity within the network and settled on direct and indirect ties as well as network efficiency as the first component of the independent variables for accessing the impact of policy on the network. The other component reviewed proximal relations between institutions, technology, and distance. The study used UCINET 6 version 6.657 to calculate for all the independent variables. Since the software is already embedded with the mathematical algorithms needed to calculate the independent variables we do not feel the need to reiterate them in this research.

3.2 *Data*

3.2.1 *Policy linked phases*

In 2013, following a policy dialogue and an advisory memo to the Minister for Education, Polytechnics in Ghana were slated for institutional remodelling after more than a decade of non-evolving state. The policy process was initiated by the President of the Country at a State of the Nations Address following which several activities were initiated; culminating in the selection and conversion of six (6) of the polytechnics into Technical Universities

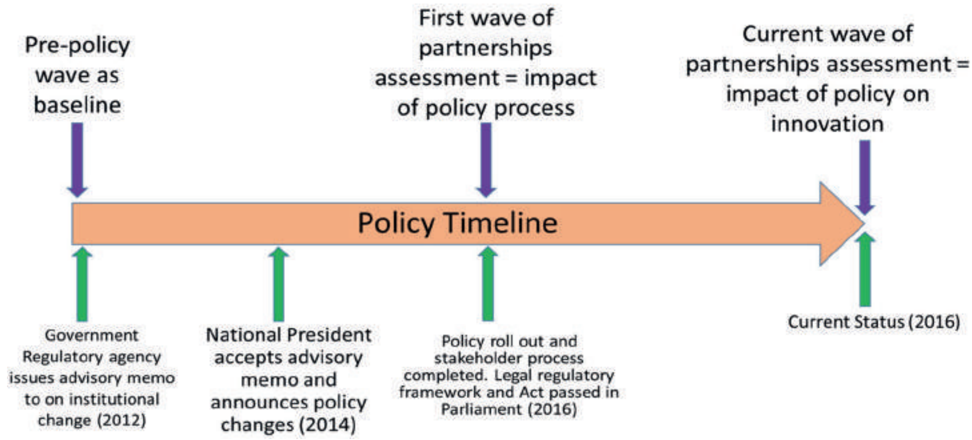

Figure 2. Data collection in relation to policy timeline.

(Afeti et al., 2014). The subsequent passage of the Technical Universities Act, 2016 – Act 922 (Ghana, 2016) saw the legal elevation of five (6) polytechnics to the status of technical universities with the ability to run diverse industry-specific technical programs concurrent to the existing higher national diploma certificates. The research focuses on the partnership network of these elevated institutions prior to elevation (baseline), during the elevation process (2014 and 2016) as well as post legal conversion (2017–2018). The data collection in relation to the policy implementation timeline is presented in Figure 2.

3.3 *Weight determination*

3.3.1 *Academic institutions*

The five institutions involved the study were scored based on metrics developed by the Times Higher Education institutional ranking system as well as the Academic Ranking of World Universities (ARWU) ranking instruments. The average score for each of the ranking factors was considered to be the score of the institution. The natural log of this score was considered as the institutional weight in the innovation network. This weight was considered as the pheromone that attracted potential partnerships with industry. Each polytechnic was connected to all government agents within the network through policy development or regulation activities.

3.3.2 *Industry and government*

Reviewing institutional partnership documents, research partners were identified and grouped into common areas of operation such as Agriculture, Finance, and Manufacturing. Each of these industrial enclaves was populated with established firms designated with numbers in relation to their unique industrial space. Small and Medium Enterprises that were linked to the institutions through these firms were considered as transitive actors. Weights for industrial partners was determined using proportionate contributions to research in real monetary values. The natural log of these proportional contributions was then considered as the weight of enterprises and firms within the innovation network.

Government weight was simply determined as the log of the committed policy allocation for each government agency within the policy network.

3.3.3 *Linkage development and link weights*

Government agencies were observed to be linked only to academic institutions (polytechnics/technical universities) within the policy space and thus were responsible for policy generation and diffusion. The academic institutions were also considered to be linked to each other by virtue of their common designation as well as their Institutional Heads being members of a national association of academic institution heads. Industrial firms were linked to academic institutions on the basis of common research outputs while being linked to other firms through common products.

Link weights was simply a sum of the weights of individual institutional actors when they form a partnership link. The software used for the network plotting and subsequent analysis does this actor-attribute-summation link-weighting automatically.

3.3.4 *Data analysis and network plotting*

The network was graphically plotted using NetDraw (Stephen P Borgatti, 2002; Steve P Borgatti, 2002) and analysed using UCINet6 (Borgatti, Everett, & Freeman, 2002; Borgatti, Everett, & Johnson, 2018). The relationship between network structure and individual network attributes of institutions within the evolving network was analysed using the STATA software based on a multiple regression approach which was logically represented as

$$Structural\ Impact = Model\ 1 = \begin{cases} F = \alpha_{11} + \beta_{11} + \beta_{12} + \beta_{13} \ldots \beta_{1n+1} + u \\ R = \alpha_{11} + \beta_{11} + \beta_{12} + \beta_{13} \ldots \beta_{1n+1} + u \end{cases} \tag{1}$$

$$Institutional\ Attribute = Model\ 2 = \begin{cases} F = \alpha_{21} + \beta_{21} + \beta_{22} + \beta_{23} \ldots \beta_{1n+1} + u \\ R = \alpha_{21} + \beta_{21} + \beta_{22} + \beta_{23} \ldots \beta_{2n+1} + u \end{cases} \tag{2}$$

where:

F = Research Funding contribution per phase;
R = Research Output per policy phase;
α = Constant as determined by the R^2 output of the analysis per policy phase;
β_{1n} = Coefficient of Structural Attributes of the network per policy phase;
β_{2n} = Coefficient of Institutional Actor Attributes of the network per policy phase;
u = Error factor.

Each model was tested per policy phase as the network evolved.

3.4 *Summary of data*

3.4.1 *Networks*

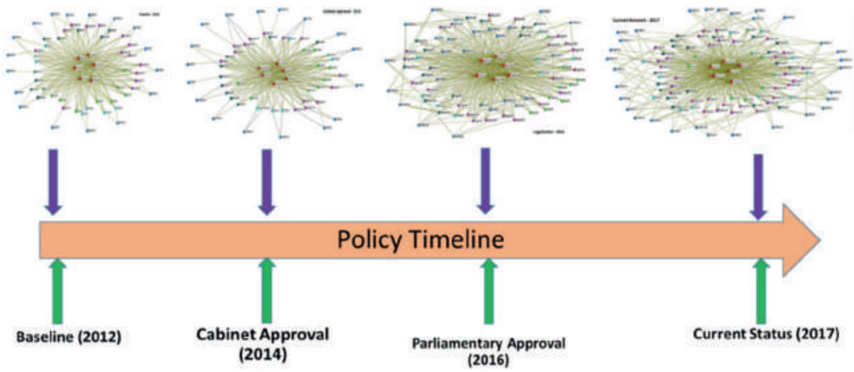

Figure 3. Policy linked evolution of innovation partnership network.

Table 1. Network evolution with the comparative proportionate contribution to R&D per period,.

	Network size				Counterpart funding of R&D				Network size				Counterpart funding of R&D		
Period	Actors	Edges	Density	Average distance	Industry	Proportionate contribution	Average research	Period	Actors	Edges	Density	Average distance	Industry	Proportionate contribution	Average research
2013	62	399	0.148	2.331	Agric.	0.26	339	2014	62	404	0.148	2.331	Agric.	0.24	394
					Manuf.	0.9							Manuf.	0.9	
					SME	0.7							SME	0.7	
					Finance	0.29							Finance	0.30	
2016	83	690	0.154	2.01	Agric.	0.40	438	2017	106	772	0.098	2.397	Agric.	0.51	448
					Manuf.	0.12							Manuf.	0.16	
					SME	0.6							SME	0.7	
					Finance	0.21							Finance	0.15	

4 RESULTS

4.1 *Structural evolutional of the innovation partnership*

In Figure 4, we present the individual structural stages of the network as it evolves in tandem with the introduced policy. The focus was on how academic institutions were providing platforms from which other actors within the network was developing new connections. This was considered in relation to the continuing dissemination of information on the policy by government agents. The combined influence of these two forces we were responsible for the observed changes within the network. Thus there is a gradual change within the network structure from base line to the current phase of the introduced policy. The data shows that on inception of the policy, the innovation networks were evolving at a rate of about 0.0078 from baseline to cabinet phase. As the government agencies activities pushed the policy towards full implementation, industrial actors renewed or established new linkages with the academic institutions. We further observe emergence of inter-firm connectivity especially among small and medium enterprises (SME's). Generally, this accounted for the progressive growth and evolution of the network as shown in Figure 4. The observed decline in the growth rate of the network in current state (F) is reflective of the reduced confidence in the sustainability of the policy by stakeholders; considering the fact that it was an election year and the possibility of a government change signalled increased probability of truncated policies as typical of emerging economies (Kugler, 2018).

We are inclined to side with the extant literature that suggests that interactive networks are structurally infused with gaps which have been termed as structural holes (Lee, Chong, Liao, & Wang, 2017; Obstfeld, 2017). Structural holes provide opportunities for network actors to serve as bridging platforms with the resulting transitive links providing diverse paths for critical information flow between probable isolates and main systems (Borgatti et al., 2018; Jung, Song, & Feiock, 2017). This provides opportunities to measure the innovation influence of actors who provide bridging characteristics between actors that fall on either side of a gap. This analogy provides that such actors are at a competitive advantage in relation to brokering connections, accessing non-redundant actors as well as controlling network flows (Burchard & Cornwell, 2018).

Network analysts review nodal influence in complex networks as a means of extrapolating their contribution to information generation and invariably their importance within the system. Studies have adopted various approaches to present how bridge-forming attributes

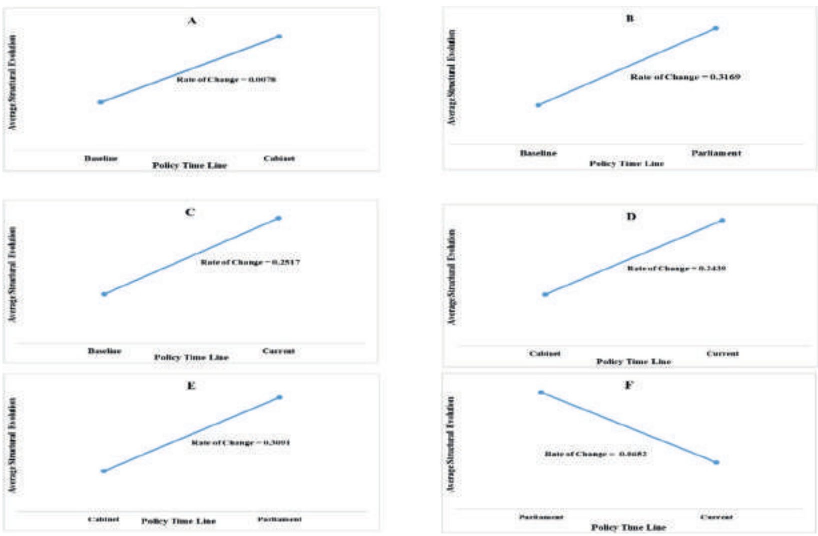

Figure 4. Comparative changes in innovation networks structural holes.

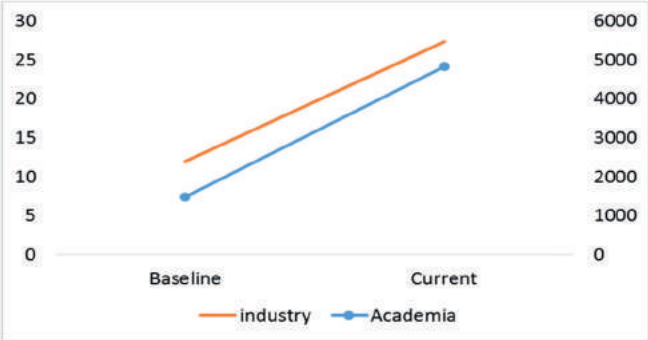

Figure 5. Comparative structural holes of industry-academia.

of key actors impact network development, evolution and sustainability. An example is a study that adopted node ranking based on the E-Burt method to determine node importance in weighted networks (Hu & Mei, 2018). In general, our research reviewed the average structural hole characteristics of actors within the policy linked evolving network to determine how actor importance within the network was evolving alongside the network (Figure 5). We considered this to be a signal of actors general impact on innovation generation (Burt, 2000; Knoke & Burt, 1983), it was observed that each phase of the policy development process resulted in the significant changes in the structure of the innovation partnership. Actors developed relevant connections as signalled by the fairly stable increase in the slope of the comparative presentation of the average bridging capacity of the key actors (Figure 5).

On the average, during baseline period academic institutions were responsible for providing access to about 1000 actors within the network whilst the actors within the research institutions reversely had access to about 10 industrial institutions as funding sources. This relatively increased to about 5000 academics to 30 industries. Relating this observation to our initial hypothesis on how policy influenced evolutionary dynamics helps improve academia-industry relations, we observe that at baseline the industry-academia ratio was at 1:100 this changed to 1: 167 within the period of assessment. The marginal change in industry-academia ratios in comparison to the research output of about 27.25% per policy phase, indicates that national policies that seek to restructure academic and or research institutions influence the interactions between industry-academia relations. Data in Table 1 suggests that the innovation networks evolved at a rate of 11% per policy period resulting in an average of 80 new partnership per phase.

4.2 *Impact of structure and actor attributes on research funding and research output*

In this section, we apply our multiple regression to check the proposed research framework. This approach was used to highlight the impact of structural evolution (Table 2) as well as evolving institutional attributes and connections (Table 3) on the Research funding and research output as a means of measuring how the introduced national policy had influenced the evolution of the innovation partnership network. In both Tables 2 & 3, we present our findings in relation to the policy evolution phases from 2013 to 2017. The *current* (2017), *legal*[1] (2016), *cabinet2*[2] (2014), and *base* (2013) periods.

1. When the policy and proposed parliamentary bill was tabled for discussion at the Parliament of Ghana. The discussion phase runs from early 2016, until September 2016 with subsequent amendments being proposed in December 2016.
2. The proposed policy was submitted to the Presidential Cabinet of Ghana through an advisory memo and was accepted by the president in the latter part of 2013. Cabinet discussions and international donor activities ensued throughout 2014 resulting in policy revaluation, stakeholder acceptance, and institutional assessment.

As per Table 2, structural evolution of the network as a result of government policy introduction had a positive impact on research funding during the current, cabinet and base periods with coefficient values of **1.1519**, **117.021**, and **6.201** respectively, which proved to be significant at one percent (1%) level in each period. The study observed that the evolution of the network had a negative impact on research funding during the legal period. The impact value though insignificant helps to provide the uncertainties industrial partners associate with government policies when resolved to parliament for rationalization in most emerging economies. The political manipulations, coupled with partisanship overshadow national development agendas in such instances in emerging economies and as a result, industrial partners are reluctant to commit funds to research partners. In the case of Ghana, the issue was strongly related to the how the proposed parliamentary bill was going to affect institutional autonomy as well as the possibility of government change since 2016 was an election year in Ghana.

The relationship between structural evolution and research output as an indicator of the networks innovation performance index, the results suggest that innovation performance benefited from the evolutionary dynamics of the innovation network. Thus the impact of policy linked changes in the network resulted in **1.435, 0.046, 45.001** and **50.494** coefficient values for research output during each period under analysis at the one percent (1%) significance level.

The research has proved that policy linked evolution of networks impacted positively on the innovation performance index of innovation networks, sort to understand how institutional characteristics within the evolving network affected research funding commitments from funding partners. The results of this test are presented in Table 3.

Table 2. Impact of structure on research funding and research output.

	Current	Legal	Cabinet	Base
Research funding as dependent				
	1.519***	–0.001	117.021***	6.201***
Structure	(9.92)	(–0.50)	(3.24)	(19.73)
R^2	0.4836	0.0031	0.1465	0.8664
Adjusted R^2	0.4787	0.0093	0.1325	0.8642
Research output as dependent				
	1.435***	0.046***	45.001***	50.494***
Structure	(6.72)	(36.99)	(7.05)	(7.66)
R^2	0.3009	0.9441	0.4492	0.4943
Adjusted R^2	0.2942	0.9434	0.4402	0.4859

***, **, * Show significant level at 1%, 5% and 10%. The t-values are in parenthesis.

Table 3. Impact of actor attributes on research funding and research output.

	Current	Legal	Cabinet	Base
Research funding as dependent				
	2.265***	–0.008***	520.875**	46.389***
Actor	(34.71)	(–4.03)	(2.02)	(7.90)
R^2	0.9198	0.1671	0.0626	0.5099
Adjusted R^2	0.9191	0.1568	0.0473	0.5017
Research output as dependent				
	2.277***	0.040***	231.939***	363.364***
Actor	(13.91)	(14.23)	(4.60)	(4.70)
R^2	0.6481	0.7142	0.2576	0.2692
Adjusted R^2	0.6448	0.7107	0.2455	0.2570

***, **, * Show significant level at 1%, 5% and 10%. The t-values are in parenthesis.

Our study suggests that institutional actors' attributes have a positive impact on research funding for the periods of 2017 (**2.265**), 2014 (**520.874**) and 2013 (**46.389**) at the significant levels of one (1%) and five (5%) percent levels respectively. The observed negative relation between the structural evolution of the network and research output was reflected in the relationship between research funding and the same phase of the policy timeline. There was an observed relational coefficient value of **–0.008** at the significance level of one percent (1%).

Interestingly, our research reports that the relationship between institutional actors' attributes and ability to generate research, was positively impacted by the dynamics of policy introduction into the evolving partnership network. The results indicate that at the one percent (1%) significance level, institutional actors impacted research output at the current phase at **2.277**, the legal phase at 0.040, the cabinet phase at **233.939** and **363.364** for the baseline phase.

5 DISCUSSION

The ability for innovating partners to develop new relations within a network through an innovating generating actor is critical to survival of the innovation system. De Silva, Howells, and Meyer (2018), argued actors that served as bridges within an innovation network evolve to be innovation intermediaries and eventually generate value for themselves through collaborations that they develop with other actors within the network.

Janssen (2019), argues that national development strategies have redefined generic policy target approaches from the general to specific aspects and actors within the innovation network. The new focus rather than prescribing a government-to-industry diffused policy, seeks to encourage all actors in the innovation space to make contributions towards the success of the policy which invariably increases the sustainability of the policy as well as the diversity and evolution of the innovation network. This happens because of the different trajectories that are harnessed during the evolution of the policy through its formulation, implementation and evaluation stages; helps alleviate inherent constraints that prevent diversification and differentiation within the network (Pietrobelli & Puppato, 2016).

The realisation that government must play steering role in innovation policy development whilst incorporating industrial participation, with the added focus on knowledge creation and diffusion has resulted in calls for transformative innovation policies (Weber & Rohracher, 2012), which results a general system evolution that can be observed analogous to the introduced policy phases. Thus as stated by Janssen (2019), and Kern, Kivimaa, and Martiskainen (2017), the overarching aim of this approach is that the general systemic evolution would provide the incentive for sustained economic growth through innovation generation, diffusion and adoption within competitive networks.

This desired systemically supported economic growth, is essential for addressing technological challenges that face developing societies considering the entrenched attitude of business approaches and institutional standards coupled with fragile political structures adopted by firms that operate in such environments. However as pointed out by Weber and Rohracher (2012) and reiterated by Söderholm et al. (2019) innovation linked sustainable development experience myriad challenges which must be resolved through the adoption of multifaceted policy interventions with well-defined targets within the innovation network. Research that employs network theories to review innovating systems should therefore base impact analysis on the observed variations between initial measures and constructs of the networks under review in relation to the phenomena under consideration. Our results provide credibility for these conclusions.

The adoption of network theory as a means of explaining innovation partnerships has provided varying results with interesting conclusions (Biemans, 2018). Early research indicates a relationship between the network structure and innovation generation alongside its diffusion and eventual adoption. An earlier research pointed out that structural attributes of networks impact the innovation process positively (D.E. Gibbons, 2004). The influence of the structural properties of networks is reported to have extensive influence on partnership developing tendencies of individuals within the network. These tendencies also become subject to the acquired evolving attributes of actors within the network as a result of the evolving contingencies with the system. Thus as the generation source of innovation evolves, the institutional attributes that it acquires within the innovation network influences its readiness-to-partner status.

Ahuja (2000), authored a research that assessed firm-networks in relation to innovation with a special focus on attribute linked ties and actor bridge formation (structural holes), to the subsequent output of innovation by firms within the network. The research indicates that network structure has a positive impact on innovation output with bridge forming actors having playing a pivotal role in the prevailing sustenance of the network through the connections they develop as the network evolves. This notion was observed through our research as reflected in Figures 4 and 5, and further reflected in the evolution linked significance on research generation and innovation adoption.

As aptly put by Pierre and Peters (2005) technological innovation network structures evolve and are shaped by the diversity of actors with varying stakes in the resultant innovation. However this diversity also raises challenges of management (Ollila & Yström, 2015) as such introduced policies must not only reduce the risk of network fracturing by strengthening the innovation capacities of bridging actors. It is imperative for innovation policies to therefore to provide resilience building support to collaborating actors in the network, which will signal reduced risk of investing in innovation generation and adoption within the network.

We set out to review how the dynamic evolution of innovation partnerships affect firm commitment to innovation generation though funding and invariably the effects on innovation generation. Using the evolving nature of the network, and resultant evolution of the individual institutions within the partnership space we showed that the introduction of policy had a positive influence on the innovation spaces and directly impacted on access to research funding, and research production. The economic landscape in which the study draws empirical support provides a unique and novel condition to test how policy linked network metrics affect innovation spaces. Our results show that government policies when supported with the substantive commitment to the policy process, assures partner confidence to sustain the innovation space. That space grows, institutions evolve, establish new partnerships and renew old ones. Though in the process, confidence may waver it is restored once national commitments assure stability.

5.1 *Policy implications*

Policy makers are always seeking innovative and diverse ways to minimize cost while optimizing desired results within economic spaces. Investor confidence in the face of national policy introduction tends to be fickle especially in environments where political control tends to be strong on research institutions. However when the policy is perceived to review the autonomy status of research institutions whilst hinting at freedom of operation, diversity of research direction that signals innovation generation abilities; the partnerships that existed spawn new and evolving versions that expands the innovation space. The observed situation in Ghana provides that when the policy process is allowed to flow and develop the affecting spaces tend to be positively impacted.

5.2 *Limitations*

Admittedly our work engaged only a small part of the innovation space of Ghana. Difficulty in accessing complete partnership documents may have resulted in the alienation of some critical partners that may have provided a different outcome to our study, however, considering the data and the observed conclusions, it is safe to accept the results of our research as reflecting the situation on the ground and further explaining the relations under consideration within the environment the research is based on.

6 CONCLUSION

The researchers hoped to showcase the impact of policy on the evolutionary characteristics of innovation spaces. Simple network analysis was adopted to establish the relationship between partnering institutions and subsequently their attributes at both the system level as well as individual level showed that policy introduction does have a positive influence on innovation spaces growth, evolution, and possible sustenance. In future research, research could examine how policy targeted at industrial spaces affect the evolutionary dynamics of research institutions.

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The 'Neutralization on a Number Line' (NNL) model for integer addition and subtraction

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ABSTRACT: Subtraction involving negative integers is known as one of the biggest problems for students. The number line and the neutralization model have been used very extensively for several decades in introducing integer addition and subtraction. While they have been proven helpful for integer addition, problems remain for integer subtraction. Therefore, this paper aims to investigate how an alternative model, namely the 'Neutralization on a Number Line' (NNL) model together with the 'two-color number card game' context, can be used in a classroom to help students develop a meaning of integer addition and subtraction. Design research methodology was used in this study by conducting three phases: first, designing a Hypothetical Learning Trajectory (HLT), second, trying out the HLT in a classroom, and third, analyzing how the learning process took place as well as how students developed during the lessons. Students' responses and performances were described and the HLT was compared to the actual learning process. The results show that the use of context and the NNL model could give meaning to students that subtracting a negative means adding a positive and subtracting a positive from a negative means adding two negatives.

1 INTRODUCTION

Studies on integer operation involving negative numbers have been a great concern for many researchers around the world, especially regarding integer addition and subtraction. When students first build meaning of negative numbers, there is a conflict between the idea of negative numbers and students' prior knowledge about the magnitude of numbers (Hativa & Cohen, 1995). Ball (1993) mentioned that the two main components of negative numbers, direction and magnitude, are at the root of difficulties seen with negative numbers. While the magnitude of a positive number represents a quantity, the magnitude of a negative number represents a number less than zero or an absence of value. Further, the direction of negative numbers goes to the left of zero on a number line, hence the farther a negative is from zero, the smaller the number. For example, the fact that –7 is smaller than –3 could potentially be confusing for students since they already know that 7 is larger than 3. Moreover, the different meaning of the minus sign is said to be one of the causes of students' difficulty in dealing with integer addition and subtraction—that is, the minus sign in a negative number (e.g. '–7') as the *unary* meaning, and the minus sign in subtraction operation (e.g. '9–2') as the *binary* meaning (Bofferding, 2014).

Figure 1 shows students' mistakes while solving integer subtraction, performed by seventh-graders involved in the present research. Students often ignore the minus sign of a negative number and perform the algorithm as if the number is positive (see Figures 1a and 1b). In Figure 1a, the students dealt with the subtraction problem '–780–30'. The students ignored the minus sign in (–780), simply performed the algorithm '780–30' to find the difference, and then inserted the minus sign after they found the result. Surprisingly, almost half of the students in the classroom of 36 students made the same mistake. In Figure 1c, the students over-relied on the algorithm procedure to find the difference between 145 and 197. The students put the number 145 on top of 197, just in the same order as in the problem,

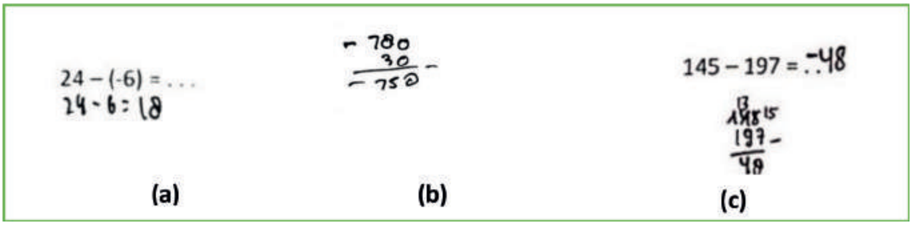

Figure 1. Students' mistakes in solving subtraction of integers problems.

and then performed the algorithm without recognizing that the hundred in the number 197 still remained.

Studies indicated that the use of models could support the development of students' thinking in performing the addition and subtraction of integers. Basically, there are two models for teaching the addition and subtraction of integers, namely the neutralization model (the cancellation model) and the number line model (Van de Walle, 2004). The neutralization model uses counters of two different colors representing positive and negative integers, while the number line model is depicted as a horizontal line on which positive integers are located to the right of zero and negative integers are located to the left of zero.

Modeling integer addition and subtraction on an empty number line follows a certain procedure. For example, to solve '6 – (–2)' using the number line model, students can start at zero facing right and then move forward six steps (+6). Afterward, students must face in the opposite direction (turn around) before they move two steps backward (–2) on the number line to represent the subtraction operation. Freudenthal (1973) pointed out that the number line model could be helpful for supporting integer addition, and NCTM (2000) also recommends students to use the number line model to explore negative numbers as extensions of positive numbers through familiar applications. Further, Stephan and Akyuz (2012) showed that the number line model together with a financial context (assets and debts) could support students' development of integer addition and subtraction, both procedurally and conceptually. Teppo and Van den Heuvel (2014) addressed a wide variety of number line models employed throughout the k-12 curriculum. A number line model can function to display integers, rational numbers and real numbers. Moreover, it also can function to display additive operation, equivalence relationships and multiplicative relationships.

Although the use of the number line model is helpful for supporting integer addition, students tend to have problems when dealing with subtraction with negative numbers because the procedure on the number line requires a shift that is more complicated. Küchemann (1981) pointed out that the number line model should be avoided in teaching the subtraction of integers, and hence a discrete model or the neutralization model was offered as a better solution. Liebeck (1990) also emphasized that the existing concept of addition and subtraction are related to 'adding' and 'taking away' objects. When students use the number line model in subtracting a negative number, there is no relevance between the intuitive concepts of subtraction as 'taking away' and the 'turn around' movement on the number line that represent the subtraction operation.

The neutralization model (also known as the cancellation model) is usually introduced with two-color counters to represent positive and negative integers. If a blue counter represents positive integer and a red counter represents negative integer, then each pair of blue and red counters is equivalent to zero, that is: '1+ (–1) = 0' or '$a + (-a) = 0$'. Hence, students must understand that when pairs of opposite colors of counters are added to a quantity, the value of the original counters remains unchanged (Van de Walle, 2004). Integer addition and subtraction can be interpreted as 'adding' and 'taking away' respectively. For example, in modeling addition of '6 + (–2)', students put six blue counters and 'add' two red counters. Since two red counters cancel out or neutralize two blue counters, then four blue counters remain, which means the result is positive 4. A problem arises when students have to 'take away' counters that do not exist before. For example, when modeling subtraction '6 – (–2)',

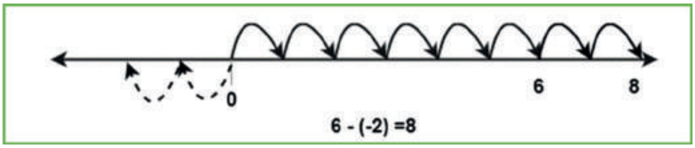

Figure 2. The NNL model for integer subtraction '6 – (–2)'.

Figure 3. The two-color number cards.

students cannot take away two red counters since only six blue counters exist. In this case, they have to 'add' two pairs of red and blue counters or zero pairs so that they can 'take away' two red counters, and eight blue counters remain as the result (Figure 3). Bofferding (2014) argued that this kind of problem could potentially confuse the binary meaning of the minus sign because subtraction operation involves both addition and subtraction—that is, adding the zero pair first and then taking away the number indicated in the problem.

Therefore, a new model is introduced in this research to help students understand the operation of addition and subtraction involving negative integers (i.e. the 'Neutralization on a Number Line' (NNL) model). This model is a combination of the two models so that students can apply the procedure of the neutralization model and trace their strategies on the number line at the same time. Figure 2 illustrates how the model represents integer subtraction of '6 – (–2)'.

The NNL model emphasizes both the ordinality and the cardinality of numbers. A positive integer is represented as a curve above the number line to the right of zero, while a negative integer is represented as a curve below the number line to the left of zero. In other words, mounds to represent positives and hollows to represent negatives. The cardinality of numbers is represented as the number of mounds or hollows on the number line, whereas the ordinality of numbers can be seen in the order of numbers marked on the number line. By using this model, (+6) can be represented as six mounds and (–2) can be represented as two hollows; hence both direction and magnitude of a number can be depicted by using mounds and hollows. To model the subtraction problem '6 – (–2)', students first draw six mounds. Since there does not exist hollows, students can add two pairs of mounds and hollows, which is equivalent to zero. Next, students can take away two hollows, which means subtracting (–2) from 6, leaving eight mounds as the result. This model can facilitate students' reasoning when working with big numbers since a curve can also be interpreted as tens, hundreds or thousands.

However, the model should not be introduced by itself without a contextual situation. The instructional sequence designed in this research presents various contexts in introducing negative numbers to students. Later, the scoring context with two-color number cards is used as an attempt to manage students' mistakes in integer addition and subtraction related to the unary and the binary meaning of the negative sign. The two-color number card is designed in such a way that students can distinguish the unary and the binary meaning of the negative sign. The blue and red figures represent positive and negative numbers respectively, while the color of the cards represents the operation involved, where blue means addition and red means subtraction (see Figure 3).

Therefore, the purpose of this present study is to contribute to the development of the local instruction theory on integer addition and subtraction, as well as to improve practice about both the process of learning and the means designed to support that learning. By designing an instructional sequence and seeing how it works in the classroom, the present study is answering the following question: How can the 'neutralization on an empty number line' (NNL) model together with the 'two-color number card game' context be used to help students develop a meaning of integer addition and subtraction?

2 METHOD

The research questions were answered by taking into account a design research methodology, also well known as design-based research (Cobb et al., 2016), educational design research (McKenney & Reeves, 2013), or classroom-based design research (Stephan & Cobb, 2013). Cobb et al. (2016) defined five characteristics of the design research methodology. First, design studies address the types of problems that arise for practitioners as they attempt to support students' or teachers' learning, and thus contribute directly to improve the quality of educational practice. Second, the highly interventionist nature of the methodology. Third, design studies have a strong theoretical as well as a pragmatic orientation. Fourth, design studies involve testing and, if necessary, revising or abandoning conjectures about students' or teachers' learning processes and the means of supporting that learning. The fifth feature is design studies aimed at generalizability.

Design research methodology has three phases: the design and preparation phase (thought experiment), the teaching experiment or the implementation phase, and the retrospective analysis phase (Cobb et al., 2003). In the present research, an instructional sequence, also called a Hypothetical Learning Trajectory (HLT), was developed in the first phase. The hypothetical learning trajectory is made up of three components: the learning goal that defines the direction, the learning activities, and the hypothetical learning process—a prediction of how students' thinking and understanding will evolve in the context of the learning activities (Simon, 1995). Before the HLT was developed, information was gathered by conducting an interview with the teacher, collecting documents, and identifying students' mistakes and difficulties in solving integer addition and subtraction. This information could help the researcher to better predict and making hypotheses of students' thinking in the HLT. The sequence of learning activities was designed, based on study literatures related to the use of models and contexts in developing the idea of integer addition and subtraction.

The HLT was then tried out in a classroom consisting of 36 students in State Junior High School 92 (SMPN 92), Jakarta. In the second phase, data such as video recordings of classroom activities, photos of students' activities, students' written works, classroom observations and interviews were gathered. A total of five classroom meetings and an interview session with some students were videotaped. Observations took place both on the classroom level and on the individual level. During the teaching experiment, some adjustments happened based on the retrospective analysis on a daily basis. Thus, the HLT reported in this article is a revision of the original HLT that was first developed.

After the lessons took place, the data from different sources were gathered, selected and analyzed by comparing the actual learning process and the HLT. Students' written works were chosen, examined and analyzed in accordance with other sources of data to improve the triangulation. These data will form an analysis to answer the research question proposed in this research.

3 RESULTS AND DISCUSSION

The following are the descriptions of the HLT, along with the results obtained from the teaching experiment. The analysis focuses on how the NNL model together with the 'two-color number card game' context can be used to help students develop a meaning of integer addition and subtraction.

3.1 *Developing concept of negative numbers*

Mathematics Learning Goal:

1. Students develop a meaning of negative integer as an extension of positive integers by using a context such as temperatures, height and depth, assets and debts.
2. Students can compare and order negative integers as well as positive integers.

Learning Activities: Discussion on the use of numbers in daily life; discussion on temperatures below zero; the emergence of a number line, exploring negative numbers in daily life.

Hypotheses of Students' Thinking: A number line emerges from the picture of a thermometer. They can perceive negative numbers as numbers below zero, an extension of positive numbers on the number line.

The results show that the use of the temperature context in developing the meaning of negative integer is very helpful. The discussion about temperature and a temperature below zero, together with the picture of negative temperature in a thermometer can build students' ideas about a negative number. The emergence of a number line from a thermometer is very natural, so that students can perceive a negative number as a number below zero, or numbers that extend to the left side of zero. Once the number line has emerged from the context of temperatures, students can explore negative numbers and the opposite numbers.

3.2 *'Scoring Context' and integer addition*

Mathematics Learning Goal:

1. Students understand that the sum of a number and its opposite is zero. e.g. $(-1) + 1 = 0$
2. Students can solve an addition problem as a subtraction, that is: $\boldsymbol{a + (-b) = a - b}$

Learning Activities: The teacher sets up a game about scoring good and bad marks; a series of questions utilizing the neutralization model is displayed; the teacher poses a series of addition problems and students discuss the strategies. During the discussion, students conclude that:

$$\boldsymbol{a + (-b) = a - b;\ (-b) + a = a + (-b) = a - b;\ (-a) + (-b) = -(a + b)}$$

Hypotheses of Students' Thinking:

- It is expected that by experiencing the scoring game, students recognize that if any negative number is added to a positive number, then the positive number will decrease. In other words: $\boldsymbol{a + (-b) = a - b}$
- In solving the problems, students are free to use any strategies. We assumed that most of students rely on the algorithm strategy in solving the problem.

Most of the students involved in this study already had knowledge and experience in working with negative integers when they were at the elementary schools. Therefore, how students responded during the lessons was very influenced by their prior knowledge. For example, a student explained in front of the classroom that to solve '$-36 + (-40)$' he started by writing (-36) on an empty number line, then performed jumps of ten backward four times to represent (-40) and then ended at (-76). Although most of the students in the classroom performed algorithm strategy in solving the problem, they were already familiar with the ‘counting backward’ strategy to explain the solution when adding two negative integers. Another segment of the classroom discussion showed how another student solved the integer addition ‘–68 + 571’. First, he solved the problem by subtracting 68 from 571 using algorithm strategy, and then he explained why the result is positive.

‘571 minus 68 is 505’
‘Look, which one is larger, 571 or 68?’ (pointing to the numbers while explaining to his friends in the classroom)
‘571 is larger than 68, since 571 is positive, so the result is positive.’

A short interview during the lesson revealed students’ prior knowledge in perceiving a negative integer as a debt, and a positive integer as the amount of money that you want to pay for the debt. If the debt is bigger than the money you have, then you still have a debt. But, if the debt is smaller than your money, then you can pay all the debt and you still have money left over. The analogy of debt and asset in solving addition of a negative integer and a positive integer is found useful to help students make sense of the problem. Therefore, to avoid students’ confusion in dealing with integer addition involving negative numbers, students were free to use any kind strategies that they were familiar with. However, a problem occurred when the algorithm strategy was applied.

Niki was struggling in determining the difference between 947 and 39. She attempted the same procedure three times until she finally got the correct answer. Niki over-relied on the algorithm strategy. She had a doubt when finding the difference between 17 and 9. If only Niki could have seen that 39 is close to 40, so when 40 is subtracted from 947 there remains 907; then 39 is subtracted from 947 and there remains 908. There is a possibility that Niki might have used this compensation strategy in her thinking, or there might have been other strategies because she realized that her first attempt was a mistake and also her second one. Thus, she made the third attempt to get to the correct answer. However, this tells us that students might think that there is no way but to use the algorithm that is acceptable for the solution of a calculating problem.

Although the students were given activities using the neutralization model with blue and red counters before they solved addition problems, there is no evidence to indicate that students used this strategy in solving integer addition involving negative integers. If the neutralization model was used to solve the problem ‘–947 + 39’, then (–947) can be seen as ‘(–900) + (–40) + (–7)’ and positive 39 can neutralize or cancel out (–39) from (–40) and (–1) is left; then (–1) together with (–900) and (–7) becomes (–908).

Niki was one of the smarter students in the classroom. Based on Figure 4, she double-checked her answer and realized there was a mistake. Based on a close examination of

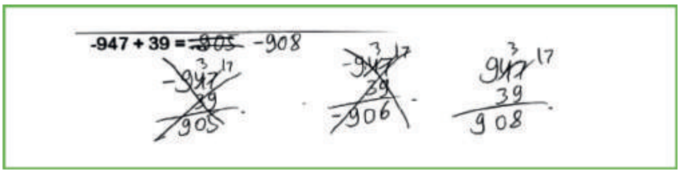

Figure 4. Niki’s difficulty in performing algorithm strategy.

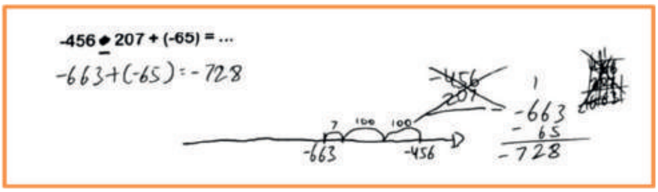

Figure 5. Niki’s strategy in solving ‘–456 –207’.

Niki's written work, she has the understanding of $(-b) + \boldsymbol{a} = \boldsymbol{a} + (-\boldsymbol{b}) = \boldsymbol{a} - \boldsymbol{b}$. However, Figure 5 shows how Niki dealt with integer subtraction '–456 –207'. Instead of using the algorithm procedure, Niki used the counting backward strategy on a number line to find the difference between –456 and 207.

3.3 *'Scoring Context with Two-Color Number Cards' game and the 'Neutralization on an Empty Number Line' model*

Mathematics Learning Goal:

1. Students understand that subtracting a negative integer means adding its opposite, that is: $\boldsymbol{a} - (-\boldsymbol{b}) = \boldsymbol{a} + \boldsymbol{b}$
2. Students understand that subtracting a negative from a negative means adding the two negatives, that is: $-\boldsymbol{a} - \boldsymbol{b} = (-\boldsymbol{a}) + (-\boldsymbol{b})$

Learning Activities:

- Students play a game with a two-color number card.
- The rule is that students have to either 'ADD' or 'TAKE AWAY' the score as many times as the number written on the card.
- The students are asked to show how they add and take away a number on a number line, by drawing a mound to represent a positive integer, and a hollow to represent a negative integer. After playing the game, students discuss and share their strategies in a classroom discussion. During the discussion, students conclude that:

$$\boldsymbol{a} - (-\boldsymbol{b}) = \boldsymbol{a} + \boldsymbol{b} \text{ and } -\boldsymbol{a} - \boldsymbol{b} = (-\boldsymbol{a}) + (-\boldsymbol{b})$$

Hypotheses of Students Thinking:

- The two-color number card is expected to be able to help students distinguish between the unary meaning and the binary meaning.
- As students are experiencing this game, they might face the following problems:
  - how to take away hollows when there are not enough hollows or no hollow exists.
  - how to take away mounds when there are not enough mounds or no mound exists.
- For students who have difficulties in 'remembering' the rule of integer subtraction, the 'neutralization on an empty number line' model might be helpful for them to explain that subtracting a negative means adding a positive, and subtracting a positive from a negative means adding two negatives.

As students are experiencing the scoring game, they can distinguish the idea of the unary and binary meanings of the negative sign by using the 'two-color number card'. Yet, the fact was seen that many of the students struggled with the instruction of adding zero pairs. However, a close observation by student Jodi indicates that there was an improvement of Jodi's understanding in integer subtraction. Before experiencing the scoring game with the 'two-color number card', Jodi's misunderstanding in solving integer subtraction is seen in Figure 6.

Jodi executed the subtraction '788 – (–92)' by performing the algorithm to find the difference between 788 and 92. He misunderstood the meaning of $\boldsymbol{a} - (-\boldsymbol{b})$ as being $\boldsymbol{a} - \boldsymbol{b}$. Figure 7 shows us how Jodi misinterpreted the subtraction problem '–780 –30' as '–780 + 30'. However, both Figures 6 and 7 reveal that Jodi did not have any problem related to integer addition. He had already built an understanding that when a negative is added to a positive, then he performs a subtraction to find the difference.

As Jodi was experiencing the scoring game with the two-color number card, he gradually developed ideas of unary and binary meaning of the negative sign. It is seen in Figure 8 that he could manage the subtraction '180 – (–70)' by drawing nine mounds, with each mound representing positive 20, and then adding a pair of a mound and a hollow to represent positive 70 and negative 70 respectively. It is observed that he developed the idea that

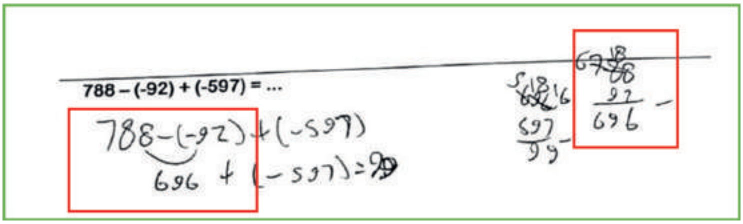

Figure 6. Jodi's misunderstanding in solving subtraction type 'a – (–b)'.

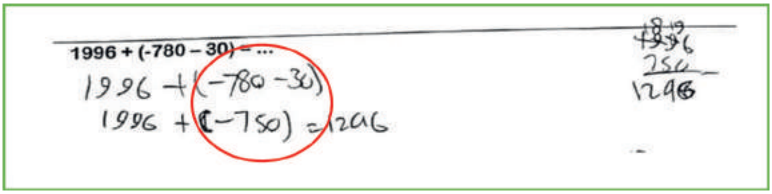

Figure 7. Jodi's misunderstanding in solving subtraction type '–a – b'.

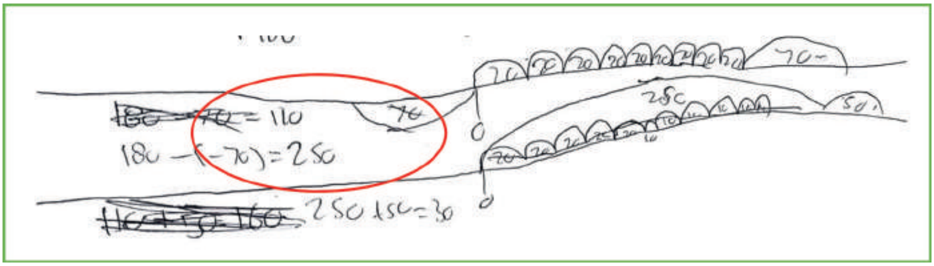

Figure 8. Jodi's strategy on the NNL model (subtraction type '*a* – (–*b*)').

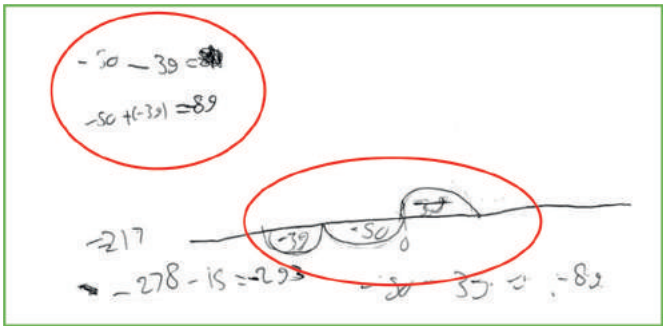

Figure 9. Jodi's strategy on the NNL model (subtraction type '–*a* – *b*').

subtracting a negative means adding a positive, that is: ***a*** – (–***b***) = ***a*** + ***b***. At the beginning of the scoring game, Jodi drew a mound or a hollow representing positive 10 or negative 10. Later, he became more confident by drawing a hollow that represented negative 70. Afterward, he did not split the integer into tens when drawing mounds or hollows. He used the hollows and mounds to help him understand the meaning of subtracting and adding an integer.

Figure 9 shows how Jodi has developed his understanding that –***a*** – ***b*** = (–***a***) + (–***b***). By drawing a hollow representing negative 50 and adding a pair of positive 39 and negative 39, and then crossing out the positive 39, Jodi understood that in the problem '–50 –39', he must take away positive 39 from the figure. Therefore, he had negative 50 and negative 39 left over in the figure, which means negative 89 altogether.

3.4 *Discussion*

The designed instructional sequence starts with a discussion on the use of positive numbers in daily life. The understanding of the use of positive numbers help students comprehend the idea of negative integers as the extension of the positive integers. This is in line with Bruno & Martinon (1999) about the importance of previous ideas on positive numbers and how these ideas influence the knowledge of negative numbers. Moreover, according to Gallardo (2002), integer concepts and operations is an extremely difficult content area for most students to learn with meaning. Hence, a context plays an important role in introducing negative integers and operations. Contexts that have been proven useful are temperatures, height and depth, assets and debts, mounds and hollows, and good and bad marks. Most of the students involved in this study already have an idea about negative integers as debts and positive integers as assets. Therefore, students are free to use which contexts and models that they are familiar with.

However, the results show that although many students had already built an understanding about integer addition and subtraction, mistakes in dealing with the algorithm strategy are apparent. Some students show their understanding on number relation and how this affects their strategies in performing integer addition and subtraction. But others show a poor understanding of number relations. At some point, it is very crucial for students to develop their mental arithmetic strategies in dealing with numbers. Buys (2001) defines mental arithmetic as a way of approaching numbers and numerical information in which numbers are dealt with in a handy and flexible way and characterized by the use of number relations. Most importantly, Ernest (1985) points out that if models are used incorrectly they can force students to engage in rote learning of procedures without connections to mathematical ideas. Therefore, the instruction of the learning activity must be given carefully so that students can develop their ideas in dealing with integer addition and subtraction.

4 CONCLUSION

This study utilizes both the neutralization model and the number line model at the beginning of the lesson. Students were given contexts related to both models to develop a meaning of the cardinality and ordinality aspects of integers. Students' prior knowledge on the use of the number line model is more dominant than with the neutralization model. Although the students were given activities in neutralizing with blue and red counters before they solved addition problems, there is no evidence showing that students used this strategy in solving integer addition and subtraction. In many cases, students made mistakes in solving integer subtractions using the algorithm strategy. They simply performed the procedure without considering the negative sign of a number.

Although the support of the game together with the model is not obviously seen in the classroom community, Jodi's development is an evidence that the scoring game with the 'two-color number card' and the 'neutralization on an empty number line' model is useful to help him manage his misunderstanding, especially in integer subtraction. He gradually improved his understanding about the unary and binary meaning of negative by using the 'two-color number card'. Both cardinality and ordinality aspects of numbers can be represented by using the NNL model. This model also allows students to work with big numbers and finally helps students to build the idea that subtracting a negative means adding a positive, and subtracting a positive from a negative means adding two negatives.

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Students' difficulties in solving algebraic operations: Case study in a Community Learning Activities Center (PKBM)

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ABSTRACT: Teaching and learning activities to be used at Community Learning Activities Centers (PKBMs) are not yet feasible. The current paper reports on the results of a case study conducted by the researcher on administering an algebra test for students. The aim is to observe students' abilities in solving algebra problems and matching the difficulty encountered by them with the type of difficulty based in Arithmetic, Variables, and Algebraic Expressions (AVAE) theory. The algebra test was administered to 15 students of package B and then the results were analyzed. It was found that students' abilities in solving algebraic operations are still low. The difficulties that we found include algebraic operations, understanding variables and using mathematical symbols. These findings suggest that students' algebra abilities need improvement and the difficulties faced by the students do not differ so much from those found in the results of the research that created the AVAE theory.

1 INTRODUCTION

Until now, the process of human development in Indonesia has been done through educational efforts, with more emphasis on education or formal education only (Hasan & Nurhayati, 2012). Whereas, the current issues facing formal education are regarding students who drop out of school. Based on statistical data issued by the Indonesian Ministry of Education and Culture in 2016, the number of drop-out students in Jakarta for Junior High School reached 1,080 (Kemendikbud, 2016). That number is not a small amount. One of the roles of informal education is to provide learning facilities outside of school. The Center for Community Learning Activities (*Pusat Kegiatan Belajar Masyarakat* (PKBM)) is one of the institutions included in informal education. PKBM provides package A chase facilities (equivalent to elementary school), package B (equivalent to junior high school) and package C (equivalent to senior high school) for students who drop out of school in formal education. However, if we observe directly in terms of quantity and quality of teachers, we find that the situation in PKBMs is far from ideal. The result of observation in one PKBM in East Jakarta revealed that the number of teachers who taught mathematics package B was only one, and this was taught by a science teacher. In addition, the math study time was only once a week and each meeting never lasted more than 60 minutes.

The topic that becomes a big part of the package B of the National Exam is algebra. In addition, algebra is a new topic introduced in junior high school, which is the development of arithmetic learned in elementary school (Kusaeri, 2012). Some research on package B programs shows that algebra is a topic that is difficult for students to understand (Masyita, 2014; Yatimah, 2014; Januarvi, 2016). In the mathematics curriculum, algebra has been widely recognized as one of the most difficult topics, leading to learning difficulties worldwide (Jupri & Drijvers, 2016). Errors committed in solving algebraic problems are manifestations of this difficulty (Jupri et al., 2014). In addition, understanding the topic of algebra is the key to success in learning the next mathematical topics, including geometry and calculus (Star et al., 2015).

Drijvers (2010) uses the term 'algebraic expertise' in reference to students' ability to use algebra that is not only basic skills, but also symbol sensitivity. That is, students cannot reason algebraically if they cannot perform algebraic operations, and vice versa, students often require algebraic reasoning to perform algebraic operations. Pujianto (2012) also shows that the ability to understand algebraic operations is still lacking, so that in the next class of algebra learning, students experience obstacles.

The purpose of this study is to conduct a case study to demonstrate students' abilities on the subject matter of the student's algebraic form in the package B program. In addition, students find difficulty in answering and matching the difficulty with algebraic difficulties based in Arithmetic, Variables, and Algebraic Expressions (AVAE) theory. The theory of AVAE in Jupri et al. (2014) includes: (1) *applying arithmetic operations* (ARITH), for example the use of systematic operations, algebraic form operations, the use of distributive and associative, and the use of inverse addition and multiplication; (2) *understanding the notion of variables* (VAR), for example understanding the meanings and constants in the algebraic form and expression; (3) *understanding algebraic expressions* (AE), for example understanding important things in the form of algebra such as <, >, ( ), negative signs; (4) *understanding the different meanings of the equal sign* (EQS), for example, using and placing the same sign correctly.

2 METHOD

This research used a qualitative approach. Qualitative research is a study that intends to understand the phenomenon experienced by research subjects related to such areas as behavior, perception and actions, holistically and by way of description of words and language, to a specific scientific context and by utilizing various scientific methods (Moleong, 2001). This type of research is a description with the intention to describe the variable or condition of 'what exists' in a situation (Furchan, 2004). The design of this study is a case study. The data collection techniques are in the form of tests and observations. The data analysis technique in this study is to reduce data, and present and draw conclusions (Huberman (in Sugiyono, 2014)). The first thing to do was to observe classroom learning, and then provide the test questions for an algebraic topic taken from the 2016/2017 National Package B equivalence exam. The question was given to the ninth-grade students of the package B program, totaling 15 people at the Awwaliyah Rohim Community Learning Center (PKBM) in East Jakarta. Of the ninth-grade students who were the subjects of this study, almost 95% were students who dropped out of school when they entered class 8. It means that these students had studied algebra before in formal school during the seventh grade. Next, we analyzed students' results and matched students' answers based on the types of algebraic difficulties in the AVAE theory (Jupri et al., 2014).

3 RESULT AND DISCUSSION

The researcher gave three algebraic test questions, taken from the 2016/2017 package B equality national exam. The test was conducted in October 2017 for as many as 15 students of class IX who took package B (equivalent to secondary school). Students who were the subjects of the 95% study had attended formal schools but dropped out of school in the second year. In other words, the subjects of this study had studied the algebra topic for a few months in the first year in formal school. Table 1 summarizes students' answers to the algebraic test.

Table 1. Results of students' answers.

Question	1	2	3
True	4	0	0
False	11	15	15
% True	25	0	0

3.1 *Problem about simplification of algebraic form such as $10y - 2x - 5y + 8x$ that only 25% can resolve. One of the student's answers has not been exact (Figure 1)*

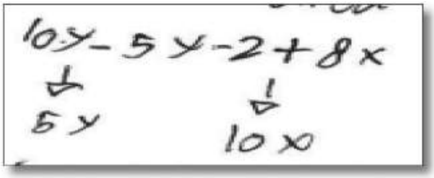

Figure 1. An answer of one student to simplification of algebraic form problem.

Based on this student's answer, the students have limited understanding on the variable only when the algebraic operation of the students' knowledge about the negative and positive meaning in each number is not correct. It can be seen when students add $-2x + 8x$ to be $10x$, which should instead be $6x$. The completion step is also not written correctly, where the term $5y$ and the term $10x$ are not connected with any symbol. These difficulties fall into the ARITH difficulty category, namely the difficulty in using arithmetic operations. In this particular case, the students were wrong in using the addition and subtraction operations that produced a negative number.

3.2 *Concerning the set of solutions for a linear equation of one variable $2x + 5 = 11$, none of which can be answered correctly (Figure 2)*

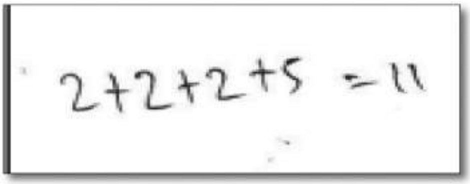

Figure 2. One student's answer about a set of solutions to a linear equation of one variable.

The student's answer has not shown a suitable solution to the way the algebraic operation works. Although the result is correct, it means $2 + 2 + 2 + 5$ are $2\ (3) + 3$ that produces 11. However, the variable in this case, the value of x asked in the question, is not raised. Students should have solved the problem using the sum inverse where the right and left segments are reduced by 5 ($2x + 5–5 = 11–5$). Then, students can continue using the multiplication inverse ($2x/2 = 6/2$). In this way students can find the value of x. This difficulty falls into the category of the VAR category, namely understanding the meaning of variables. In this case, the student interprets the variable only as a single value rather than as a unity of values, so that the variable x is considered to have no meaning.

3.3 *Concerning the set of linear inequalities of one variable $3x - 4 <20 + 5x$, no one could answer correctly (Figure 3)*

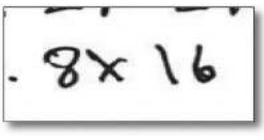

Figure 3. One student's answer about a linear set of resolutions of one variable.

One way in which students answered the question on linear inequality of one variable shows the concept of algebra that is not yet correct. Students tried to add together similar variables

($3x$ and $5x$) and those with no variables (–4 and 20), but were still incorrect in the final answer. Students also did not show the '<' sign in the completion step. It shows that students do not understand the meaning of the '<' sign in the problem. The correct solution should be the sum inverse ($3x - 5x - 4 + 4 < 20 + 4 + 5x - 5x$), and then the multiplication inverse ($-2x/-2 < 24/-2$). These difficulties are included in the ARITH category, which is an error in using arithmetic operations. More specifically, it does not use inverse sum or multiplication so that there are errors in different sections and subtractions. In addition, this difficulty is considered as being in the AE category, that is, the difficulty in understanding the expression of algebra. Students ignore the algebraic form of the '<' sign, so that the results obtained are not appropriate.

Based on the findings, it can be seen that the students' understanding and concepts of algebra are still low, especially in the algebra counting operations. This reinforces the results of the questionnaire used in a study conducted by Masyita (2014) in one of the PKBMs in Jakarta. It was found that in the package B program, algebra material is considered to be the most difficult, especially regarding the system of linear equations of two variables. The difficulty that can be seen from the mentioned finding is performing operations on algebra forms that are not appropriate. This is also in line with the findings of Surati's (2014) study, which reported that students' understanding of addition and subtraction of algebraic forms is still low, with errors made by students including summing unequal terms, adding up variables, and making mistakes when summing algebraic forms' coefficients. Similarly, the results of the study of Chamundeswari (2014) concluded that mathematical operation errors in algebra in middle school students were due to a lack of fundamental knowledge of mathematical operations, namely addition, subtraction, and arithmetic multiplication and division. This is in line with Nuraini's opinion (2017) that students' understanding of arithmetic concepts that are not good causes difficulties in understanding the basic concepts of algebra.

The findings also show that students seem to ignore variables, existing operating signs and mathematical symbols (e.g. =, <, >). This was also revealed by Linchevski and Herscovics (1996) in their research, when they found that students often have an issue with variables or symbols when doing algebraic operations, where they ignore variables and only focus on addition operations. Therefore, Jupri et al. (2014) suggested that the mistakes made in solving algebraic problems are manifestations of the difficulties expressed in his theory. Supported by the opinion of Knuth et al. (2006), those students who did not understand the 'equivalence' symbol tended to have difficulty with algebraic forms.

4 CONCLUSION

Two main points can be concluded from the findings of this research. First, the operational ability to calculate the algebraic form of the average student is still weak. Therefore, it needs to be a major concern to be improved. Second, the difficulties encountered in students are not much different from the findings obtained in the results of expert research that makes the theory of AVAE. For further investigation, we consider examining the problem that is designed on the basis of the difficulties put forward in AVAE theory on students of package B, and then analyzing the results.

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Images of the mathematics curriculum held by school mathematics teachers: Mapping the road for transformative pedagogies

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ABSTRACT: The images of the mathematics curriculum created by the teachers play a vital role to incorporate the substantive and transformative pedagogy inside the classroom. Similarly, included content in the curriculum and the ways of delivering it matters a lot in creating the sustainable future for learners. The images of the mathematics curriculum indirectly or directly have a positive or negative influence during the teaching and learning process. Thus, the paper explores the images of the mathematics curriculum held by the secondary school mathematics teachers. We subscribed Habermasian knowledge consecutive interests (technical, practical, and emancipatory) as the theoretical orientation to evaluate the teachers' images of the mathematics curriculum and to discuss the transformative pedagogies. The study is carried out by using interpretative approach based on formal and informal semi-structured interview to generate and construct the data texts of the three participants who have been working as secondary-level mathematics teachers for around ten years. The pedagogical implications of such images of the mathematics curriculum are discussed and the roadmap is suggested for transformative pedagogies for a sustainable future. We conceptualized the images of the mathematics curriculum as a view or mental representation which are created during the interaction in schools, universities, and society as well.

1 INTRODUCTION

First, we have introduced the context of the study. Second, we have reviewed the previous literature briefly. Third, the purpose as well as the research questions have been discussed. Fourth, we have discussed the theoretical orientation for this study in terms of the Habermasian technical, practical and emancipatory interests in curriculum images. Following this, we have outlined the method of data text collection and construction, as well as the process of meaning-making. Finally, we have discussed images of the mathematics curriculum under the four different categories with the pedagogical implication, in order to promote transformative pedagogies (Ukpokodu, 2009), for a sustainable future. We have used the notion of transformative pedagogy as an activist pedagogy combining the elements of constructivist and critical pedagogy that empowers students to examine critically their beliefs, values, and knowledge to develop a sense of critical consciousness and agency (Ukpokodu, 2009).

During our experiences of learning mathematics from school level to university, rote learning and memorization are dominant in teaching and learning mathematics. The schoolteachers in Nepal normally ask students to memorize such things as the formulas, standard steps for problem solving, important definitions, theorems, facts, postulates, and axioms (Pant, 2017). It is believed that 'practice makes man perfect' and mathematical knowledge can be achieved best through practice. Nowadays, students in the school are facing the same problems regarding learning mathematics. The school-level mathematics textbooks are heavily content-loaded with lots of routine problems. We have been observing that the consultations with various stakeholders are not enough during the curriculum development process in Nepal. The majority of schoolteachers perceive the narrow view of curriculum: curriculum as a list of contents (Luitel, 2009). Unless and until teachers reject such a narrowly conceived view of the curriculum, mathematics teaching and learning will remain the same. On the other hand, in our experience, most of the teachers in schools do not consult the curriculum during the preparation of a lesson plan or for other activities. It shows that mathematics teachers consider the textbook as being the major resource. Thus, the tendency to underrepresent teachers and other stakeholders in the curriculum development process has contributed to an unsustainable and elitist mathematics education that rarely provides an opportunity to enrich the existing mathematics curriculum by including local contexts and content (Luitel & Taylor, 2005). These types of tendency in the curriculum-making process enable teachers to create different images of the curriculum. Here, images of a mathematics curriculum mean the process of representing the understanding of the curriculum. Those images not only enable but also constrain teachers to make teaching and learning meaningful and contextual. Similarly, those images of the mathematics curriculum play an important role in preparing the transformative pedagogies. Here, a transformative pedagogy aims to produce a critical and creative citizen with life-related skills. This is because a pedagogy is important to make the connection between teaching and learning and is therefore vital for education's contribution to sustainable development. Higher education for sustainable development is also inspired by the aim to help students: (i) develop sustainability attitudes, skills, and knowledge that inform decision making for the benefit of themselves and others, now and in the future; (ii) act upon these decisions (UNESCO, 2009, as cited in Seatter & Ceulemans, 2017). Thereby, to maintain the sustainable development of a future sustainable pedagogy on school education, a transformative pedagogy plays a vital role, which is based on a transformative teaching approach.

2 BRIEF REVIEW OF LITERATURE

Meyers (2008) has discussed the transformative pedagogy as being a social action that encourages students to critically examine their assumptions and beliefs. The transformative pedagogy is such a teaching strategy that promotes the student's engagement and participation by posing real-world problems that address societal inequalities and help students to implement action-oriented solutions. A transformative pedagogy is one 'that relentlessly questions the kinds of labor, practices, and forms of production that are enacted in public and higher education' (Giroux, 2001).

The research conducted by Alsubaie (2016) has mentioned that an effective curriculum should reflect philosophy, objectives, learning experience, goals, and assessment that comprise a specific educational program. Further, it is a tool to assist teachers in the development of individualized strategies and the methods and materials necessary for them to be successful. Mainly, the paper has highlighted the importance of the teachers' involvement in curriculum development, challenges, and preparation for the teachers' involvement in curriculum development and the teachers' role in curriculum development.

Schubert (1986) has discussed eight images of the curriculum. This represents different versions of the conceptualization of the curriculum. The pedagogy, assessment system, and the role of students and teachers for each image of the curriculum were discussed. The images of the curriculum (curriculum as content or subject matter, curriculum as a program of planned activities, curriculum as intended learning outcomes, curriculum as cultural reproduction) are guided by Habermasian technical interest that serves the interest of knowledge reproduction in a more structured and traditional setting. The next two images (curriculum as experience, and curriculum as discrete task and concepts) are mostly guided by practical interest that puts emphasis on the understanding of the mathematical concepts and process. The other two images of the curriculum (curriculum as agenda for social reconstruction and curriculum as *Currere*) are mostly guided by emancipatory interest that creates spaces for the transformative pedagogy.

3 PURPOSE AND RESEARCH QUESTION

The main purpose of this study is to explore the images of the mathematics curriculum held by secondary school mathematics teachers during their educational and professional journey.

Moreover, the paper is looking for the transformative pedagogies for a sustainable future of the students based on different images of the mathematics curriculum. For this, the research question of the study is: How have mathematics teachers been employing different images of the mathematics curriculum in developing and applying mathematics pedagogies? It also aims to explore the influences of such images in developing the transformative pedagogy in teaching mathematics.

4 THEORETICAL REFERENTS

We have used the notion of theory as referent (Tobin & Tippins, 1993) rather than a complete framework that makes everything fixed and rigid. As teacher educators, we have realized that the deep-seated belief about the nature and role of theory as an overall controlling framework was unduly restrictive to welcome new ideas and practices (Pant, 2019). We subscribe to knowledge constitutive interest (Habermas, 1972) as providing a theoretical referent throughout the study. The authors Cornbleth (1990), Grundy (1987), and Kemmis and Fitzclarence (1986) expounded those interests, maintaining that the curriculum is a social and cultural construction, where the purpose is determined by the three Habermasian fundamental human interests (Fraser & Bosanquet, 2006). Thus, the technical interest (empirical ways of knowing), practical interest (interactive ways of knowing), and the emancipatory interest (critical and transformative ways of knowing) have guided us to explore the knowledge about the curriculum throughout the study in multiple ways.

4.1 *Mathematics curriculum and technical interest*

Technical interest is one of the fundamental human interests in which the purpose is controlling the environment through rule-centric actions based upon empirically grounded laws (Grundy, 1987). Thus, the essence of technical interest in the mathematics curriculum is incorporating more content and subject matter in which students are asked to memorize the facts for examination purposes. The teaching and learning process are highly oriented to being teacher-centered, in which students become passive listeners rather than active learners. Fraser and Bosanquet (2006) mentioned that the technical interest focuses on structuring and managing the environment. By supporting this, the mathematics curriculum has been formed in such a way that it follows a rigid structure and experts' prescriptions to maintain the status quo in society. Then, the teachers are supposed to deliver the contents inside the classroom to fulfill the curriculum objectives.

4.2 *Mathematics curriculum and practical interest*

The practical interest is a fundamental human interest situated in understanding the environment through communication and collaboration, based on a consensual interpretation of meaning (Grundy, 1987). Thus, the main purpose of this interest is to understand the context through interaction among the group of people. Producing the subjective knowledge is another purpose of this interest. Thus, it respects the people's views and ways of understanding. The mathematics curriculum oriented by practical interest follows the students' experiences and diverse culture, as well as focusing on real-life activities. It means that the students themselves are a part of curriculum development. Such approaches as a collaborative and cooperative approach, constructivist approach, and activity-based instruction are the appropriate teaching approaches which are regarded as student-centered. The students and teachers interact to find meaning in the subject matters, thus equipping students to act on these meanings (Fraser & Bosanquet, 2006).

4.3 *Mathematics curriculum and emancipatory interest*

The emancipatory interest is concerned with empowerment and autonomy—ability of individuals and groups to take control of their own lives in autonomous and responsible ways

(Grundy, 1987). It enables one to critique the false consciousness and beliefs system, which are governed by the invisible and visible sources of society. 'The curriculum develops through the dynamic relationship between action and reflection, in which the process of critically reflective practice is incorporated into the process of curriculum development' (Fraser & Bosanquet, 2006, p. 281). Thus, the curriculum guided by this interest is more critical, and that challenges the status quo as well. One of the purposes of such types of the curriculum is to emancipate the learners from the dogmatic dependence. In this context, teaching is for emancipation of the learners by challenging the common understanding and practices, and enabling students and teachers to change the constraints of the (learning) environment (Fraser & Bosanquet, 2006).

5 RESEARCH METHODOLOGY

The study explores the images of the mathematics curriculum held by secondary-level mathematics teachers. The narrative research design is used to capture the experiences of participants from their own perspectives (Clandinin & Connelly, 2004). In this regard, we have collected the participants' experiences of working with the mathematics curriculum and pedagogy. Qualitative data often focus on smaller numbers of people than quantitative data, yet the data tend to be detailed and rich (Cohen et al., 2007). So, three participants who may provide rich narratives about this are purposefully selected. We have collected and constructed the data text through 'free' interview (Corbetta, 2003) with the help of open-ended and probing questions. The purpose of qualitative research is to explore the interviewee's individuality and to see the world through his eyes (Corbetta, 2003). Moreover, textual data were generated by using open-ended interviews, informal communication and their stories about the mathematical experiences during their educational journey.

The analysis the data text in this research study involves summarizing the mass of data collected and presenting the results in a way that communicates the most important features (Hancock, 1998). Thus, we have analyzed the data text in such a way that enables the readers to make sense of the mathematics curriculum and pedagogy and realize them by comparing their own experiences. For this, we have generated possible categories on the basis of participant voices, narration, as well as categorization. Based on the three participants' experiences of the mathematics curriculum, we came up with four different categories that represent the understanding of the mathematics curriculum and the associated pedagogy.

6 RESULTS AND DISCUSSION

We have discussed the images of the mathematics curriculum under four different themes, which were created on the basis of interactions with three research participants. Throughout this research study, the themes are demonstrated through the use of indicative quotes from the interview, where pseudonyms have been used to preserve anonymity. Moreover, we have discussed the pedagogical implications of those images of the mathematics curriculum relating to technical interest, practical interest, and emancipatory interest in order to promote the contextual and inclusive nature of the mathematics curriculum development process.

6.1 *Category A: Curriculum as the format used by textbook writers*

Technical interest is one of the fundamental human interests in which the purpose is in controlling the environment through rule-centric actions based upon empirically grounded laws (Grundy, 1987). Thus, the essence of technical interest in the mathematics curriculum is incorporating more content and subject matter in which students are asked to memorize the facts for examination purposes. The teaching and learning processes are highly oriented to be teacher-centered, wherein students become passive listeners rather than active learners. Fraser and Bosanquet (2006) mentioned that the technical interest focuses on structuring and managing the environment. By supporting this, the mathematics curriculum has been formed in such a way which follows a rigid structure and experts' prescriptions to maintain the status quo in society. Then, the teachers are supposed to deliver the contents inside the classroom to fulfill the curriculum objectives.

6.2 *Category B: Curriculum as per the proverb 'the jack of all trades, master of none'*

One of the research participants, named Hari, related mathematics curriculum to the proverb '*the jack of all trades, master of none*'. It means that he is trying to indicate the mathematics curriculum that covers various contents in a superficial way. According to his point of view, the mathematics curriculum tries to cover a lot of content, which is difficult to cover in one academic session in meaningful ways. Teachers are forced to cover the contents and syllabus in one academic session. Because of that situation, superficial teaching and learning is superior in which teachers are not able to focus on in-depth knowledge. In this regard, Hari mentioned that: *I am always in a rush to finish the course and syllabus so that I am not able to go in-depth on any topic. I just introduce the topic and focus on some routine problems. I think it would be better if the content is smaller and more contextual.* While talking with him, we were reminded of our schooling, which was almost the same as that which Hari experienced. Hari has shared that such a type of schooling also plays an important role in developing unhelpful images of the curriculum. Similarly, teachers are not able to assess the students' work continuously. In such a context, students are more dependent on summative testing in order to demonstrate their progress in mathematics.

6.3 *Category C: Curriculum as the student's experience of learning*

This view of the mathematics curriculum is different than that in the previous categories. The previous categories of the curriculum are more product-oriented and guided by technical rationality, as mentioned by Habermas whereas; this category is process-oriented and guided by the practical interest as discussed by Habermas. This view of the curriculum focuses on student-centered learning, and a flexible teaching and learning process. Teachers have autonomy to revise the curriculum on the basis of the students' specific needs and interests under the framework of the curriculum development center. Goals and objectives are important, rather than contents. In this category, students explore the knowledge on the basis of their experiences and prior knowledge in which teachers create the rich learning environment. Again, Bikram said: *I always keep the students' prior knowledge and experience as curriculum in center during planning. I design the activities, choose the pedagogies based on their prior knowledge and experiences so that I prefer differentiated instruction in my class. I assess the students' learning outcome via both formative and summative ways. Similarly, the mathematical problems are more contextual and related to day-to-day activities.*

Moreover, maintaining open communication between teacher and students is therefore dominant in curriculum development. The framework of the curriculum emerges from the research, which supports such things as the context, students' needs and interest, and societal change in the framework of the curriculum development center. Both formative and summative assessment tools are used to assess the students' learning outcomes.

6.4 *Category D: Curriculum as an interactive process of teaching and learning*

This view of the curriculum is understood as curriculum as a collaborative and cooperative process of learning, involving students with students, and students with teachers. Thus, teachers and students are acting as co-constructors of knowledge. There is not any rigid structure for the curriculum and learning. Teacher and students are the component parts of the curriculum development. In this context, one of our research participants (Prakash) said that: *students themselves create the mathematical problem related to the topics instead of solving the ready-made problem. Students are trying to connect each and every topic to daily activities. They are free to ask questions and critique the existing practices.* In this view of the curriculum, instead of replicating the ideas mentioned in the textbook and curriculum, teachers and students sit together and incorporate the local practices, and value the students' experiences in classroom practices. He further remarked that: *I don't believe the view that curriculum is an ultimate and final document and try to make the students, parents, and schools administration aware of this.* The process-oriented view of the curriculum also suggests that the curriculum means not only the document provided by the curriculum experts but also all activities that a school premise conducts for the holistic development of the child. Similarly, such things as autobiographical texts and reflections are also sources for assessing their learning outcomes.

There are many reasons to see the mathematics curriculum differently. The ways of developing mathematical knowledge and skills by students matters a lot in understanding the mathematics curriculum. Similarly, their working environment, school context, the teachers' professional development programs, for example, play an important role in understanding the dynamic nature of the mathematics curriculum. It is important to prepare a plan and design the activity to teach mathematics meaningfully. For this, choosing a textbook or curriculum depends upon the school's environment, and the teachers' knowledge and availability of the resources in the schools. So that time is very important to understand the mathematics curriculum.

7 CONCLUSIONS

This research study indicates that when the word curriculum is used at the school level, a variety of definitions and meanings are likely to be attributed according to the people's understanding. Those understandings, definitions and meanings of the curriculum play a vital role in choosing various pedagogies in mathematics. Moreover, pedagogical practices of mathematics teacher are also guided by their beliefs towards the nature of mathematics (Pant, 2015; Luitel, 2019). For example, four categories emerged from this research in a different way of teaching and interacting, curriculum development, and assessing the students' learning and achievements. Mathematics teachers are likely to act on the basis of their understanding of the mathematics curriculum. In this 21st century, the understanding and development of the curriculum through traditional ways, guided by the technical interest, is no more effective than to promote the inclusive and contextual teaching and learning, as well as the transformative pedagogy. It is also concluded that curriculum development and implementation is a social process where the transformative pedagogy could help to make changes in the present context (Meyers, 2008). The above discussion indicates that the curriculum development and understanding based on practical and emancipatory interest may be better than the curriculum guided by technical interest. *Curriculum as the students' experience of learning* and *curriculum as the interactive process of teaching and learning* are the images of the mathematics curriculum, guided by the practical interest as well as the emancipatory interest. Both of these images of the mathematics curriculum help students to develop critical thinking and allow them to reflect critically, which is a part of the transformative learning approach. For critical thinking there must be a process by which learners consider how the dominant ideology shapes assumptions that maintain inequality (Brown, 2013), and those processes can proceed through the transformative pedagogy. Finally, a transformative pedagogy also enables students to reflect critically, which means a process of analyzing, questioning, and critiquing the established assumptions that hinder growth and sustainable development in society.

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Learning composition and decomposition of a function with a realistic mathematics education approach for senior high school students

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ABSTRACT: The purpose of this article is to explain how a Realistic Mathematics Education (RME) approach can develop student understanding of the composition and decomposition of a function. The background of this article is based on difficulties experienced by students when they were decomposing a function, especially when they had to find $f(x)$ if $f \circ g(x)$ and $g(x)$ were given. This article uses design research methodology and was implemented for senior high school students in Jakarta, Indonesia. Retrospective analysis showed that the learning trajectory, which was developed at preliminary design, could help students to understand the composition and decomposition of a function concept. As a result, students developed the inverse of $g(x)$ as a strategy for decomposing function f$\circ g(x)$. Therefore, it could be a recommendation for teachers to introduce inverse learning before students learn about function decomposition.

1 INTRODUCTION

Function learning represents the vast majority of the sphere of mathematical learning for middle and high schools. That would be an advantage for students to be more easily understood about function and can be made as a knowledge capital at a higher level. However, it needs to be done if the learning in school does not go well, as it will greatly affect the students' mathematics learning as a whole.

A study by Artiyani et al. (2016) revealed that there were some difficulties for students in understanding functions, especially regarding the composition and decomposition of functions. The difficulties included the complexity in understanding problems, solving algebraic problems, and also difficulties in understanding the concept of the composition and decomposition of functions. The consequence is that students made some mistakes in solving composition and decomposition problems.

An error when solving the composition and decomposition of functions was observed when we were once at a high school in Indonesia. The error occurred when a student had to find the function $f(x)$ if $f \circ g(x) = 3x^2 + 6x - 9$ and $g(x) = x + 1$. There were 31% of students who made a mistake and 55% of the students could not do it. We can see such a mistake in Figure 1.

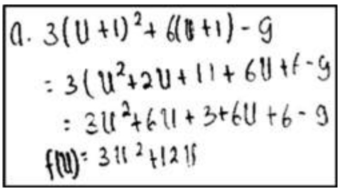

Figure 1. A mistake in decomposing a function.

The problem was about how to decompose $f∘g(x) = 3x^2 + 6x - 9$ and find $f(x)$. However, from Figure 1 we know that students composed the functions for finding $f(x)$. Students substituted function $g(x) = x + 1$ into $f∘g(x) = 3x^2 + 6x - 9$ and then operated on them to find a formula for $f(x)$. Based on that situation, it can be concluded that students still did not understand about the concept of composition and decomposition of a function.

Another mistake was revealed in a study by Meel (1999): errors were made when respondents deduced the nature of function $f(x)$ if the composite function $f∘g(x) = \cos^2 x$ and $g(x) = \sin x$ were given. There were only two out of 22 respondents who could construct $f(x) = x^2 + 1$. Most of the respondents claimed that the symbol '∘' is for multiplication operations. Thus, they found $f(x)$ by dividing $f∘g(x) = \cos^2 x$ by $g(x) = \sin x$. Figure 2 shows an example.

The function composition has a definition: if f and g are functions and $R_f \cap D_g \neq \phi$, then there is a function h from the subset of D_f to the subset of R_g, which is called the composition function f and g (written $g∘f$) where $h(x) = g∘f(x) = g(f(x))$. The domain of a composition function is D g∘f = {x ∈ D_f | f (x) ∈ D g}. The function f can be considered as the inside of the function and function g as the outer side of the function.

Function decomposition is the process of determining the forming function of a composition function. Suppose a composition function $g∘f(x) = g(f(x))$. Function decomposition is the process of finding $f(x)$ or $g(x)$ if the composition function is known. According to Kozen et al. (1996), the decomposition of functions is representing a function of $f(x)$ as a composition of functions that are 'smaller' than function $g(f(x))$. The meaning of the phrase 'smaller' here is a function that has a simpler form than the composition function.

The reason that Realistic Mathematics Education (RME) is chosen in this study is because RME theory is used in several countries, especially Indonesia. The concept of RME that is important is the emphasis on student-active learning, problem-solving and the application of mathematics. It is a common belief in Indonesia that an objective of teaching and learning mathematics is to develop students' reasoning and logical ability. The (re)construction of mathematical ideas and concepts goes hand in hand with the process of the development of the students' reasoning ability. This can be achieved in RME through the students' exposure to contextual problems within the framework of the interactive teaching and learning process (Sembiring et al., 2008).

The RME approach is designed specifically for mathematics subjects. The 'realistic' term in RME comes from the Dutch 'realiseren', which means that they can be realized or imagined. RME is a theory which discusses what mathematics is, how it is taught and how students learn mathematics. According to Gravemeijer and de Lange (Hadi, 2017), students must be given the opportunity to reinvent mathematics under the guidance of adults, and the creation of mathematical concepts must begin with an exploration of various real-world problems and situations.

There are five characteristics of the RME approach, which include the context, models for progressive mathematics, the use of student construction results, interactivity, and entertainment. So for maximizing those characteristics, teachers have to increase their function in the learning process of the class. There are four aspects to the role of the teacher that relate to the realistic learning process (Hadi, 2017):

1. The teacher is only as a facilitator;
2. Teachers must be able to build interactive learning;

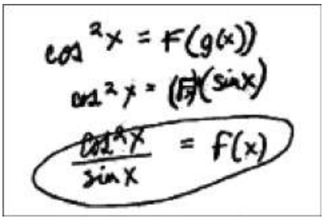

Figure 2. Another mistake in decomposing a function.

3. Teachers must provide opportunities for students to actively contribute to their learning process and actively assist students in interpreting real problems;
4. Teachers are not subject to the material contained in the curriculum, but actively link the curriculum with the real world, both physical and social.

Many researches shows that the RME approach can help toward better learning in a class. So based on that statement, and difficulties experienced by students about understanding composition and decomposition of the function concept, this study develops a research question as to how the use of the RME approach in the class can help students to understand composition and decomposition of the function concept. The explanation of the students' strategies will also be discussed in the next section of this article.

2 METHOD

This study uses design research methodology in class X IPS 1 of 99 Senior High School of Jakarta in the period 2017/2018. The steps of design research methodology include: (1) thought experiment (preparation and design phase); (2) teaching experiment; (3) retrospective analysis. In the preparation and design phase, an instructional local theory is composed, and also a learning trajectory hypothesis of the learning process, which perhaps happens in the teaching experiment phase. The teaching experiment phase is the implementation of instructional local theory and learning design. During this phase, the researcher records data by observing the students' strategies and their understanding development. Then the data is analyzed in the retrospective analysis phase: does the learning trajectory hypothesis accord with the facts observed in the field?

The local instruction theory of this study is divided into three stages of understanding, where each stage has the learning objectives to be achieved. The first stage is to build the students' understanding of the concept of function, determining the domain and range of functions and algebraic operations on the function. The second stage is to build the students' understanding of the concept of composition of function. The last stage is to understand the function decomposition process. Learning is conducted during five meetings. The tools used in the design research learning include projectors, laptops, and student activity sheets. Based on the local instruction theory, we can see the learning trajectory hypothesis in Figure 4.

The reason for using this method is because the design research methodology is signified for the development of RME curriculum materials. The role of design research in supporting the dissemination of RME in Indonesia is important (Sembiring et al., 2008). Therefore, this methodology is chosen in this study.

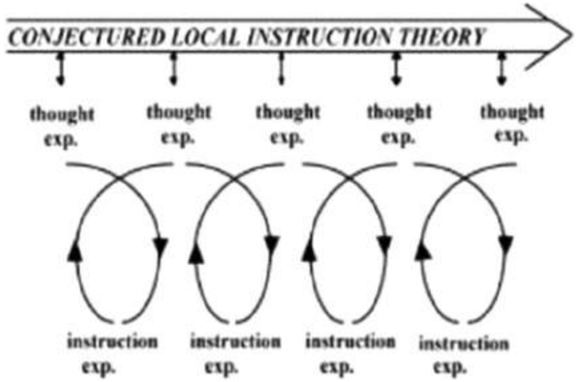

Figure 3. Conjectured local instruction theory. (Figure taken from conjectured local instruction theory of design research in general.).

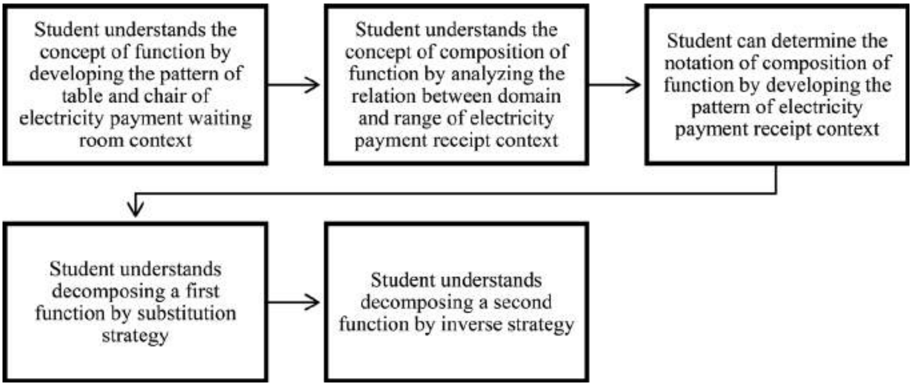

Figure 4. Learning trajectory hypothesis.

3 RESULT AND DISCUSSION

In the first stage of learning, the context developed was the electricity payment waiting room that has unique table and chair placement rules. The rules then formed a developing pattern that has a recursive relationship, where the students understood it as the concept of a function. Then in the next stage of learning, the context used is the electricity payment receipt. Based on the electricity payment receipt, students understood the composition events that occurred between the amount of electricity used in kWh, the usage costs, and the total electricity bill. The relationship that occurred between the amount of electricity usage in kWh and usage costs was understood as a function of the first stage, while the relationship between usage costs and the total electricity bill was understood as a second-stage function. Based on this, students then understood the procedure to complete the function of composition and decomposition of functions.

3.1 *The first meeting*

Based on the pattern when the learning process takes place, according to the hypothesis, students would try to expand the given pattern of tables and chairs. On this occasion, several students tried to expand the given pattern by drawing the next pattern and then manually counting the number of seats produced. In the next step students then directly used table representations to understand the concept of the function of the situation. However, there were also groups of students who directly made table representations of the given pattern. Based on the table representation, students then represented the number of tables by variable x and the number of seats by $f(x)$, and the recursive relationship that occurs was understood as the function formula $f(x) = 2x + 2$ (see Figure 5).

3.2 *The second meeting*

The second meeting contained activities that led students to understand the concept of composition of functions by using electricity payment receipts. In this lesson the students observed the electricity payment structure for four months. The data that students observed was the difference in receipt data in each month, especially regarding the data on the amount of electricity used in kWh, usage costs, and the total electricity bill. Based on these data, students then understood it as a function and developed it into an arrow diagram representation. Students then determined the domain and range of each function. This step aims to give students awareness regarding the similarity of data between the range of the first function and the second function domain. After students were aware of the similarity of the data, there was a class discussion between the teacher and students, which led students to the concept of composition of functions:

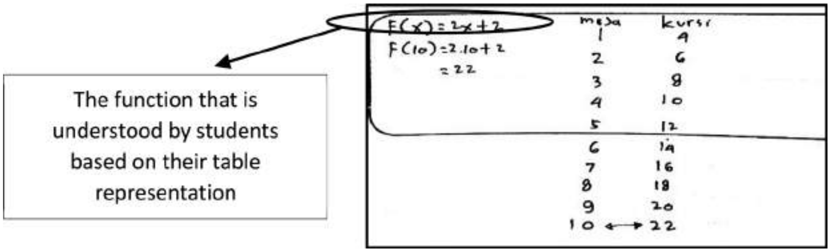

Figure 5. Pattern of table and chairs representation.

Teacher : *OK students, please show range of first function?*
Students : *This is it, Mam* [students show range set of function 1].
Teacher : *Then, please show domain of second function?*
Students : *This is it, Mam* [students show domain set of function 2].
Teacher : *Are they the same?*
Students : *Yes, Mam.*
Teacher : *OK, we know the similarity of two sets in this diagram. Could we combine these diagrams?*
Students : (Silent)
Students : *How come, Mam?*
Teacher : *Who can?*
S III : *Is it true, Mam? We built three sets like this and then we put a same set in the middle* [she shows her task].
Teacher : *Yes, right. Do you understand, students?*
Students : *Yes, Mam.*
Teacher : *OK, we can call this situation composition of function. So, do you understand what it is?*
Students : *Combination of two functions.*
Teacher : *What combination is it like?*
S III : *Combination like I built, Mam.*
S IV : *…where the domain and the range are the same.*
Teacher : *Who can complete the statement of your friend?*
Students : (Confused)
Teacher : *Ok, let's see the problem. What's your reason to put this set in the middle?*
Students : *Because the domain of function f and the range of function g are the same.*
Teacher : *So, what can you take as the conclusion of this? What is the composition of the function?*
Students : *When the domain of first function and the range of second function are the same.*

Based on the conversation above, we can understand that the students were able to develop their understanding of the concept of composition of functions. From this lesson, students understand that the concept of composition is not just about combining two functions, but a condition in which the range of a function becomes the domain of another function. The role of the teacher in facilitating students to find information that must be observed, to find relationships that occur from each piece of information, and to find the concept of composition of functions becomes very important in this learning. One of the teacher's efforts in facilitating students to find the concept of composition of functions in this lesson is to ask the students questions about which sets are the domain and range of functions 1 and 2. The teacher then provokes the students' ideas by asking: '*We know the similarity of two sets in this diagram. Could we combine these diagrams?*'

3.3 *The third meeting*

The third meeting continued with collecting information from each electricity payment receipt using table representations. The table representation between the amount of electricity usage and the usage cost was developed into the function $f(x) = 1467x$, while the table between usage costs and the total electricity bill was developed as a function of $g(f(x)) = 1.024\,f(x)$. To direct students in determining the composition function, the teacher then posed the question: '*Can we substitute $f(x)$ into $g(f(x))$*?' Then the students substituted and operated on them to be a composite function.

3.4 *The fourth meeting*

After students understood the concept of composition of functions and determined a composition function, then they would solve the opposite activity in the fourth meeting. In the fourth meeting, students learned how to determine the first function when the second-stage functions were known and their composition of function was known. We could call it a decomposition of the first function. At this meeting students then developed their understanding to create a strategy that completes the decomposition of the first phase of the function. The strategy used by the students in this decomposition learning was to substitute the function of the first stage into the second-stage function, and then to make the equation of the composition function. After students made the equation of the composition function, students then rearranged it algebraically and got the first stage function (refer to Figure 6).

3.5 *The fifth meeting*

Activities at the fifth meeting contained the completion of questions that developed the students' understanding of the material decomposition of functions, especially in determining the second function if the composition function and the first function were given. At this meeting students then developed their understanding to create a strategy to complete the decomposition of the second function. The strategy used by students in this decomposition lesson was to substitute the inverse function of the first stage into the composition function, and then rearrange it algebraically to obtain the second function (see Figure 7).

Based on Figure 7, it can be seen that students used two different strategies in completing the second stage of the function decomposition. Students also did not know whether the reverse function developed by students using examples was actually an inverse function. Therefore, the teacher then asked the representative of the student group to present in front of the class his understanding of the procedure for solving the decomposition problem, and directed the student toward the inverse strategy in order to complete the second stage of the function decomposition.

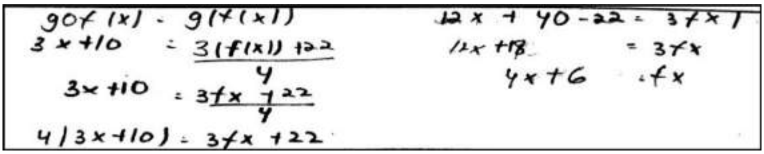

Figure 6. Students' strategy to decompose the first function.

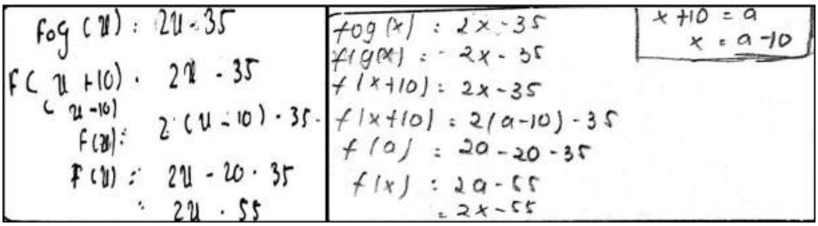

Figure 7. Students' strategy to decompose the second function.

Teacher : *Let's see each of your strategies. Do you see the difference?*
S IV : *Our strategy is easier.*
Student : *Erm... S I's strategy uses a variable, S II's strategy is operating the function directly.*
Teacher : *Yes, you are right. How about the formulas? Are they the same?*
Student : *Yes.*
Teacher : *OK. Do you know how we calculate x-10?*
Student : (Silent)
Teacher : *S II, what did you say last time?*
S II : *Opposite, Mam.*
Teacher : *Nice. Do you still remember about inverse functions, students?*
Students : *Yes, Mam.*
Teacher : *So, we can say that the inverse of* $g(x) = x + 10$ *is* $x - 10$*, isn't it?*
Students : *Yes, Mam.*
Teacher : *So if you find this problem, you can substitute …?*
Students : *Inverse of given function, Mam.*
Teacher : *Right.*

Based on the conversation above, we can understand that the students were able to develop their understanding of the concept of the decomposition of functions. From this lesson, students understand that to decompose a composite function they must substitute the inverse of the function and not just compose the functions again. The role of the teacher in facilitating students to find the strategy in this learning is to invite students into a class discussion, especially when the teacher asks: '*Do you still remember about inverse functions? So, we can say that the inverse of* $g(x) = x + 10$ *is* $x - 10$*, isn't it?*' This question led the students to be aware that their strategy actually is the inverse strategy.

Five characteristics of the RME approach are applied in this lesson. We know from before that electricity payment is the context of this lesson. The context then led the students to develop their strategies and build a model to describe the context that is understood by them. Learning cooperatively and in group discussion gives an emphasis of interactivity and the use of student constructs a result characteristic. Furthermore, the use of the inverse strategy makes sure that mathematics is not a separate subject, but has an intertwinement characteristic with other subjects. Based on retrospective analysis in the result and discussion section, we know how the good learning of composition and decomposition of functions can form the students' strategies, and they develop them very well.

4 CONCLUSION

The composition and decomposition of functions are abstract subjects. With the RME approach, learning about the composition and decomposition of functions means that they no longer appear to be abstract subjects. Study proves that the electricity payment context can help students to understand the composition of function concept, such that they can be solving composition and decomposition of function problems. It means that the RME approach can be applied to the class to help senior high school students to understand the composition and decomposition of function concept.

In this study, the use of inverse strategy by students for solving a decomposition problem was revealed. We can see in the fifth meeting discussion above especially on Figure 7 and class conversation. So, it is recommended that teachers give lessons in inverse strategy before the students learn about the decomposition of functions at school.

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A comparison between the discovery and expository methods of teaching mathematics among secondary school students in the Nassarawa Local Government Area of Kano State, Nigeria

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ABSTRACT: Despite the great importance of mathematics, a significant number of students still record mass failure in public examinations in Nigerian secondary schools. To some educationists this mass failure is linked to how the subject is taught. This study was designed to compare and analyze students' performance in the discovery and expository methods of teaching mathematics among senior secondary school students in the Nassarawa Local Government Area of Kano State, Nigeria. Five items were raised as objectives, research questions and hypotheses respectively. A systematic random sampling was used to select 200 students from a population of 2,915 of of Senior Secondary School II (SSII) students. The experimental group was taught using the discovery method while the control group was taught using the expository method for teaching mathematics. The instrument used was a teacher-devised Mathematics Performance Test (MPT). The results of the study showed that students taught by the discovery method performed better than those taught by the expository method. Based on the findings of the research, it was recommended that mathematics teachers should use the discovery method in teaching mathematics in senior secondary schools. It was also recommended that there should be training and retraining of mathematics teachers on the use of the discovery method for teaching mathematics in secondary schools.

1 INTRODUCTION

Mathematics has no doubt contributed immensely to the development of science, technology and engineering the world over. Mathematics is often regarded as a methodical application of matter. It's so said because the subject makes a man methodical and systematic in nature. Certain qualities that are nurtured by mathematics are the power of reasoning, creativity, abstract or spatial thinking, critical thinking, problem solving ability and even effective communication skills. Mathematics is the cradle of all creations, without which the world would be at a standstill. Indeed, Odiri (2011) cited Kolawole and Oluwatayo (2005) who described the subject as "a human invention borne out of human in an attempt to solve human problems."

Meanwhile, science, which is a basic requirement for all national progress as well as development, cannot impact meaningfully without mathematics (Ibe, 2013). Mathematics is therefore essential for any meaningful scientific and technological advancement in all walks of life (Emoko, 2007, in Ibe, 2013). Mathematics remains an important tool in the study of science, technology and other human disciplines.

Despite the huge importance of the subject, student performance in public examinations continues to deteriorate. This poor performance is linked to some factors such as the students' interest (Isa, 2017), the way instructions are presented to the students (Nizoloman, 2013) as well as mathematics phobia (Bature, 2006). A teaching method is seen as any maneuver that can be used to facilitate students' learning and understanding (Dorgu, 2015).

Examples of activity-based teaching methods include inquiry, discovery, process approach, demonstration, programmed learning method, and microteaching (Dorgu, 2015). It is therefore necessary for students to be taught mathematics using appropriate teaching methods that will enhance their interest in the subject. A number of teaching methods such as lectures and play do not seem to yield the desired results especially at secondary school level. These appear to be mostly helpful at lower levels and appear more teacher-centered than student-centered.

Therefore, there is a need to deviate from this teacher-centered approach to a student-centered approach which perhaps may yield the desired results. Thus, in this paper, the discovery and expository methods of teaching were considered.

The discovery or diagnostic method of teaching is a method where the teacher presents a problem to the students to solve, and after solving them, the teacher will then ask the students to explain how they answered the questions. If the students' responses or answers are wrong, the teacher will then explain how to get the correct answer. Polya (1962) defined the discovery method of teaching as a method which allows for a more active role in the learning process. According to Polya (1962), numerous benefits of the discovery method include: (a) encouraging students to learn by themselves; (b) bringing intrinsic motivation through their involvement in the discovery process; (c) encouraging students to be able to organize resources in tackling problems.

The expository method is a technique using questions and interaction (Tenbrink, 2012). With this method, the sequence is expected to draw information out of the students rather than pouring it into them. Some of the advantages of this method include: (a) it considers individual differences; (b) it caters for below-average students.

This study also brings the gender issue into focus, which has been generating a lot of interest among the mathematics teaching-learning community. In some research, girls outperform boys (Stevens et al., 2007) while in the majority, boys perform better than girls (Preckel et al., 2012). Studies worldwide stressed the importance of effective teaching and it is a fact that effective teaching depends heavily on good teaching methods (Abbas, 2000). Brown and Kanyongo (2010) conducted a study aimed at investigating gender differences in mathematics performance in Trinidad and Tobago. They found out that while boys and girls did not differ with regard to their perception of the school environment, educational values and goals and general academic self-concept, they differ significantly on persistence.

1.1 *Purpose of the study*

The major purpose of the study is to compare the discovery and expository methods of teaching mathematics on student performance in the Nassarawa Local Government Area of Kano State, Nigeria.

1.2 *Objectives of the study*

The following objectives guided the study:

i. To determine if there is any significant difference in the mathematics performance of the experimental and control groups after intervention.
ii. To find out the extent to which the performance of the female students differs between the discovery and expository groups.
iii. To investigate the performance by gender within the discovery group.
iv. To investigate the performance by gender within the expository group.
v. To find out the extent to which the performance of the male students varies between the discovery and expository groups.

1.3 *Research questions*

Specifically, the study sought to answer the following research questions:

i. How does the performance of the experimental group differ from that of the control group after intervention?

ii. How does the performance of the female students vary in the experimental and control groups?
iii. Is there any variation in the mean performance of each gender within the experimental group?
iv. Is there any difference in the mean performance of each gender within the control group?
v. How does the performance of the male students differ in the experimental and control groups?

1.4 *Hypotheses*

In line with the objectives of the study, the following null hypotheses were formulated and tested at $p \leq 0.05$ to determine the relationship between the variables in the study:

$H0_1$: There is no significant difference in the mean performance of students taught with the discovery (experimental) and expository (control) methods of teaching mathematics.
$H0_2$: There is no significant difference in the mean performance of the female students taught with the expository (control) and discovery (experimental) methods of teaching mathematics.
$H0_3$: There is no significant gender difference in the mean performance of the students taught within the discovery (experimental) group.
$H0_4$: There is no significant gender difference in the mean performance of the students taught within the expository (control) group.
$H0_5$: There is no significant difference in the mean performance of the male students in the discovery (experimental) group and the male students in the expository (control) group.

2 METHOD

2.1 *Research design*

This study is quasi-experimental, made up of experimental and control groups.

2.2 *Population*

The population of the study consisted of all 2,915 senior secondary school students in the Nassarawa Local Government Area of Kano State at the time of this study.

2.3 *Sample*

A total of 200 students were randomly selected out of a population of 2,915 from the two girls' and two boys' secondary schools selected. Thus, 100 girls and 100 boys were randomly selected as the sample for the study.

2.4 *Sampling technique*

A random sampling technique was used both at the level of selecting the schools used as well as in selecting the classes used.

2.5 *Research instrument*

The research instrument used for the study is a teacher-devised Mathematics Performance Test (MPT).

2.6 *Instrumentation*

As a necessary requirement, permission from the principals of the two selected schools was obtained. Two mathematics teachers, one from each school, were recruited to serve as research assistants. They were trained for one working week (i.e. five days) by the researchers. The assistants were given a detailed plan of the study prior to the treatment. A pre-test was administered to the students in both groups and scores were compiled. The pre-test was meant to assess the knowledge of the students before administering the treatment.

The treatment lasted for two working weeks (10 days). The experimental group was taught quadratic equations using the discovery method of teaching. The students were divided into groups of five and given the necessary instructional materials. The topic was introduced with the provision of the instructional materials as well as guiding the students to find the solutions to the problems. This student-centered approach allows students to ask questions and gives room for free discussions.

The control group was taught the same topic using the expository method of teaching. The lessons were based on minimal interaction between the teacher and his students. Students were expected to listen and assimilate the process leading to the correct answers to the given problems.

A total of two periods of 40 minutes per period were used per week. This is in line with the school timetable. Immediately after the treatment, a post-test was administered simultaneously to the two groups which lasted for one-and-a-half hours. The major purpose of the post-test is to assess the effect of the treatment on the students' performance when compared with the pre-test result. This will help to establish the degree of difference (if any) arising due to the treatment.

2.6 *Validity of the instrument*

For this study, two commonly used techniques of determining the validity of the research instrument, namely content and face validity, were used. Two mathematics educators and two curriculum specialists as well as an English language expert were used to validate the test instruments. Their suggestions and criticisms were taken into account.

2.7 *Reliability of the instrument*

A mixed school not used in the main study was selected for the pilot trial. The two tests, pre-test and post-test, similar to the ones used in the main study, were used. The reliability coefficient was obtained using Kuder–Richardson formula 21. A coefficient of 0.67 was obtained.

2.8 *Data analysis technique*

In analyzing the data obtained from the study, a series of t-tests was used on all the hypotheses to ascertain whether to retain or reject the decisions.

3 RESULTS AND DISCUSSION

3.1 *Data presentation and analysis*

$H0_1$: There is no significant difference in the mean performance of students taught with the discovery (experimental) and expository (control) methods of teaching mathematics.

Table 1. *t-test* result between experimental group (discovery) and control group (expository).

Group	N	X	SD	df	t-calc.	t-crit.	Remark
Experimental (discovery)	100	73.42	10.21	198	4.92	2.73	Significant
Control (expository)	100	67.21	9.80				

$p \leq 0.05$.

The result from Table 1 indicated that the t-calculated value is greater than the t-critical value (i.e. t-calc. = 4.92 > t-crit. = 2.73) with df = 198 at $p \leq 0.05$. Thus, the null hypothesis is rejected. This implies that the discovery group performed better than the expository group.

$H0_2$: There is no significant difference in the mean performance of the female students taught with the expository (control) and discovery (experimental) methods of teaching mathematics.

Table 2. *t-test* result between experimental group (female) and control group (female).

Group	N	X	SD	df	*t*-calc.	*t*-crit.	Remark
Experimental (female)	48	64.23	10.54	96	2.82	1.96	Significant
Control (female)	50	62.14	9.32				

$p \leq 0.05$.

Statistical evidence on this null hypothesis showed that the *t*-calculated value is 2.82 while the *t*-critical value is 1.96 at a $p \leq 0.05$ level of significance, indicating that there is a significant difference in performance. The female students in the discovery group obtained higher results in the mean and standard deviation respectively. Hence, the null hypothesis is rejected.

$H0_3$: There is no significant gender difference in the mean performance of the students taught within the discovery (experimental) group.

Table 3. *t-test* result between male and female stdents in experimental group.

Group	N	X	SD	df	*t*-calc.	*t*-crit.	Remark
Experimental (M)	50	67.83	10.82	96	4.21	1.98	Significant
Experimental (F)	48	59.34	10.01				

$p \leq 0.05$.

The result from Table 3 indicated that the *t*-calc. > *t*-critical with df = 96 at a 0.05 level of significance. Thus, the null hypothesis is rejected. The male students of the experimental group performed significantly better than the female students.

$H0_4$: There is no significant gender difference in the mean performance of the students taught within the expository (control) group.

Table 4. *t-test* result between male and female stdents in control group.

Group	N	X	SD	df	*t*-calc.	*t*-crit.	Remark
Control (M)	50	65.34	10.62	98	4.36	1.96	Significant
Control (F)	50	58.23	10.12				

$p \leq 0.05$.

The result from Table 4 showed that the *t*-calculated value is 4.36 while the *t*-critical value is 1.96 at a $p \leq 0.05$ level of significance. Thus, the null hypothesis is rejected. This implies that the male students in the control group performed better than the female students.

$H0_5$: There is no significant difference in the mean performance of the male students in the discovery (experimental) group and the male students in the expository (control) group.

Table 5. *t-test* result between experimental group (male) and control group (male).

Group	N	X	SD	df	*t*-calc.	*t*-crit.	Remark
Experimental (M)	50	72.81	10.22	98	8.63	1.96	Significant
Control (M)	50	68.24	9.32				

$p \leq 0.05$.

Statistical evidence revealed that t-calc. is 8.63 while the t-crit. is 1.96 at a $p \leq 0.05$ level of significance, indicating a significant difference in the performance of the two groups. Thus, the male students in the experimental group performed better than the male students in the control group.

3.2 *Discussion*

Findings from the study revealed a significant difference in the performance of students in mathematics when taught with discovery and expository methods of teaching. The discovery method appears to be more effective when compared with the expository method of teaching. This finding is in line with and Ibe (2013).

Another finding showed a significant difference among female students taught with the discovery method compared to those taught with expository method. This is also in line with the finding of Ibe (2013).

A significant difference was observed among students (male and female) when taught mathematics using the expository method. This gives credence to the belief that mathematics is a male domain. Similarly, male students performed significantly better than female students when taught using the discovery method.

In the same vein, male students taught using the discovery method performed significantly better than the male students taught using expository method.

The discovery method tends to boost students' interest in science subjects when compared to other conventional methods of teaching. Boosting students' interest will certainly improve their academic performance (Ifeakor, 2007, cited in Ibe, 2013).

4 CONCLUSION

Nowadays, based on the influence of drastic changes in the contemporary world, the attention of developing countries like Nigeria is on improving the educational sector with special attention on science and mathematics education. Thus, all aspects of the teaching-learning process need attention and the main precondition of a successful teaching-learning process is the use of an effective teaching method. This paper made a strong comparison between two teaching methods, namely discovery and expository. Having shown that the discovery method is more effective than the expository method, the findings also showed that even though mathematics is generally considered as a male domain, an effective teaching method can narrow the gap between male and female students. Boosting students' interest is essential in improving their academic performance. It also showed that a good instructional strategy based on a student-centered approach has a significant influence on mathematics performance.

4.1 *Recommendations*

From the foregoing, the following recommendations are made:

1. Teachers should use an appropriate teaching method such as the discovery method to stimulate students' interest for effective results.
2. Teacher training institutions should emphasize the use of the discovery method of teaching mathematics in our secondary schools.
3. Our professional associations such as Science Teachers Association of Nigeria (STAN) and Manufactures Association of Nigeria (MAN) should complement the efforts of teacher-education institutes by organizing workshops for mathematics teachers for appropriate teaching methods regularly.
4. Federal/state ministries of education should organize periodic in-service training for teachers on new methods of teaching mathematics.

4.2 *Recommendations for further studies*

The study has the following suggestions:

1. This study could be extended to other institutions, colleges of education, polytechnics and universities in Nigeria for widening and generalizing the scope of this study.
2. The results obtained in this research were for mathematics, therefore the method can be tried in other disciplines such as physics, biology and chemistry in senior secondary schools.
3. There is a need to use different methods of instruction for the teaching of mathematics concepts such as through play or the discussion method.
4. This study was limited to Nassarawa zonal education offices of Kano State. A similar study could be extended to other zonal education office of the state, or in other states of the country.
5. Similarly, other concepts/topics other than quadratic equations could be used.

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Organ-specific expression revealed using support vector machine on maize nested association mapping datasets

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ABSTRACT: Gene expression datasets provide powerful insight into functional genomics in life sciences. We used the maize Nested Association Mapping (NAM) expression datasets from maize qTeller and performed the Support Vector Machine (SVM) to classify the high-dimensional information on gene expression based on organ-specific characteristics: apex, ear, root, shoot, and tassel. We conduct a filtering process by removing null values and an ANOVA test to reduce the data complexity before the SVM analysis. We used the ratio of 70:30% for training and testing datasets and the cost value parameter equal to 0.1. We evaluate the SVM prediction using accuracy, precision, and recall functions. As a result, the accuracy rate is 100% for apex, ear, and tassel, while it is 88.89% for root and shoot with an Area Under the Curve (AUC) value = 0.9895. We obtained 8,470 gene expressions with the SVM weights and visualized the expression of the gene based on a weight value of ≥ 0.03. Hence, we found genes that are probably the key players in a specific metabolic pathway in maize organs. Moreover, the SVM provides new insight to analyze the gene expression datasets.

1 INTRODUCTION

In recent years, the development of information technology has had a significant impact on other disciplines. One of the new disciplines is called bioinformatics (Jiang et al., 2013). Bioinformatics originates from an increase in the amount of biological observation data. The term bioinformatics was put forward in the mid-1980s to refer to the adoption of computers in biology (Rahayu & Nugroho, 2015).

Increasing human understanding in bioinformatics causes the development of data volumes to increase rapidly. The availability of an open database is an excellent opportunity to dig up valuable information. Technology to obtain biological data becomes cheaper and more effective, giving rise to a big new data era in bioinformatics (Kashyap et al., 2015; Behjati & Tarpey, 2013).

The data currently available is not possible to analyze effectively due to amount of data stored. Therefore, we need solutions to solve the data mining problems, one of which is machine learning. Machine learning is a computational science that can identify large dimension data. Machine learning is also expected to meet the expectations of big data analysis in biology (Greene et al., 2014).

Machine learning techniques are found to be very practical and relevant for many applications in bioinformatics, network security, health, banking and finance, and transportation. Over time, bioinformatics and health-related data were created and accumulated continuously resulting in extraordinary data volumes.

There are two types of learning methods in machine learning, namely, supervised and unsupervised. The supervised learning method is a method that aims to predict class labels on test data based on the results obtained from available training data, often called training sets. On the other hand, the unsupervised learning method does not depend on the availability of previous training data.

Classification is the supervised machine learning type where one of the classification techniques is the Support Vector Machine (SVM). It was developed by Boser, Guyon and Vapnik to find the optimum *hyperplane* to separate two classes in the *input space* (Nugroho et al., 2003). In the beginning, SVM was used to solve a linear classification. Moreover, its development shows that it can be implemented for non-linear classification as well.

The application of SVM method can be seen in papers by Cahyo (2018), Handayani et al. (2017), Munawarah et al. (2016), Naufal et al. (2015), Octaviani et al. (2014), Puspitasari et al. (2018), Tripathi (2000) and Vanetha et al. (2015).

Maize (*Zea mays* L.) is an essential commodity in Indonesia. It has significant potential for the food and animal feed industries and cereal commodities have a strategic role play as a rice substitute (Bunyamin et al., 2013). To improve corn's properties, genetic diversity via genetic crop breeding needs to be done. With the existence of extensive variability, the selection process can be carried out effectively because it will provide more opportunities to obtain the desired characters (Sobir, 2007, p. 105, quoted in Sain, 2016). The classification of maize organs based on gene expression sets will provide the valuable information on molecular basis of organ metabolisms. In this paper, we aim to evaluate the pattern of gene expression related to the organ-specific expression of maize NAM using a support vector machine.

2 METHOD

2.1 *Types and data sources*

We used the gene expression dataset from the maize Nested Association Mapping (NAM) from qteller.com (http://www.qteller.com/NAM4/).

2.2 *Research variables*

The research variable used is the *gene_names* variable which consists of 39,498 gene names. These are the collections of gene expression values in the maize NAM dataset, and 134 types of maize strains which have the characteristics of five organs including apex, ear, root, shoot, and tassel. The *gene_names* variable is an independent variable and the organ characteristic is the dependent variable.

2.3 *Data analysis methods*

All learning methods of the machine require pre-processing from the dataset for useful results. There are two kinds of pre-processing here, namely filtering and feature selection. Feature selection leads to better results and reduces the time spent (Kashyap et al., 2015).

First, we removed the expression value of the gene which has a mean value = 0, and a standard deviation value > 0.7. Secondly, we performed the ANOVA test using a significance value <0.0001 to perform the feature selection process. We built the SVM model using training and testing datasets using a partition of 70% of a total of 134 samples and organs. Then we calculated the accuracy of the SVM model from 30% of the total sample data resulting in the confusion matrix tables. Furthermore, we predicted the SVM method classification based on the accuracy, precision and recall values from the confusion matrix table. All analysis is done in the R software together with the Support Vector Machine (SVM) package (Boser, et al., 1992). The simple explanation is that the SVM aims to find a hyperplane. This is the best separator between two classes, and measures the hyperplane margin and the maximum point. *The margin* is a distance between the hyperplane and the nearest pattern from each class. The nearest is called a support vector.

Therefore, the initial step of SVM is the definition of the separator hyperplane, which is:

$$W.X + b = 0 \tag{1}$$

W is a weighted vector $W = \{W_1, W_2, \ldots, W_n\}$, where n is the attribute size and b is a scalar (bias). Suppose there two attributes A_1, A_2 where $X = (x_1, x_2)$. The x_1 and x_2 is the value from

A_1 and A_2 attributes, and if b is considered as the additional weight (w_0), then the equation of the separator hyperplane can be re-written as:

$$w_0 + w_1 x_1 + w_2 x_2 = 0 \quad (2)$$

Each point above the hyperplane separator is defined as:

$$w_0 + w_1 x_1 + w_2 x_2 > 0 \quad (3)$$

Each point beneath the hyperplane separator is defined as

$$w_0 + w_1 x_1 + w_2 x_2 < 0 \quad (4)$$

Further, from the equations above we have two equations for the hyperplane:

$$w_0 + w_1 x_1 + w_2 x_2 = 0 \quad (5)$$
$$w_0 + w_1 x_1 + w_2 x_2 = 0 \quad (6)$$

3 RESULTS AND DISCUSSION

3.1 *Filtering*

By removing rows that have a mean value = 0 and removing rows that have a standard deviation value > 0.7, this process results in reducing the 39,498 genes to 13,197 genes. Then we use the mt.teststat function to perform a feature selection with ANOVA, and the significance level is 0.0001. This further reduces the genes to 8,470. We use these genes in the SVM classification.

3.2 *SVM classification*

We classified the organ-specific characteristics for maize NAM datasets based on the value of gene expression. The training data is a set of datasets that are used to form a classification model in predicting new data classes, while the testing data is a collection of new datasets that are used to measure the extent to which the system successfully classified correctly. Data are classified into training data and testing data randomly.

Maize NAM has five organ-specific classes, namely apex, ear, root, shoot, and tassel. The researcher divided the training data by 70% from each classification class, such that the total training data we used was 90 samples, while the testing data was 30% with a total of 44 samples.

The package e1071 is used to obtain the best model for the classification class from the training dataset and computed its accuracy using the testing dataset. To create the best model (based on the smallest cost value), SVM requires the right tuning parameters. The values of the cost used in the study are 0.1, 0.01, 0.001, 1, 10, and 100. The cost parameter affects the accuracy of the classification in the testing data. We found out that the best cost value is 0.1.

3.3 *Confusion matrix*

The confusion matrix can be used to measure the performance of a classification method. The prediction class is compared to the actual class, and the training dataset gives a complete classification, based on its actual and prediction classes. In this case, the SVM algorithm implemented with a linear kernel and the cost parameter = 0.1, see Table 1.

Table 2 shows that there are two errors in the classification, in class 1 (ear) and class 2 (root). We found false classification between classes 1, 2, and 3. Out of nine organs, one organ is recognized as class 2 and one organ from class 2 is recognized as class 3. Further, the accuracy of the classification reached 95% so the model can classify very well.

Table 3 shows us the precision values for each class.

The recall value for classes 0 (apex), 3 (shoot), and 4 (tassel) is 100%, which means that the proportion of positive classes that are correctly classified by the system reaches a perfect value, while the value of recall for classes 1 (ear) and 2 (root) shows that the classification results are not perfect because there are still errors in the classification. The accuracy of the model is obtained using the test data which is 95%. Furthermore, we obtained an Area Under

Table 1. Confusion matrix from training dataset.

Prediction	Actual Class 0 (apex)	Class 1 (ear)	Class 2 (root)	Class 3 (shoot)	Class 4 (tassel)
Class 0 (apex)	18	0	0	0	0
Class 1 (ear)	0	18	0	0	0
Class 2 (root)	0	0	18	0	0
Class 3 (shoot)	0	0	0	18	0
Class 4 (tassel)	0	0	0	0	18

Table 2. Confusion matrix from testing dataset.

Prediction	Actual Class 0 (apex)	Class 1 (ear)	Class 2 (root)	Class 3 (shoot)	Class 4 (tassel)
Class 0 (apex)	9	0	0	0	0
Class 1 (ear)	0	8	0	0	0
Class 2 (root)	0	1	8	0	0
Class 3 (shoot)	0	0	1	9	0
Class 4 (tassel)	0	0	0	0	8

Table 3. Precision and recall values.

Prediction	Class Class 0 (apex)	Class 1 (ear)	Class 2 (root)	Class 3 (shoot)	Class 4 (tassel)
Precision	100	100	88.89	90	100
Recall	100	88.89	88.89	100	100

Table 4. Weighted values of genes.

Gene name	Weighted value
Zm00001d002420	0.04318470
Zm00001d006641	0.04030337
Zm00001d037461	0.03898047
Zm00001d031923	0.03763193
Zm00001d024229	0.03742036
Zm00001d024229	0.03558894
Zm00001d043896	0.03537451
Zm00001d021376	0.03457250
Zm00001d003472	0.03311318
Zm00001d036611	0.03291094

the Curve (AUC) value = 0.9895 (Park et al., 2004), which means that the accuracy of the SVM model is good (Sofi & Jajuli, 2015).

3.4 *The variables importance*

The SVM model we obtained ten variables importance model (Table 4) from 8,470 genes which described below.

The highest weight is at gene Zm00001d002420, and the lowest is at gene Zm00001d036611. All genes are the most influential genes that can be used to distinguish the organ-specificity of maize. These genes are probably the key players in a specific metabolic pathway in maize organs.

4 CONCLUSION

We have performed the SVM analysis on gene expression datasets of maize nested association mapping. As a result, the SVM analysis showed the classification results from the testing data indicate that there are two errors in the classification in class 1 (ear) and class 2 (root). However, the accuracy value from the testing data is 95% with an AUC value of 0.989. In summary, the high accuracy value indicates the SVM model is a perfect model to classify the organ-specificity of the maize dataset. Further study can be done to compare the results to other algorithms.

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Enhancing fault tolerance in MapReduce tasks

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ABSTRACT: MapReduce is a programming model and a runtime environment for big-data processing over distributed systems (e.g. clusters, cloud and grids). Task failure has become a critical issue and could increase the cost of jobs and affect resource utilization in MapReduce. Currently, the MapReduce fault-tolerance mechanism is based on rescheduling failed tasks on other nodes, where they are re-executed, and this rescheduling affects resource utilization, as well as execution time. In this paper, a new rollback-recovery model called Pessimistic Log-based Rollback (PLR) is introduced for MapReduce fault tolerance. The central principle of the proposed PLR model is a logging process to enable rollback when failure occurs by recording the task as the determinant of the log report. When a task fails, the proposed PLR model will reactivate the execution of this task on the same node starting from the last state before failure, which optimistically can solve the MapReduce task failure problem. In the worst case, the task will be rescheduled into another node for re-execution. The experimental results for the proposed PLR model show that MapReduce performance is improved in the case of failure, reducing execution time by approximately 35%.

1 INTRODUCTION

MapReduce is a big-data processing framework, which is deployed in a distributed environment to support complex task execution in large scalable systems (Dean & Ghemawat, 2004). In MapReduce, data is divided up, and then it is processed via separate tasks over distributed nodes. Functionally, the MapReduce program is composed of *Map* and *Reduce* functions. A map function takes a list of key-value pairs as input, processes them and then generates its output in terms of key-value pairs. As for the reduce function, it takes key-value pairs output by the map function, processes them and generates the desired result.

Hadoop is an open-source system developed by many companies (e.g. Yahoo). It is designed to support the distributed storage and processing of huge data sets on clusters built from commodity hardware (White, 2015; Apache Software Foundation, 2018). Essentially, Hadoop is comprised of two main components: the storage part, known as the Hadoop Distributed File System (HDFS), and a processing part known as MapReduce. Hadoop's HDFS is a distributed file system (Abdel Azez et al., 2018; Mahmoud et al., 2018; Kaseb et al., 2018) that stores the input and output data on commodity machines and provides very high aggregated bandwidth across the cluster, similar to Google's file system (Ghemawat et al., 2003).

With the growth of data and the need to use large-scale distributed environments (Sahal et al., 2016, 2018; Shanoda et al., 2014) such as Hadoop, the possibility of task failures has become a big challenge. Therefore, poor fault tolerance is considered one of the main drawbacks of the MapReduce framework (Apache Software Foundation, 2018). On the other hand, software failure in MapReduce (i.e. MapReduce task failure) has had less attention despite its importance. Fundamentally, such failures can occur because of map/reduce code runtime exceptions. Another cause of failure is the Java Virtual Machine (JVM) exit task for a particular set of circumstances exposed by the map/reduce code. In particular, the primary goal of the current fault-tolerance methodologies is the elimination of single points of failure, which will cause the entire system to break down (Sarhan et al., 2009).

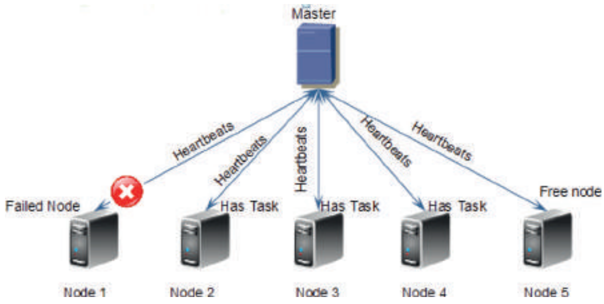

Figure 1. Hadoop fault tolerance.

In this paper, the fault tolerance of the Hadoop MapReduce framework is considered. Essentially, Hadoop splits the input data into blocks to be stored in the HDFS, where each block is processed by a map task. The fault tolerance of the HDFS occurs when replicating and storing data blocks in the data center nodes. Furthermore, Hadoop assigns a task to a node, which has HDFS replication of the input data to support data locality. The map tasks store their results (i.e. intermediate data) in local storage rather than in the HDFS. So, if a map task crashes, it will be re-executed in another node without saving its results (see Figure 1). The performance impact of task failures is very severe in that the job completion time typically increases fourfold and, in the worst cases, can increase up to 68-fold (Kim et al., 2015).

Therefore, a new rollback-recovery model, which is based on the logging process, is proposed, called Pessimistic Log-based Rollback (PLR). The PLR model aims to enable rollback by recording the task and making it the determinant of the log report in the case of a failure. The key idea of the proposed PLR model is reactivation when a task has failed. Thus, the proposed PLR model will reactivate the execution of this task starting from the last state on the same node prior to failure, which optimistically can solve the MapReduce task failure problem. In the worst case, the task will be rescheduled into another node to be re-executed. Figure 1 depicts a simple scenario for the proposed PLR model that supposes that Node 1 or its task fails, caused respectively by hardware failure or software failure; the task will be assigned to a node that is currently free (i.e. Node 5 in Figure 1). The main principle of the proposed fault-tolerance solution is reuse of the intermediate data of a task to enable rollback in the case of failure.

The rest of this paper is organized as follows: related work is described in Section 2, and details of the proposed PLR system are presented in Section 3. Experimental evaluation is presented in Section 4, with conclusions in Section 5.

2 RELATED WORK

MapReduce is designed for parallel processing of big data using a cluster of small and cheap servers with high availability and scalability. With the growth of data, cloud applications are frequently needed to handle this data processing efficiently and achieve the minimum level of task failure in MapReduce jobs. The history of recent MapReduce fault-tolerance evolution is summarized in the following subsections.

2.1 *He et al. (2012)*

The third level of fault tolerance in Hadoop is the site failure level, extending the traditional two levels (node and rack) already provided in the standard implementation (He et al., 2012). Three components are included in the Hadoop On the Grid (HOG) architecture: the grid submission/execution system, the HDFS, and the MapReduce framework. The grid submission/execution system uses HTCondor and a Glidein-based Workload Management System (GlideinWMS) to allocate and manage tasks, as well as initializing the environment to execute on the Open Science Grid (OSG) organization and sending the Hadoop executable packages. The rack level is implemented in both the HDFS and MapReduce components, and provides the load-balancing and improved fault-tolerance features (He et al., 2012).

2.2 *Kadirvel and Fortes (2013)*

A dynamic resource-scaling approach was proposed to improve the fault-tolerance capabilities of the MapReduce paradigm for a given set of job characteristics and framework parameters (Kadirvel & Fortes, 2013). The authors focused on Hadoop, and the proposed system is based on applying a scaling method that dynamically increases the number of slave nodes assigned to a given Hadoop job when a node failure occurs. New nodes are used to execute failed tasks and to apply a load-balancing scheme to share the load of healthy tasks. On the other hand, another method was proposed to replicate intermediate data to the reduce processes but this method is expected to produce a large number of I/O operations, consume a lot of network bandwidth, and only support recovery for single-node failures.

2.3 *BeTL (2015)*

The BeTL model proposed a finer-grained level of checkpointing. A complicated strategy may keep track of every single record, but will probably bring many overheads due to the limited capability of fault tolerance. Instead, BeTL keeps track of consecutive records, which are parsed from a segment of the input data file. The fault-tolerance strategy of the current MapReduce framework is also based on checkpointing to some extent; however, the checkpoint granularity is determined before execution and cannot be adjusted on the fly. BeTL manages finer-grained checkpoints under the scope of a single task by permitting the task to attempt the checkpoint at an arbitrary point on demand (Wang et al., 2016).

The majority of the related work considers enhance fault tolerance at Node level using passive or optimized replication which is a high cost and Hadoop has default fault tolerance for node failure which is enough and suitable for many jobs. Therefore, a fault-tolerance model, based on the rollback-recovery model, has been added to the MapReduce model. It can reduce job execution times, and the task can continue to execute in the case of failure by using the last information stored in the logging report.

3 PESSIMISTIC LOG-BASED ROLLBACK (PLR)

The proposed PLR model is implemented as a component that has been added to map processing in the Hadoop framework. The PLR component is based on a rollback-recovery model, which consists of checkpoint, failure detection, and recovery processes. In terms of the checkpoint process, this is done by taking a snapshot of a task determinant at a particular point. If a task fails, the failure detection process will detect it. After that, the recovery process will be started to recover the failed task by restarting it from the last checkpoint.

A rollback-recovery model can be implemented by checkpoint- or log-based models. In this paper, PLR uses a log-based model that depends on recording task events such as the number of processed keys and task variables in a report called *logged-report*. The recorded information about task events is called the determinant. The *logged-report* is used to enable the failed task to continue running from the last recorded events. Moreover, it is executed and saved locally on task nodes (i.e. map nodes) to avoid network transfer costs.

There are two approaches that can be used to implement a log-based model: pessimistic and optimistic. In the case of the pessimistic approach, the task determinant is recorded *before* its execution is triggered. Thus, it can be done before the map function is processed (see Figure 2). The main advantage of this approach is that it enables the task to restart from a known state when a failure is detected, and to save storage it only records the latest checkpoint events, with older checkpoints discarded. However, the main disadvantage of this method is the blocking of the map function process until the event determinant is

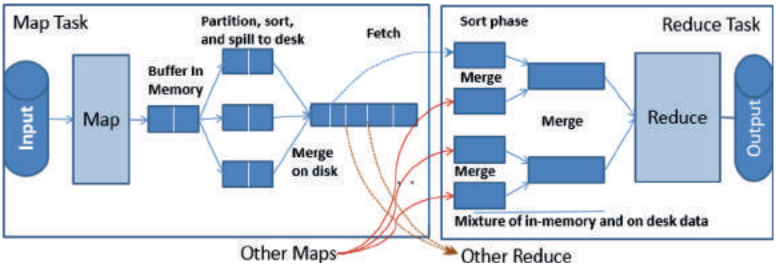

Figure 2. MapReduce model.

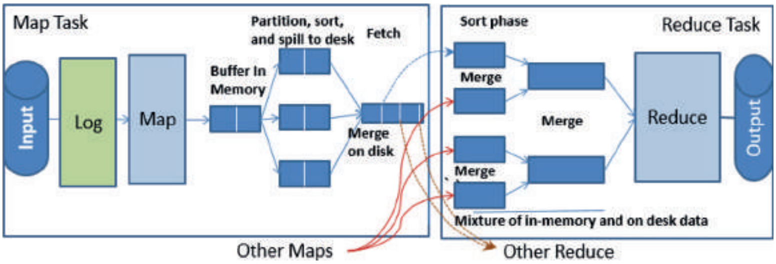

Figure 3. PLR model.

successfully stored in the *logged-report*, which causes task execution overhead. In the optimistic approach, the determinant of the task is recorded *after* its execution has been triggered (see Figure 3). The main disadvantage of this approach is that a failure can occur after the processing of the map function and, therefore, the event determinant fails to be stored. All *success-processed* keys are lost, and the map function must start from the last complete checkpoint. Because of the advantage of the pessimistic approach, we use it to implement our log-based rollback model (PLR) in the MapReduce model.

The MapReduce programming model consists of two main functions (see Figure 2):

- The *Map* function starts processing data and writes its output to a memory buffer (default size 100 MB). When the memory buffer fills up, there is a background thread that starts to 'spill' data to the disk. The map thread continues to write to the memory buffer while the spill thread runs until it can no longer write to the buffer. At this stage, the map thread waits until the spill thread completes. Every time the memory buffer reaches the spill threshold, a new spill file is created. After the map thread processes all input data and the last spill output has been written, a thread will start to sort and merge all spill files into a single file, and then sends an acknowledgment to the master node that it has finished its work and that it will start to transfer its output's key-value pairs to the corresponding reduce process.
- The *reduce* function waits until all map processes have finished their tasks and then starts a number of threads (default five) in parallel to copy data from the map processes. Reduce processes can run in parallel with map processes, but will only copy finished map outputs, and will wait until all map processes complete their tasks. After a reduce process has successfully collected a map process's data, it will start to sort and merge threads and if the amount of sorted data reaches the memory threshold, it will spill data onto the disk. Once all data are sorted and merged, the reduce process can start its task. A reduce function will be invoked for each key in its input and it directly writes its output to the file system, HDFS.

The proposed pessimistic log-based rollback model is presented in Figure 3. PLR adds a logging process to enable rollback if a failure occurs. It records the task determinant in the log report, invoked before the map function is applied. The PLR model makes a log-report entry after reading a number of key-value pairs from input data. It uses a key counter to start the snapshot of task status. Depending on their job, a user can change the PLR log key size in the configuration file. Initially, the default value is set to 175 keys after a number of runs on different jobs. The map task waits when the log-report event is invoked to ensure that the logging is successful. In terms of the default Hadoop approach, if a task fails, the master node tries to re-execute the task on another node, which is called a task attempt. According to the proposed PLR model, a task attempt will be made on the same node and if the task attempt fails after a preconfigured number of retries (default number of attempts is three), task execution will be moved to another node. When a slave node receives a task that attempts a request, it will read the task *logged-report* from the local storage. If the *logged-report* is found, the slave node will start from the last recorded task.

4 EXPERIMENTAL EVALUATION

To evaluate the fault tolerance using the proposed PLR model, we have used a Hadoop cluster to measure the performance and overhead aspects. The implementation of the PLR model is based on Hadoop 2.4.0, Java 1.7 and an HDFS with data block size of 64 MB. The Hadoop cluster is deployed on six Dell PowerEdge R720 servers, each with two Intel® Xeon® processors. Each node is configured to hold seven virtual machines, and thus we have 42 nodes. The PLR model estimation depends on running the same job on the cluster twice, once with the default Hadoop fault-tolerance model and again with the proposed PLR model. Then, the execution time and overheads are estimated. The Hadoop cluster consists of one master node with the 41 remaining nodes acting as worker nodes. Each worker node can run two map tasks in parallel and one reduce task, which is the Hadoop default. In the experiment, a word counting job is used to find the occurrence of a list of words among a huge amount of web-page data. This job requires intensive computation, but it generates fewer intermediate results. A subset of the ClueWeb09 dataset (Lemur Project, 2018) is used, involving about 1.68 million web pages at an average of 1 MB per file. Each map task can handle approximately 140 MB, so each node is assigned 286 map tasks.

In the case of task failure, Figure 4 shows the comparison between the normal Hadoop fault-tolerance model and Hadoop fault tolerance with the PLR model where the backup key size is 175. The x-axis represents the probability of task failures per 200 tasks, and the y-axis represents the total time execution of the job in minutes. As the number of failed tasks in the jobs increases, the PLR fault-tolerance model decreases the total time of execution compared to the default Hadoop model. This is because the default fault tolerance in Hadoop re-executes the failed tasks from the beginning, whereas the PLR model starts the task execution from the last process in the log report.

As can be seen in Figure 5, system performance with a variety of data sizes was measured. In practical terms, five task failures occurred for every 200 tasks. When data size increases, the proposed PLR model gives an increasing execution-time advantage over the normal Hadoop fault-tolerance model.

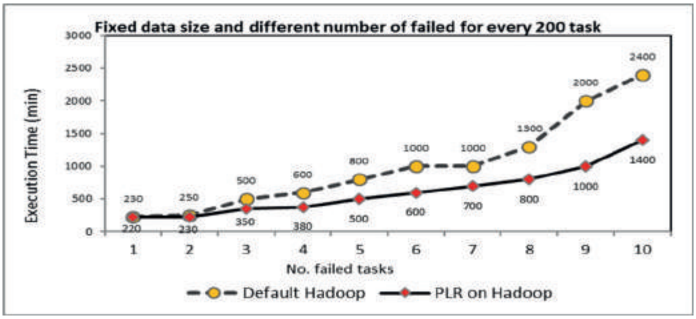

Figure 4. Task failures comparison.

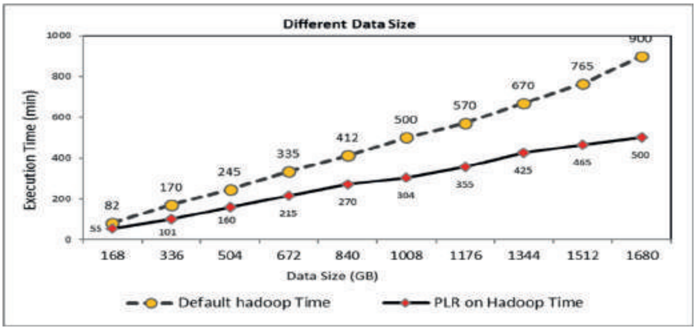

Figure 5. Task failures with changing data size.

We note that the log-report key size will affect PLR performance, because if the key size is large, the log-report process overhead will be increased as the log-report has I/O overhead and map processes waiting on logging to complete.

The task failure position affects the total job execution time when dealing with default MapReduce fault tolerance. Clearly, when the failure occurs at the beginning of task execution, it has a smaller overhead than failures that occur at the end of a task, which have an overhead of up to 100%. In contrast, the task failure time for the proposed PLR fault-tolerance model is very low because it restarts exactly from the last point where the failure occurred in the log-report process, whereas a Hadoop system with default fault tolerance noticeably affects task execution time because it restarts task execution from the beginning. In PLR fault tolerance, the overhead is incurred only in the worker nodes in the log-report process and in the case of the restored process. The proposed PLR model has zero network overhead compared to Hadoop's default fault-tolerance model.

5 CONCLUSION

In this paper, a PLR model is proposed as an enhanced solution for fault tolerance in MapReduce tasks. The PLR model is based on use of a logging process to enable rollback by recording task determinants in a log report in case of failure occurrence. In addition, the performance evaluation results for the proposed PLR model show a significant reduction in MapReduce execution time relative to the native fault tolerance of Hadoop MapReduce.

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Classification of crimes based on socioeconomics using multinomial regression

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ABSTRACT: Prisoner coaching will be more effective if factors relating to the causes of crime are classified. Statistical analysis is used to classify the prisoners' socioeconomic factors. The multinomial logistic regression method is suitable for this study because the response variable is in more than two categories. In this study, the response variables were narcotics crime, fraud, theft, and other crimes. The explanatory variables that affect the response variable are socioeconomic. The data relates to inmates in DKI Jakarta in 2018 using 600 respondents. Based on the odds ratio with a significant level of 0.05, it is known that 11 explanatory variables together have a substantial influence on the type of crime associated with inmates in DKI Jakarta. Variables that partially affect the crime of theft are age, income, expenditure, communication tools, and homeownership. Influencing variables for narcotics crime are religion, age, education, income, expenditure, dependency burden, course, and communication tools, while some of the variables that influence other crimes are religion, age, education, income, expenditure, dependency, and homeownership.

1 INTRODUCTION

Crime is some action that violates legal norms (Rahman, 2016). The action will give rise to various negative things that will harm others (Hanim & Prakoso, 2015; Hapsari et al., 2016). Coaching inmates aims to act as an effective deterrent to prisoners when it comes to repeating crime, and could build a level of trust in themselves to be better people. The coaching of inmates will be more effective if the factors that cause the occurrence of crime are classified (Abdullah, 2015). The classification of the causes of crime is carried out in the socioeconomic field (Santi et al., 2017).

Several methods can be used for classification, including multinomial logistics regression, the Generalized Linear Model, and the Bayesian Generalized Linear Model. In this study, the technique uses multinomial logistics regression. The method was chosen because of the level of ease it involves in processing data (Santi et al., 2017). An appropriate method is used to see the relationship between the types of crime and socioeconomic variables, namely the multinomial logistic regression method. This method is very suitable because the response variable (Y) has four categories, namely narcotics crime, murder, theft, and other crimes (Hosmer & Lemeshow, 2000). Socioeconomic variables are used as explanatory variables (X).

This study discusses the multinomial logistic regression model to connect the response variable (Y) with socioeconomic variables. This research was conducted in one of the prisons in Jakarta with 600 respondents and the four types of crime observed.

2 METHOD

2.1 *Multinomial logistic regression analysis*

Multinomial logistic regression is a continuation of binary logistic regression in which the response variable category is more than two categories (Myers et al., 2010; Santi et al., 2017; Apsari et al., 2013). Multinomial logistic regression is very interesting because multinomial logistic regression does not test standard assumptions.

The general form of logistic regression models is as follows:

$$E(y) = \frac{e^{g(x)}}{1 + e^{g(x)}} \tag{1}$$

Suppose x is a vector of explanatory variables measuring $p + 1$ with $x_0 = 1$. The constants of the logit function are:

$$\pi 0(x) = \frac{1}{1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)}} \tag{2}$$

and

$$\pi j(x) = e^{g_j(x)} \frac{1}{1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)}} \tag{3}$$

for $j = 0,1,2,3$.

2.1 *Parameter estimation*

The response variable is assumed to be mutually independent, and then the log-likelihood function is obtained as follows (Hogg et al., 2013):

$$L(\beta) = \sum_{i=1}^{n} y_{1i} g_1(x_i) + y_{2i} g_2(x_i) + y_{3i} g_3(x_i) - \ln\left(1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)}\right) \tag{4}$$

based on the theory of maximum likelihood, to estimate variants and covariances obtained through the derivative of the two likelihood functions.

2.2 *Test of parameter estimator significance*

The hypotheses used are (Winarti et al., 2016):

H_0: $\beta_k = 0, k = 1,2, \quad , p$ (there is no influence between the p-explanatory variable and the response variable);

H_1: $\beta_k \neq 0, k = 1,2,\ldots, p$ (there is an influence between the p-explanatory variable and the response variable).

Test statistic (Hosmer & Lemeshow, 2000; Tampil et al., 2017):

$$W_p = \left(\frac{\mathcal{B}_p}{SE(\mathcal{B}_p)} \right)^2 \tag{5}$$

where $\mathcal{B}_p$ = coefficient estimator β_p; $SE(\mathcal{B}_p)$ = standard error for parameter estimator β_p.

Statistic W_p follows a chi-squared distribution with one degree of freedom. Reject H_0 if $W_p > \mathcal{X}^2_{1,\alpha}$ or p-value is less than α, meaning that the p-explanatory variable partially affects the response variable.

2.3 *The goodness of model test*

A residual is a measure of the compatibility between the observation of a response variable and its predicted value. This measure provides information on how well the model matches each observation in the data (Hollander et al., 2013). The hypotheses used are:

H_0: There is no difference between the results of observation and the results of prediction;
H_1: There is a difference between the results of observation and the results of prediction.

To test the goodness of logistic regression, models can use deviance as follows:

$$D = 2\sum_{i=1}^{n}\left[y_i ln\left(\frac{y_i}{n_i - \pi_i} \right) + \left(n_i - y_i \right) ln\left(\frac{n_i - y_i}{n_i\left(1 - \pi_i\right)} \right) \right] \tag{6}$$

With D distributing $\mathcal{X}^2_{n-p}$, then accept H_0 if $D > \mathcal{X}^2_{n-p}$ or sig. $> \alpha = 0.05$, which means there is no difference between the results of observation and the results of the predictive model (Tabachnick et al., 2001).

2.4 *Research framework*

The research framework is described in Figure 1.

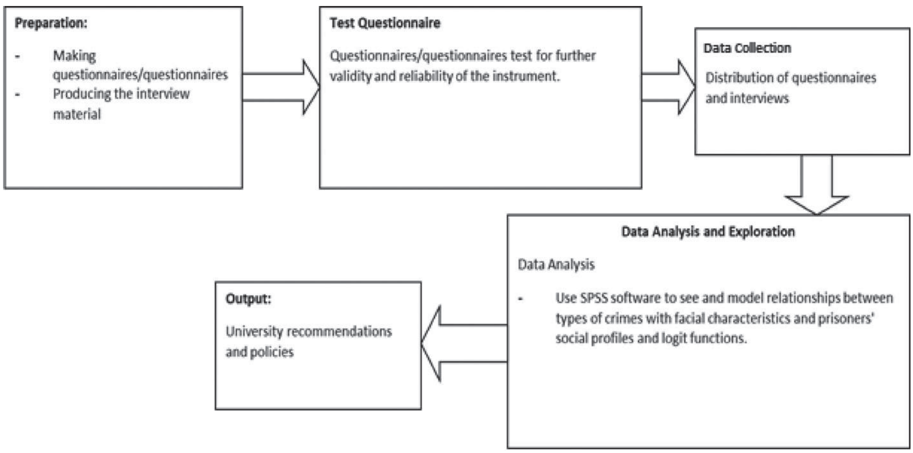

Figure 1. Research framework.

3 RESULTS AND DISCUSSION

3.1 *Test validity and reliability*

Validity and reliability testing is the process of testing the questions in the questionnaire. With test statistics (Yuniarti & Suprianto, 2014):

$$r = \frac{n\sum_{i=1}^{n} x_i y_i - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{\sqrt{\left\{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2\right\}\left\{n\sum_{i=1}^{n} y_i^2 - \left(\sum_{i=1}^{n} y_i\right)^2\right\}}} \tag{7}$$

Valid variables are obtained, namely religion, age, last education, monthly income, monthly expenses, life expectancy, film genre, courses, communication tools, homeownership, lighting sources, and fuel. These variables are valid because the significance value for each variable $\leq \alpha = 0.05$ and the value of $\alpha_{\text{Cronbach}} = 0.63$. Therefore, these variables are reliable and the questionnaire can provide consistent data. After the questionnaire is declared valid and reliable, this research can be conducted using the questionnaire to obtain the overall data to be analyzed.

3.2 *Multinomial regression analysis*

3.2.1 *Significance test*

- Concurrent Test

The significance test of the model was simultaneously carried out using the likelihood ratio test. The test results obtained a value of sig. = 0.000 < α, so that the decision is to reject H_0. This means that the 12 explanatory variables together have a significant influence on the characteristics of the prisoners' crimes.

- Partial Test

The response variable consists of four criminal acts, so that three logit functions are formed. The category used as a comparison is the category of fraud crimes. Based on the results of testing for a theft crime, the logit function can be written as follows:

$$\begin{aligned} Y_1 = 2.672X_{2,1} + 5.764X_{4,1} + 5.489X_{4,2} + 4.954X_{4,3} + 5.45X_{4,4} - 3.633X_{5,3} + 8.260X_{9,1} \\ +5.364X_{9,2} - 2.668X_{10,1} \end{aligned} \tag{8}$$

Variables that have a partial effect on theft crime are age, income, expenditure, communication tools, and homeownership.

Table 1. Pearson correlation coefficient of variables.

Variable	Pearson correlation coef.	Sig.
Religion	0.281	0.02
Age	0.325	0.00
Education	0.579	0.00
Income	0.713	0.00
Expenditure	0.755	0.00
Dependency burden	0.187	0.04
Film genre	0.390	0.00
Course	0.588	0.00
Communication tools	0.629	0.00
Homeownership	0.347	0.00
Home lighting source	0.445	0.00
Fuel	–0.319	0.00

Table 2. Model-fitting information.

	Chi-squared	Sig.
Final	478.502	0.000

Table 3. Goodness of fit.

	Chi-squared	Sig.
Deviance	834.437	0.075

The logit function is based on the results of testing for narcotics crime as follows:

$$Y_2 = -2.813X_{1,1} + 1.649X_{2,1} - 12.179X_{3,1} - 12.453X_{3,2} - 13.693X_{3,3} - 14.598X_{3,4} - 14.613X_{3,5} \\ +2.431X_{4,1} + 1.922X_{4,2} + 2.192X_{4,3} + 2.750X_{4,4} - 2.409X_{6,1} - 2.524X_{6,3} \\ +1.732X_{8,1} + 2.166X_{8,2} - 4.118X_{9,1} \quad (9)$$

Variables that have a partial effect on narcotics crime are religion, age, education, income, dependency burden, courses, and communication tools.

The logit function is based on the results of testing for other crimes, as follows:

$$Y_3 = -3.159X_{1,1} - 1.587X_{2,3} - 11.747X_{3,1} - 11.6X_{3,2} - 12.369X_{3,3} - 11.739X_{3,4} + 1.866X_{4,4} \\ - 2.066X_{5,3} - 3.777X_{5,4} - 3.427X_{6,1} - 2.214X_{6,2} - 3.394X_{6,3} - 2.978X_{6,4} \\ - 2.416X_{6,5} - 2.272X_{10,3} \quad (10)$$

Variables that have a partial effect on other crimes are religion, age, education, income, expenditure, dependency burden, and homeownership.

3.2.2 *The goodness of model test*

Testing the suitability of the model is done to find out the difference between the results of the observation and the results of the prediction after the model is simultaneously formed. Based on Table 2 above, it is known that the value of sig. > $\alpha = 0.005$, so that the decision is to accept H_0. This means that there is no difference between the results of observation and the results of the prediction of the model.

3.2.3 *Model interpretation*

The odds ratio for all explanatory variables for each type of crime are shown in Table 4.

Table 4. Logit function odds ratio.

Theft		Narcotics		Other crimes	
Explanatory variable	Exp (β)	Explanatory variable	Exp (β)	Explanatory variable	Exp (β)
Age	[1] 14.46	Religion	[1] 0.6	Religion	[1] 0.042
	[2] 2.102		[2] 0.151		[2] 0.139
	[3] 0.807	Age	[1] 5.201	Age	[1] 1.309
Income	[1] 318.585		[2] 1.838		[2] 0.392
	[2] 242.13		[3] 1.090		[3] 0.205
	[3] 141.702	Education	[1] 0.000	Education	[1] 0.000
	[4] 232.704		[2] 0.000		[2] 0.000
Expenditure	[1] 0.203		[3] 0.000		[3] 0.000
	[2] 0.073		[4] 0.000		[4] 0.000
	[3] 0.026		[5] 0.000		[5] 0.000
	[4] 0.056	Income	[1] 11.365	Income	[1] 0.210
Communication tools	[1] 3866.681		[2] 6.837		[2] 0.617
	[2] 0.0001		[3] 8.953		[3] 1.189
	[3] 0.000		[4] 15.638		[4] 6.462
Homeownership	[1] 0.069	Dependency burden	[1] 0.09	Expenditure	[1] 11.765
	[2] 0.000		[2] 0.248		[2] 1.292
	[3] 0.110		[3] 0.080		[3] 0.127
			[4] 0.270		[4] 0.023
			[5] 0.871	Dependency burden	[1] 0.032
		Course	[1] 5.654		[2] 0.109
			[2] 8.724		[3] 0.034
			[3] 4.321		[4] 0.051
					[5] 0.089
				Homeownership	[1] 0.254
					[2] 0.081
					[3] 0.103

According to the calculation of the odds values for the logit theft function shown in Table 4 (column 1):

- Age [1] has an odds ratio of 14.46, which means that the likelihood of being under 25 years of age as a convicted thief is 14.46 times that of being over the age of 46. Similarly with other age groups.
- Income [1] has an odds ratio of 318.585, which means that as a convicted thief the likelihood of having a monthly revenue below Rp 500,000 is 318.585 times that of having a monthly income above Rp 5,000,000. Similarly with other monthly income groups.
- Expenditure [1] has an odds ratio of 0.203, which means that the likelihood as a convicted thief of having monthly expenditure below Rp 500,000 is 0.203 times that of having a monthly expenditure above Rp 5,000,000. Similarly with other monthly expenditure groups.
- Communication tools [1] has an odds ratio of 3,866.681, which means that as a convicted thief the likelihood of not having communication equipment is 3,866.681 times that of being someone who uses a cell phone, telephone, and internet communication device. Similarly with other communication tools groupings.
- Homeownership [1] has an odds ratio of 0.069, which means that as a convicted thief the likelihood of renting a house is 0.069 times that of being someone who does not own a home. Similarly with other homeownership groups.

According to the calculation of the odds values for the narcotics logit function shown in Table 4 (column 2):

- Religion [1] has an odds ratio of 0.6, which means that as a narcotics inmate the likelihood of being Muslim is 0.6 times that of having another religion. Similarly with other religious groups.
- Age [1] has an odds ratio of 5.201, which means that as a narcotics inmate the likelihood of being under 25 years of age is 5.201 times that of being aged over 46. Similarly with other age groups.
- Education [1] has an odds ratio of 0.000, which means that as a narcotics inmate the likelihood of their highest education level being elementary education is almost 0.000 times that of not having attended school. Similarly with other education groups.
- Income [1] has an odds ratio of 11.365, which means that as a narcotics inmate the likelihood of having a monthly revenue below Rp 500,000 is 11.365 times that of having a monthly income above Rp 5,000,000. Similarly with other monthly income groups.
- Dependency burden [1] has a value of odds ratio of 0.09, which means that as a narcotics inmate the likelihood of having a life expectancy is 0.09 times that of being someone who has more than four dependents. Similarly with other life response groups.
- Course [1] has an odds ratio of 5.654, which means that as a narcotics inmate the likelihood of never having taken a course is 5.654 times that of being someone who has attended a course for more than one year. Similarly with other courses.
- Communication tools [1] has an odds ratio of 0.016, which means that as a narcotics inmate the likelihood of not having communication equipment is 0.016 times that of being someone who uses a cell phone, telephone, and internet communication device. Similarly with other communication tools groupings.

According to the calculation of the odds values for the other-crimes logit functions shown in Table 4 (column 3):

- Religion [1] has an odds ratio of 0.042, which means that the likelihood of someone having been convicted of other crimes being a Muslim is 0.042 times that of having another religion. Similarly with other religious groups.
- Age [1] has an odds ratio of 1.309, which means that the likelihood of someone having been convicted of other crimes being under 25 years of age is 1.309 times that of being aged over 46. Similarly with other age groups.
- Education [1] has an odds ratio of 0.000, which means that the likelihood of someone having been convicted of other crimes having their highest education level being elementary education is almost 0.000 times that of never having attended school. Similarly with other education groups.

- Income [1] has an odds ratio of 0.210, which means that the likelihood of someone having been convicted of other crimes having a monthly revenue below Rp 500,000 is 0.210 times that of having a monthly income above Rp 5,000,000. Similarly with other monthly income groups.
- Expenditure [1] has an odds ratio of 11.765, which means that the likelihood of someone having been convicted of other crimes having a monthly expenditure below Rp 500,000 is 11.765 times that of having a monthly expenditure above Rp 5,000,000. Similarly with other monthly expenditure groups.
- Dependency burden [1] has an odds ratio of 0.032, which means that the likelihood of someone having been convicted of other crimes having a life expectancy is 0.032 times that of being someone who has more than four dependents. Similarly with other life response groups.
- Homeownership [1] has an odds ratio of 0.254, which means that the likelihood of someone having been convicted of other crimes renting a house is 0.254 times that of being someone who does not own a house. Similarly with other homeownership groups.

4 CONCLUSION

Based on the analysis of the data produced, it can be seen that 12 variables have influence together, namely the variables of religion, age, occupation, education, income, expenditure, dependency, film genre, communication tools, homeownership, lighting sources at home, and fuel. Variables that have a partial effect on the category of crime inmate theft are age, income, expenditure, communication tools, and homeownership. Variables that partially affect the crime category of narcotics inmates are religion, age, education, income, life expectancy, courses, and communication tools. The variables that have a partial effect on other categories of crime inmates are religion, age, education, income, expenditure, dependency, and homeownership.

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Identity construction of female mathematics teachers during their school education

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ABSTRACT: School education is the basis of identity construction for girls in mathematics. Different stakeholders such as family, school, teachers, friends, and society play an important role in the construction of identity within school education. The main purpose of this study is to explore the identity construction of girls in school education. I adopted narrative inquiry as the research method for the analysis of the study. I have used Vygotsky's self in cultural-historical activity theory as a theoretical perspective. I have selected four female participants, all purposively university-level mathematics teachers. The study is focused on how females are able to build up their identity in mathematics during their school education. The results show that for girls that are facing problems in their day-to-day life, it is critical for them to build up their identity during their time in school education. To establish the identity of a female, the family has to be encouraged and persuaded to support school education, the school needs to create a suitable environment for studies, teachers act as motivators and supporters, and society should not overshadow them with negative thoughts and beliefs.

1 INTRODUCTION

Humans, as social beings, have different identities according to place, time and circumstance. Rø (2015, p. 3234) defines identity as 'Identity is understood as a function of participation in and at the boundaries of various communities of practice, during university teacher education and at school'. Likewise, Andreouli (2010, p. 141), depicts identity 'as a process which incorporates self-identification and recognition by others. Identity is a social construct to look at how a person understands his or her relationship with the world, how that relationship is constructed across time and space, and how a person understands the possibilities for the future' (Norton, 2013, as cited in Basnet, 2017). Identity includes the inner and outer nature of a person who may or may not be the mathematics educator. Those nature of a person can play important role to create the beliefs towards nature of mathematics. More specifically, pedagogical practices of them (mathematics teacher) may be guided by their beliefs towards nature of mathematics (Luitel, 2019). It shows what kind of people they are, where they belong, and their influence in society. Identity can be established by focusing on the person's past, visualizing their present, and then realizing their future expectations (Leary & Tangney, 2011). Students do not autonomously construct their identities in a social, cultural and political vacuum, but as a result of sociocultural and socio-political discourses. While participating in the class, the mathematics students construct multiple identities either by being a member of a group (social identities), or by having certain roles (role identities), or by being the unique biological entities that they are (personal identities), and so on. These are the social lenses by which social identities are constructed. It is a continuous process of transformation and social interaction. The social interaction process of males and females is the same but a female's identity construction is more difficult due to our social norms, values, and psychology.

School education is the basis of identity construction for girls in mathematics. The school provides the mathematical knowledge and skills needed to function in everyday life. Eckert, Goldman, and Wenger (1997) claimed that the role of the school is to help students to expand their knowledge and skills, and to gain experience. Each and every female student's identity is associated with the mathematics-classroom community through relationships and experiences with their peers, teachers, family, and community (Anderson, 2007). Female students construct their identities by understanding themselves through their actions and their minds, based on time and space. Their identity is constructed by negotiating experience, community membership, the nexus of multi-membership and relationships between the global and the local. They generate identity based on their work, social discourses, and their communication skills, and from their existence in the class. When they are in the classroom, they rehearse this identity through mutual engagement, joint enterprises and shared repertoire (Wenger, 1998).

Normally, in school education, identity is affected by family, friends, the wider community, and society as a whole. In a similar way, social factors such as culture, language, and tradition also affect one's identity. So, identity is the individual and social lifestyle of a person. It includes how you are, how you carry out your studies and how you are perceived in society. Social identity is a person's sense of who they are based on their group membership(s). Additionally, Jenkins (2008) proposed that people belonged to different social groups (e.g., social class, family, football team, gender, tribes, and other differences) and build up different aspects of identities depending on the situation and time. Identity construction is a continuous process informed by hermeneutic self-understanding and social interaction, and it requires the acceptance of significant others, social groups, and the community (Bennett, 2013). Therefore, the identity of female mathematics teachers during their own school education is directly linked to their roles in the classroom, social participation, involvement in society, and institutional context and memberships.

I was born and brought up in a small village in Baglung district, in the western part of Nepal. It was a remote place with just one lower secondary school in the entire village. As a traditional legacy, no girls were sent to school at that time. Society and culture didn't support sending girls to study. Girls were supposed to stay at home and assist their parents in household and farm chores. I grew up in this kind of society and had to overcome this situation. I fought hard to go to school, and struggled during my school life and university education. I was finally able to reach the position of a lecturer at Tribhuvan University and a research student of Kathmandu University. During my learning journey from school to university, there were fewer female students than male ones. I was the only female student in mathematics. This situation surprised me. I used to wonder why the number of female students taking mathematics as their major subject was so low in school education? Why do they perceive it to be a tough subject? Why was mathematics said to be irrelevant for girls? Why did society not support the idea of girls studying mathematics? Despite the low participation, some females are building identities in mathematics during their school education. How are they constructing their mathematics identity in school education? To find out the answers to these questions, in this research paper, I have tried to explore how females construct their identity in school education in mathematics.

The purpose of this study is to explore female mathematics teachers' narratives about their experiences of identity construction during their school education and what they perceived in the course of time. This research questions how female mathematics teachers construct their identity in their school education.

2 METHOD

I used a qualitative method and followed with a narrative inquiry to analyze this study. Webster and Mertova (2007) explained that a narrative inquiry is an event-driven research tool which helps us to recall our life experiences. My research is based on the experiences of female mathematics teachers' journeys through their school education. For this study, I purposively chose four female mathematics teachers who have between 12 and 22 years of mathematics teaching experience at university level. Of the four participants, two of them have completed a Master's of Education and the other two have completed a Master's of Philosophy in mathematics. They are also actively involved in research. I used in-depth interview and conversation methods along with open questions to develop the female teachers' narratives about their past experiences in their school education. In order not to reveal the identity of the participants, pseudonyms were used. After collecting the required information, I have transcribed the interview information in narrative form as a story. I have presented the findings of the construction of female mathematics teachers' identities during their school education.

3 THEORETICAL REFERENT

I used Vygotsky's Self in Cultural-Historical Activity Theory (SCHAT) in my study. Vygotsky's important insight into the dynamics of consciousness was that it is essentially subjective and shaped by the history of each individual's social and cultural experience. This theory helps to understand and analyze the relationship between what people think and feel. It also relates to what people do, and how they act and performs. An individual is always affected by social and cultural norms and values, and they will create their identity within that society. Stetsenko and Arievitch (2004) explain that human beings are social animals; they live in a society, they act collectively and do new things together, they learn by doing, and communicate with each other via their actions. Likewise, humans make, employ, and adapt tools of all kinds in order to learn and communicate. The community is the place where all actions are performed, shaping and interpreting their meaning. So, female teachers are not separate from our society. They all act as social beings; they also learn by doing, communicating and interacting. They are also capable in the meaning-making of mathematical terms.

My research topic is the identity construction of female mathematics teachers. The SCHAT seems to be applicable to my research. Female mathematics teachers are not separate in our society and culture. Baumeister and Muraven (1996) say that 'societies clearly play an important causal role in creating and shaping identity'. A female teacher's self-identity is interlinked with society and mingles collectively (Jenkins, 2008). They also learn by doing, communicating and interacting and become capable in the meaning-making of mathematical terms. Mishra (2013) explained that, at the core of Vygotsky's theory, there is a belief that the development of all humankind is the result of interactions between people and their social environment, and also the specific knowledge gained by student and teacher through these interactions with society and culture. They are free to establish their career, personality, and self-esteem within a society. The contribution of a female's experience and knowledge to a society helps them to establish a social identity. This is how individuals set up their identity in a society.

With the help of the SCHAT theory, I evaluated different experiences of female mathematics teachers in their school education. This theory helped me to understand and penetrate the identities of female mathematics teachers with reference to their school education in Nepal. Furthermore, this theory guided me to narrate the details of how female mathematics teachers construct their identities during their school education in Nepal.

4 ANALYSIS AND DISCUSSION

From the narrative inquiry of four female mathematics teachers, Kiran, Nisha, Mamata, and Sabina, I have articulated a theme of the ways in which female mathematics teachers constructed their identities when they were students in school education. This research paper identifies the different themes that helps me to address my research question and meaning-making to relate with the theory about the role and contribution of different stakeholders, such as family members, school environments, teachers, friends, and society in general, in constructing female teachers' mathematics identities when they were students in school education.

4.1 *Role of the family*

After listening to the participants' narratives, it seems apparent that the family has an important role in constructing their daughter's identity in school education. This was seen in all of the four participants' narratives.

Thus, Kiran narrated that she was born and brought up in a society where females were limited to just knowing the basics of writing and speaking. But her father sent her to school and encouraged her to study. Furthermore, her father was a Nepali teacher at a university, so he suggested to her that she should study mathematics because he didn't get a chance to study mathematics and wanted his daughter to study optional mathematics from the eighth grade. He promised that he would provide extra private tuition classes if needed.

Nisha shared her experiences of being born and brought up in an ethnic community; she had encountered problems in that the entire society did not support the concept of educating females, and had a misguided belief that girls should not be sent to school. They were to get married to the Indian Army or the British Army. It was a deeply rooted trend in her society. Despite being faced with that kind of challenge, her mother succeeded in sending her to school. Her mother had felt her lack of education when she faced problems while reading a letter sent by her husband from overseas. She could not read it and had to ask others to read it for her. Similarly, she was not able to solve mathematics-related problems or calculate the financial expenses of her home. Considering the importance of general education and mathematics education, she did not want to see her daughter facing the same kind of problem.

Mamata said she was born and brought up in a low-class family in the western part of Nepal. She was the eldest daughter of five children. Her family's financial status was very low. While she was studying in fifth grade, her family didn't encourage her to go to school; her family's weak financial status led to an inability to support her education, therefore she could not continue her studies. Her father and mother were illiterate. They were farmers; they used to earn their living by farming in the fields. Her parents wanted her to leave school, work on the farm, and get married early, but she wanted to continue her studies. The headmaster of her school was her neighbor. He was on the board of directors at her school. He believed in her schooling potential; seeing her financial status and her passion for study, he arranged a scholarship for her to complete her schooling. Fortunately, she got an opportunity to continue her studies. Seeing her scholarship award and passion for study, her family made the environment easier for her to go to school and study. However, she still had to do household work and daily field work in the morning and evening, and in the day-time she went to school.

Sabina unpacked her story: she was born in a low-class family in a remote village that lies to the north of the Kathmandu Valley. She was the fifth child in her family. Despite being very close to the capital city, the village was deprived of developmental activities. She used to get up early in the morning as she had to go to the field and cut grass. She had to feed the grass to the goat, cow, and buffalo. After 9 am she would go to school. This was her daily routine. In her society, there was no trend of sending girls to school but her family sent her to school. She was lucky enough to go to school. She grew up in a place where physical facilities were limited and had to cope with many deficiencies such as a lack of stationery, clothing, and pocket money. Despite these challenges of physical facilities, she was committed to further her studies as she was an excellent student in her class. She had been interested in and curious about mathematics since childhood. She collected small pieces of stone and played with them, learning addition and subtraction. Sometimes, she would draw mathematical figures with the help of a piece of stone. She was also an accountant at home, she used to help her father to keep a record of household expenses and income. Seeing her poor financial condition and her deep interest in studying, one of the German international projects working in her village offered her a scholarship to help her continue her studies. Seeing Sabina's dedication to studying, her parents created a good environment for her to study at home. Looking at her leaning towards mathematics, her father literally told her to study mathematics.

The narrative inquiry of the participants shows that the role of the family is a significant part of the females' construction of their identity, especially if the family creates an environment for young female children to study mathematics. Cole (2011) agreed that parents have the greatest influence on the achievement of young people by supporting their learning at home.

After listening closer to the participants' narratives, I, as a researcher, found that the family was an informal supporter in mathematics learning. Parents played a critical role in providing learning opportunities at home and in linking what children learn at school with what happens around them (Emerson et al., 2012). Therefore, a family must be aware of the need to enroll their daughters in education. The family was pivotal in creating space for the construction of their daughter's identities within school education. The home environment supported Kiran by providing a suitable space in which to learn mathematics. The family was the main stakeholder in getting her to that position. Moreover, parents educational and economic status, environment, etc. can plays important role to choose and develop the career of their daughters. Nisha had the same environment as Kiran had. Her father, mother, and maternal uncle motivated her to study. There was financial support for Kiran and Nisha from the home. Parents play a crucial role in nurturing their children's educational aspirations through financial support, attendance, monitoring, and follow-up on achievement (Institute of Education and Action Aid, 2010, as cited in Munakarmi, 2015).

But the case for Mamata was totally different as her family had a weak financial status and her parents were not educated. There was no one in her family to encourage her to study mathematics as she was the eldest daughter in her family. Despite all this, she was an excellent student. Her self-interest was to study more. Self as a mental construct encourages people to study more (Oyserman et al., 2012). Fortunately, seeing her capability and self-interest, she was granted a full scholarship from the school for secondary level study. The school community understood her commitment and dedication to studying. Thus, societies clearly play an important causal role in creating and shaping identity (Baumeister & Muraven, 1996). She had to help her parents in the morning and evening to do household work and work in the fields, and during the daytime she went to school. She studied without interruption and topped the School-Leaving Certificate (SLC). She got the highest mark in mathematics and shaped her identity in school education. Stetsenko and Arievitch (2004) examine Vygotsky's SCHAT, explaining that the self is an important agentive dimension within a profoundly social and relational view of human life and development. Hence, Mamata was self-inspired to learn during her school education. Sabina had a slightly different situation; her family's financial status was the same as Mamata's but her parents wanted her to study further. Fortunately, seeing her financial condition, a German project funded her further studies. After getting financial support, the family also managed their time, and supported her to study further. In this regard, Munakarmi (2015) agrees that the role of parents and an enabling environment at home are the foundations for a girl's learning process. In my view as a female mathematics teacher, the participants' homes and family members created the space to allow their daughters to construct their identities by providing a suitable environment to gain a school education as well as to learn mathematics. Parents have a role in motivating their daughters to acquire a school education and build their identity in the society and the nation.

4.2 *School and school environment*

From the narrative inquiry of Kiran, Nisha, Mamata, and Sabina, I analyzed that school is an environment that forms the basis of the future education of girls. Schools encourage female children to learn mathematics. The role of the school is that it has to create a gender-friendly environment, so that female students are psychologically motivated to go to school without any hesitation. Schools have an important responsibility to help nurture and teach future generations (Haines et al., 2015). This responsibility is to create a learning environment to enable study and the construction of identities through learning mathematics.

A school provides the mathematical knowledge and skills needed to function in everyday life. Eckert, Goldman and Wenger (1997) claimed that the role of the school is to help students to expand that knowledge, skill, and to gain experience. My participants also gained knowledge and acquired skills in their school education. The school environment shaped the path of their future. The school environment is closely linked to the interpersonal relationships between students and teachers (Korir & Kipkemboi, 2014). This relationship stands out as the key role player in their development in terms of constructing their identity. During the interview, the way all the participants expressed their views made me feel a sort of nostalgia. I experienced emotional flashbacks time and again. I came up with a new definition of school as a second home (Mamata), a home of learning (Nisha), an environment-generating zone (Kiran), and a source of encouragement and inspiration (Sabina). According to Shamoon (2014, p. 12), a school has a shared vision; it acts as a learning organization, gives direction, and leads as a motivating force for sustainable action to achieve individual as well as school goals. It is one of the most important places where every female gets a basic education which forms the base in which to build the gateway towards their careers. When a girl begins her schooling, she enters into her mathematical life. Not only do the students focus on the mathematics course books given to them, they also get to learn much more about life. The school also provides exposure to activities, ideas, and fields of knowledge that you might never encounter otherwise (Basnet, 2017). I think a school culture gives a female orientation, support, values, norms, and practices that hold an educational unit together and gives it a distinctive identity.

4.3 *Role of the teacher*

Teachers are regarded as the supreme source of knowledge, encouragement, and correct pathfinding. A teacher's knowledge of how students think and reason in mathematics is a key component of pedagogical content knowledge for a teacher of mathematics (Hayes et al., 2006). A teacher motivates female students and nurtures them so that female students have positive feelings towards the study of mathematics and teachers. Bieg, Backes, and Mittag (2011) believe that interpersonal relationships and the student's perception of their teacher's behavior in the classroom are important sources for a student's motivation and engagement. However, Kiran didn't find her mathematics teacher inspiring. Her teacher said that *you are a girl and also average in your studies. Can you learn optional mathematics? It is a difficult subject, this subject was literally designed for boys, and you are not at the top of the class either. In the history of our school, girls don't choose optional mathematics.* He did not support her study of optional mathematics in school. But she herself dared to study major mathematics. She was committed to study mathematics against the will of her teacher. Self-perceptions of mathematical competence can enhance or impede mathematical participation, commitment, and ambition depending on whether the attitude of the student is positive or negative (Anderson, 2007; Bandura, 1997; Walker, 2012, as cited in Kilinc, 2016). She decided to prove that females can do something in mathematics and she didn't lose hope. It was actually a good decision for her. From the narrative of Kiran, it is clear that she did not receive much support from her teacher so she faced a some difficulty in constructing an identity in mathematics in her school education. Nisha faced even more problems in that she couldn't even study optional mathematics. Her teachers had a traditional view that mathematics is a male-centric subject. Arhin and Offoe (2015) agree that mathematics has, over the years, been seen as the preserve of male students. So, Nisha was discouraged from selecting mathematics as an optional subject in grade eight. Both Kiran and Nisha's educational experiences have given them self-confidence and self-commitment. These experiences have been influential in forming their identity in school education.

Unlike other participants, Mamata had a very good relationship with her school teachers. She was a friendly and dedicated student. She was, in fact, the apple of their eye. Because of the full support and care, she could enhance her studies, particularly in mathematics. Her personal relationship with the teacher was sound. Whenever she had a learning-related problem she shared it with the teacher. Sabina had the same opportunities as Mamata. She was supported by her teachers in every subject. I agree with Schuck and Pereira (2011, as cited in Pant, 2015) that creating a positive and encouraging environment to improve the attitudes of students towards mathematics, and disrupt their negative beliefs towards mathematics and learning in general, is essential. Looking at the interpersonal relationships between teachers and students, in my long experience as a university mathematics teacher, real teachers are those who can create a supportive learning environment, inspire, motivate, and support their students to learn mathematics, and support whatever efforts they have made to achieve their identity.

Here we see that the role of the teacher is also to mingle with the students and assist them in building up their future careers. Students are dependent on teachers in one way or another for their future endeavors. Teachers give suggestions on which subjects to study to enable a better future career. Their experiences are useful for female students as well. Teachers can also apply their pedagogic skills to deliver career-related knowledge in learning mathematics. The role of the teacher helps to unlock a female student's potential in mathematics. According to Smith (2014), the role of mathematics teachers in supporting girls and getting to know them individually is valued by female students. As a consequence, their perception of mathematics becomes positive and they develop their career in mathematics.

4.4 *Role of friends*

Basically, friends have important place in each individual and play important role in decision making process. In other words, they share problems and help to sort out our problems, as well as sharing good times in order to increase our happiness. Friends are the biggest support in our lives. Friendship is one of the most powerful predictors of long-term social adjustment (Joseph et al., 2006). Friends play an even stronger role in career development. s. Students tend to build up their intimacy with their friends easily and naturally as they belong to a similar age group. They share their problems within their group. Most of their choices are similar... They are a source of motivation. Friends give suggestions and feedback on choices; which subject would be better and how they should behave in the school environment. They have a crucial role, especially in subject choice, cooperation in combined study, encouragement, and making an identity. But Kiran's friends didn't suggest that she should go for mathematics as her major subject. She was the only one in her group of girls to pursue optional mathematics. Male students always teased her. Even though they teased her, they still helped her to solve mathematical problems. Nisha's friends did not support her study of mathematics. She was resented by her friends because, even though she was from the ethnic community, she was good at mathematics. Mamata's case was different to that of the others. Her friends were very helpful and she used to help them as well in their homework. As her financial situation was weak, they would help her by buying her, pencil, and other stationery items. Sabina's friends were slightly different; they were jealous of her good performance. Friends are supportive in encouraging their friends in order to build up their identity.

4.4.1 *Gender-biased complex relationship between support and ego*

Friends are supportive as well as egoistic. In Kiran's case, I found that her friends at school were not initially supportive. They were talkative and sometimes used to tease her about being a female alone in a mathematics class among a huge crowd of male students. She faced their insulting laughter and hue and cry. Her friends were growing up with this kind of social practice. However, the participant's sense of gender was shaped by the prevailing sociocultural practices of society. Her continuous effort, passion, and dedication towards the study of mathematics motivated Kiran's friends to find the right track. Para (2008) explained that friends and peers can influence attitudes, behaviors, and characteristics and can affect an individual's thoughts and actions. They often adopt similar beliefs and values to those of their friends. They may shape their identities around their friends' attributes. Similarly, the role of Nisha's friends was the same as Kiran's, but she had to bear additional challenges from her friends due to the fact that she was part of an ethnic community. Children from the ethnic community didn't pay much attention to studying. Even though she was from an ethnic community, she would score more in mathematics than her friends. Because of her achievement in school, her male friends regarded her with jealousy. She had to struggle to find her identity. However, she had the chance to prove herself as a competitive female mathematics student and she did.

Mamata had a different experience in her school life regarding her friends. In her school days, she was lucky to have such cooperative and friendly friends. She had friends of her own kind. Not many people can be as supportive as Mamata's friends, especially in the ways that they sometimes helped her in her difficult times. She remembered the time when her friends gave her some money to pay her school fees. It was so kind of them. With the valuable support of her friends, she was able to continue her studies. A person's relationship with their peers helps them to establish their identity (Vieira et al., 2014). Mamata got persistent support from her friends to establish her identity.

Another participant, Sabina, didn't create a friendly environment with her friends as she was a slightly reserved person. She maintained a position in the top five in her class up to sixth grade. She did not have much interest in making friends as she was totally focused on her studies. With her hard work, she became top of the class in grade seven. Looking at her progress, most of her peers did not like her; they teased her in a scornful manner. On the other hand, her teachers continuously helped her. She was an honest girl so her peers realized what they had done to her and became her friends. Following this, everything went right. With the support of her friends and teachers, she carried on with her identity in her school life. She said that whatever identity she got, it was her complex relationship between the support and attitude of her friends. From the voice of the researcher, friends can provide a ladder which helps to connect the one stair to another stair of life as well as helps to develop a career.

4.5 *Role of social context*

There are different attitudes towards females in different societies; some are liberal, some are traditional, and some have negative beliefs. Kiran, Nisha, Mamata, and Sabina were brought up in a society where, as women, they were seen as having less essence or priority; society thinks that the daughter is not the property of the father and mother. This was the negative thinking embedded in society. Traditional practices, social norms, and values have created a big gap between men and women by considering men to be superior to women. In this regard, Bhattarai (2014) explains that Nepal is a male-dominated, so-called patriarchal, country where men are considered superior and the leader of the family in the prevailing sociocultural traditions and norms. Due to the perceived superiority of men, they were dominant in the realm of education. Only males were sent to school, not females. Local sociocultural beliefs differ between regions in Nepal. A variety of socially constructed systems are responsible for such discrimination. The misconception associated with the education of girls was that educated girls tend to be overly smart. A patriarchal culture implicitly lets men disempower women, which leads to this unequal treatment of girls within families, societies, and histories, affecting the education of girls (Kilinc, 2016). Because of the traditional and negative influence of society, it is difficult for a female to go to school or pursue further studies and shape their identity.

Society is one of the most important places in which females spend their lives; they perform all kinds of activities within it. They experience ups and downs, good things, irrelevancy, and so forth. Society not only helps females to learn the necessary concepts and skills, but it also allows them to socially, academically, and emotionally interact with other females. Every female wants to live their life with dignity in society. Therefore, they forge their career based on social expectations. Societies clearly play an important causal role in creating and shaping identity (Baumeister & Muraven, 1996). Society's conceptualization of female education and career remains narrow even if there has been some modernization. Olmos (2011) was of the view that 'Female education is consequently viewed as an empty investment and irrelevant'. Because of the bias of societal perception, Kiran didn't get any support to go to school and study mathematics. Although she was also a part of that kind of society, she dared to study with full passion and conviction, which gave her the path to success. Finally, she got a first-division score in the school-leaving certificate. When the news of her successful result spread across the village, people began regarding her in a positive way. They regretted that they had viewed her negatively and that she had not been paid due respect. This was how she established her identity in society. Every participant in this study grew up in a similar type of society.

Mamata's story was not any different to Kiran's. She spent her childhood within an imperfect conceptualization of the female in society. But she was a remarkable girl, which earned her positive attitudes from her society. She actually empowered her society by helping children and illiterate villagers, calculating their sum of income and expenses, especially in barter exchange. She was independent in herself and built up her identity despite having no support from society. Sabina stepped into the field of education, ignoring what people around her had opined about her. She was only thinking about how to silence their criticism and continue her studies. She topped not only her school but the entire district in the school-leaving certificate. She built up her identity through her continuous dedication and conviction. Nisha had the same story as the others. She also had to cope with many social problems to establish her identity in her school education. According to Stetsenko & Arievitch (2004), in Vygotsky's SCHAT, the view of an individual is always affected by social and cultural norms and values, and thus an individual creates their identity within a society accordingly. Here Kiran, Nisha, Mamata, and Sabina created their identity according to their social environment. I think that society and culture indeed affect the construction of a female teacher's identity in the course of their school education.

5 CONCLUSIONS

In conclusion, in the early education of a female, it is apparent that there are various stakeholders in boosting their identity construction. These stakeholders include family, school, teachers, friends, and society. They each have their own role to play in creating an environment where the female can nurture her identity. These stakeholders sometimes play a role of providing strength, whereas others can be obstacles and hindrances. The family supports and influences the building of their daughter's identity. But, in the case of Mamata, her self-motivation formed her identity in mathematics. The school creates an environment as the basis of their future education. A school has to provide equal opportunities to study mathematics to males as well as females. Teachers should act as motivators and supporters for female students. In the case of Kiran and Nisha, their teachers did not support their study of mathematics, whereas the teachers had supported Mamata and Sabina in their study of mathematics. Friends were also part of their journeys of identity construction. Here, friends of Kiran, Nisha and Sabina were not very supportive whereas Mamata's friends were quite supportive. Similarly, society is a place where the female is bounded by the rules of social behavior which greatly defines their identity. All the participants had to face and overcome the biased ideas and barriers of society to construct their identities.

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Implementation of Voice over Internet Protocol (VoIP) using softphone applications based on Session Initiation Protocol (SIP)

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ABSTRACT: Voice over Internet Protocol (VoIP) is a technology that can pass voice, video, and data over an Internet Protocol (IP) network. This study aims to implement VoIP using softphone applications based on Session Initiation Protocol (SIP) at the Said Na'um Education Foundation and to recognize both the voice quality resulting from the communication made using VoIP as well as the bandwidth required for voice quality that will be used appropriately. This study used Trixbox CE as the VoIP server while the client used two softphone applications installed on the client device for testing, 3CX for computers and Zoiper for the smartphone. The bandwidth system was set to 64, 128, and 256 Kbps and the voice quality was measured in terms of two tests, Quality of Service (QoS) and Mean Opinion Score (MOS). Quality was measured twice a day, in the morning and in the evening, and the results were compared to learn about its network traffic. The results of this study show that implementation of VoIP using softphone applications based on SIP works well in terms of the results of QoS and MOS, and a minimum bandwidth for the communication on VoIP was obtained at 64 Kbps.

1 INTRODUCTION

Nowadays, technological development, especially in Information and Communication Technology (ICT), brings fundamental changes in telecommunication. The importance of the need for communication today is very high, including in institutions, offices, schools, and even among individuals, all of whom need communication to interact with each other.

The media used for communication are very diverse and using a computer network is one such channel. At present, the internet is used not only to chat, browse, and send e-mail but also as a communication technology at a very low cost (Wibowo & Windarti, 2014). One form of real-time communication using internet technology is Voice over Internet Protocol (VoIP).

VoIP, which is also referred to as internet telephony, is a technology that can pass voice calls, videos, and data through an Internet Protocol (IP) network (Papakotoulas, 2014) using Asterisk@home as a server and IP phone, X-Lite softphone, as a client (Warman & Maknun, 2014).

Using VoIP phone give many advantages especially in terms of cost. Call using VoIP obviously is cheaper than use Public Switched Telephone Network (PSTN) or fixed tele-phone network (with cable) because IP network and infrastructure is global and free (Wahab et al, 2013). VoIP system can installed in any Ethernet and IP address, and its characteristic is not like PSTN which has its own port in the central or PBX (Lazuardi, 2008; Wibowo & Windarti, 2014).

Besides the advantage explained above, VoIP or IP telephony also gives a comfortable call technique that is not available with a traditional telephone or PSTN, such as a virtual number (Webopedia, 2008). With this technique, users can use a different telephone number or cell phone with the area code they live in.

Regarding several advantages Voice over Internet Protocol (VoIP) as explained above, Voice over Internet Protocol (VoIP) could be implemented in various institution, office and school to minimize the cost of communication and maximize e-communication media using computer network technology (Khan & Sadiq, 2017).

The Said Na'um Education Foundation has five schools: (1) Said Na'um Integrated Islamic Kindergarten School (TKIT Said Na'um), (2) Said Na'um Integrated Islamic Elementary School (SDIT Said Na'um), (3) Said Na'um Integrated Islamic Junior High School (SMPIT Said Na'um), (4) Said Na'um Islamic Senior High School (SMAI Said Na'um), and (5) Said Na'um Islamic Vocational High School (SMKI Said Na'um). All five schools of the Said Na'um Education Foundation have good computer network infrastructure, but this infrastructure has not been maximally utilized for communication media like VoIP. Before it, the Said Na'um Education Foundation uses paid communication media (PSTN) to communicate with the school units, which makes it difficult to communicate freely.

Based on the problems, this study aims to implement communication system between unit and foundation to communicate with each other units using internet technology. VoIP technology can give a new way to the foundation and schools to communicate with each other. Besides we want to implement Voice over Internet Protocol (VoIP) within the Said Na'um Foundation and its units, we want to know the bandwidth needed so that communication can be carried out using Voice over Internet Protocol (VoIP).

2 METHOD

This research was conducted in SMKI Said Na'um Jakarta, Jl. KH. Mas Mansyur No. 25, Central Jakarta. It was conducted to integrate the Said Na'um Foundation network of schools—Said Na'um Integrated Islamic Kindergarten School (TKIT Said Na'um), Said Na'um Integrated Islamic Elementary School (SDIT Said Na'um), Said Na'um Integrated Islamic Junior High School (SMPIT Said Na'um), Said Na'um Islamic Senior High School (SMAI Said Na'um), and Said Na'um Islamic Vocational High School (SMKI Said Na'um)—as in Figure 1, by connecting with a VoIP server network to enable communication between units. Furthermore, this study aims to know the voice quality produced by communication using VoIP technology and the minimum bandwidth required for smooth and clear voice quality. The research method used in this study is the engineering method, where science and technology is applied to solve human problems (Simarmata, 2010).

In this study, the stages of research carried out to implement VoIP using softphone applications based on Session Initiation Protocol (SIP) are as follows:

1. Designing VoIP network technology as in Figure 1 using Internet Protocol (IP) version 4.
2. Installing the VoIP server with the Trixbox CE operating system in Virtual Machine (Virtualbox).
3. Configuring the Trixbox CE server extension.
4. Configuring softphone applications (3CX application for computer and Zoiper application for smartphone).
5. Testing the system and analysis of data.

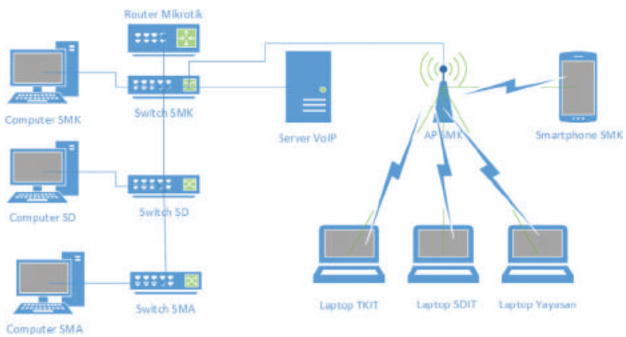

Figure 1. VoIP Network Technology.

This study compares the bandwidths used in the implementation of VoIP with the voice quality produced on client devices by using two testing measures, namely, Quality of Service (QoS) and Mean Opinion Score (MOS). The bandwidths used in this study are 64, 128, and 256 Kbps. To determine whether the voice quality is good or bad, it is necessary to analyze voice data directly in the system that will be created later. Therefore, bandwidth limits have been used so that the voice quality obtained can be used properly at the time of implementation.

2.1 *Quality of Service (QoS)*

In general, there are some important parameters affecting QoS that measures voice quality on a VoIP network. These parameters have been used as an illustration of the performance measurement of a VoIP network. Three of these parameters are delay, jitter, and packet loss.

The first parameter of delay refers to a time delay in data processing, where the quality of delay is said to be good if the time delay is below 150 ms (ITU, 2003; Behdadfar et al, 2015). Table 1 shows the delay parameter.

The second parameter of jitter refers to the difference between the arrival intervals between packages in the destination terminal. In other words, jitter is a variation of delay. The quality of jitter is said to be good if the time delay is below 20 ms (Setiawan, 2012). Table 2 shows the jitter parameter.

Packet loss, the last parameter in QoS, is the number of lost packages in a data packet transmission on a network. Packet loss in VoIP is said to be good if the percentage of lost

Table 1. Delay parameter.

Delay value (ms)	Quality
0–150	Good
150–400	Adequate, acceptable
>400	Bad, unacceptable

Table 2. Jitter parameter.

Jitter value (ms)	Quality
0–20	Good
20–50	Adequate
>50	Bad

Table 3. Packet loss parameter.

Packet loss value (%)	Quality
0–0.5	Very good
0.5–1.5	Good
>1.5	Bad

Table 4. Assessment of MOS based on voice quality heard.

MOS value	Quality of conversation
5	Very clear, without noise
4	Clear, little noise
3	Quite clear, a lot of noise
2	Less clear, difficult to understand
1	Unclear, not understood

Table 5. Assessment of MOS based on effort needed to hear.

MOS value	Quality of conversation
5	Comfortable, relaxed
4	Need little effort to concentrate
3	Need adequate effort to concentrate
2	Need more effort to concentrate
1	Not understood with full effort

Table 6. Assessment of MOS based on the intensity of volume heard.

MOS value	Quality of conversation
5	Much larger than expected
4	Larger than expected
3	As expected
2	Smaller than expected
1	Much smaller than expected

packages ranges from 0% to 0.5% of data transmission (Setiawan, 2012). Table 3 shows the packet loss parameter.

2.2 *Mean Opinion Score (MOS)*

MOS gives a numerical indication of the perceived quality of the media received after being transmitted and eventually compressed using codecs. It is expressed in a number from 1 to 5, 1 being the worst and 5 the best. MOS is quite subjective, as it is based on figures that result from what is perceived by people during tests (Unuth, 2017).

To make it easier to assess MOS parameters, three assessment categories are used that still refer to International Telecommunication Union (ITU) standards (ITU, 1996). The assessment based on the categories of voice quality heard, effort needed to hear, and intensity of volume is shown in Tables 4, 5 and 6, respectively (Simarmata, 2010).

3 RESULTS AND DISCUSSION

3.1 *Data description*

The data obtained in this study uses three different bandwidths of 64, 128, and 256 Kbps. Data collection was carried out in the morning from 7:00–10:00 am and in the afternoon from 2:30–5:00 pm. This study was conducted by making SMKI Said Na'um a center for the VoIP technology, so all units including the Said Na'um Foundation can use a smartphone to call devices at SMKI Said Na'um. The measure used to test voice quality was produced in the form of QoS using the Wireshark software for data retrieval in the form of delay, jitter, and packet loss. The second measure of Mean Opinion Score (MOS) assessed media quality of two people having a conversation.

3.2 *Research data analysis*

3.2.1 *Quality of Service (QoS)*

Quality of service, consisting of the delay, jitter, and packet loss parameters, is an average value obtained from the experiments carried out using a smartphone to call the Said Na'um Islamic Vocational High School (SMKI Said Na'um), from the foundation and the kindergarten (TKIT Said Na'um), elementary (SDIT Said Na'um), junior high (SMPIT Said Na'um), and senior high (SMA Said Na'um) schools. The bandwidths used for comparison in this experiment were 64, 128, and 256 Kbps, and data were collected in the morning and evening.

1. *Delay parameter:* As seen in Figure 2, the delay value for the 64 Kbps bandwidth is greater than that of the 128 and 256 Kbps bandwidths, because this study used the G.711 codec that has a bit rate of 64 Kbps. So, the 64 Kbps bandwidth produces a higher delay value.
2. *Jitter parameter:* Figure 3 shows a comparison of average values from different bandwidth use. The greater the bandwidth, the smaller the jitter value generated from experiments in the morning and afternoon. Thus, overall, the average jitter values in Figure 3 indicate good quality because they are between 0 and 20 ms.
3. *Packet loss parameter:* Based on the data obtained from the experiments using different bandwidths and carried out in the morning and evening, the packet loss value is 0%, which means it has very good quality because it is in the range of 0–0.5%.

3.2.2 *Mean Opinion Score (MOS)*

The MOS parameter is an assessment instrument that is carried out by two people conducting an experiment, with one person in SMKI Said Na'um and one person in another place. The score of the MOS parameters uses a 1–5 scale.

1. *Mean Opinion Score (MOS) for the category of the voice quality heard:* As seen in Figure 4, in the morning experiment there is an increase in voice quality at each bandwidth. However, in the afternoon there is no change at bandwidths of 64 and 128 Kbps, while at the bandwidth of 256 Kbps a decrease in quality from the previous bandwidth can be noted. Overall, the quality of the conversation produced is very clear and without noise.

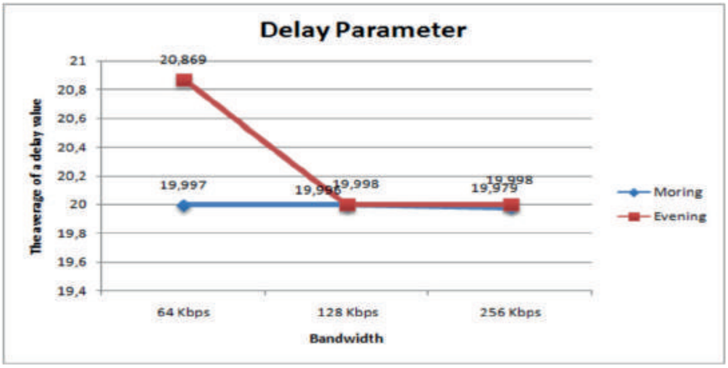

Figure 2. Comparison of average delay values.

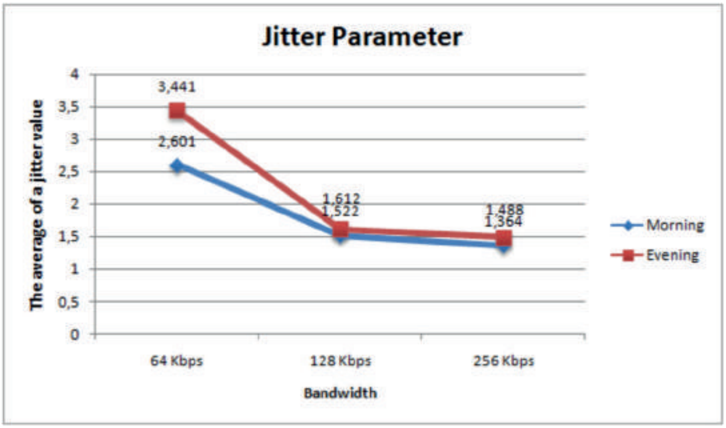

Figure 3. Comparison of average jitter values.

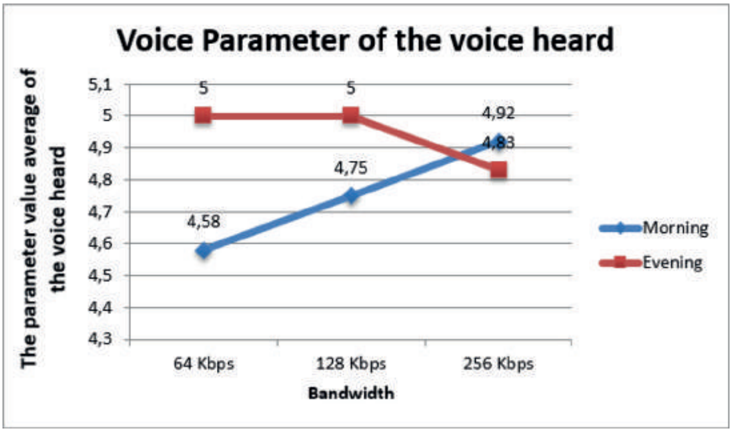

Figure 4. Comparison of voice quality heard.

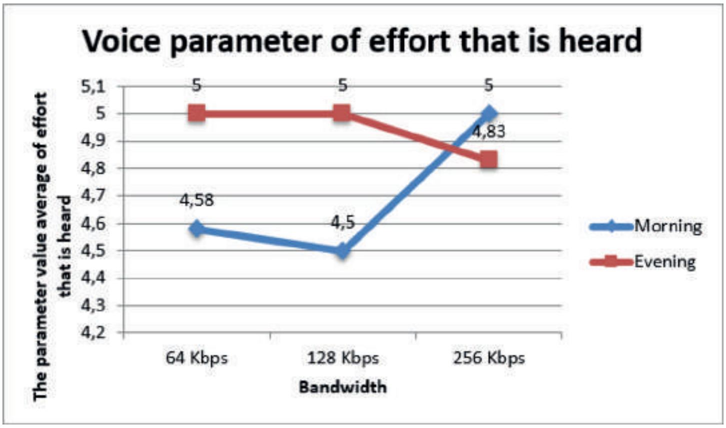

Figure 5. Comparison of effort needed to hear.

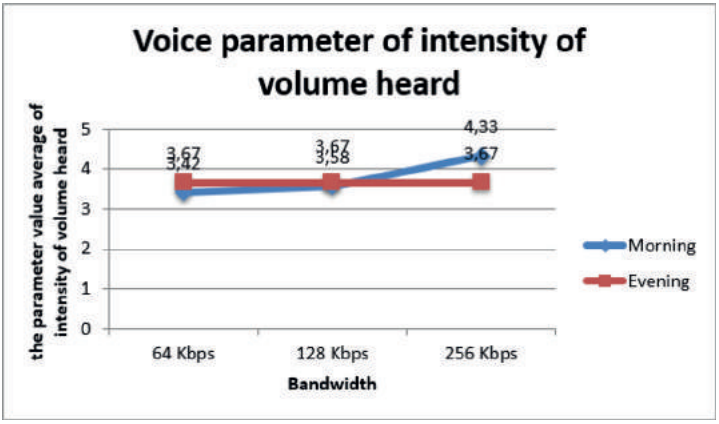

Figure 6. Comparison of the intensity of volume heard.

2. *Mean Opinion Score (MOS) for the category of effort needed to hear:* As seen in Figure 5, in the morning experiment there is an increase in effort needed to hear at each bandwidth. However, in the afternoon there is no change at bandwidths of 64 and 128 Kbps, while at the bandwidth of 256 Kbps a decrease in effort needed to hear from the previous bandwidth can be noted. Overall, the quality of the conversation produced is very clear and without noise, and little effort is needed to concentrate.
3. *Mean Opinion Score (MOS) for the category of intensity of volume heard:* As seen in Figure 6, there is an improvement in the quality of the conversation from bandwidths of 64 to 128 to 256 Kbps in the morning, while in the afternoon the average value generated remains the same. Overall, the intensity of volume heard is in accordance with expectations.

4 CONCLUSION

After designing the network topology used in this study, implementing VoIP in the Said Na'um Education Foundation and in all school units of the foundation, and testing and analyzing the data collected, it can be concluded that Voice over Internet Protocol (VoIP) can be used for local (adjacent) areas. To make the VoIP system, the Trixbox CE operating system can be used as a server that already has the Centos Linux operating system and Asterisk application, while (softphone) clients can use the 3CX and Zoiper applications. Based on studies conducted in VoIP testing, the minimum bandwidth required to communicate in VoIP is 64 Kbps according to the codec used, namely, G.711 with a bit rate of 64 Kbps. However, to get better voice quality, a higher bandwidth than that used in this study can be used.

Further study is needed so that the voice quality is clearer and the technology can be used comfortably, especially by using higher server specifications. In addition, it can be developed by adding video features and allowing calls not only to fellow VoIP users but also to Groupe Speciale Mobile (GSM) and Code-Division Multiple Access (CDMA) users.

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Practicality of constructivism-based workbook as argument and deduction materials to improve learning outcomes

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ABSTRACT: This study aims to develop a practical constructivism-based workbook for the teaching of argument and deduction methods at STKIP PGRI, West Sumatera, a teacher-training college. These methods are taught in the Basic Introduction to Mathematics course in the second semester. It uses a general model of Plomp's research design, namely preliminary research, prototyping phase, and assessment phase. The preliminary rese*arch phase* shows that students need teaching materials that can build a conceptual understanding, called a constructivism-based workbook. The *prototyping phase* was conducted as a one-to-one evaluation practicality test given to three students and a small group evaluation was conducted on nine students who had already taken the Basic Introduction to Mathematics course and each of whom represented high, medium, or low ability. The workbook is validated according to expert reviews. Data of the one-to-one test and small group evaluation were collected from interviews and a questionnaire. Results show that the workbook is practical based on the time needed, ease of use, and benefits of use.

1 INTRODUCTION

Studying mathematics for higher education is expected to make students actively think and practice their reasoning skills. Bani (2011, p. 12) states that mathematics and mathematical reasoning are two things that cannot be separated because mathematics is understood through reasoning, and reasoning is understood and trained through learning mathematics.

One of the courses that can improve reasoning skills at STKIP PGRI, West Sumatera, is the Basic Introduction to Mathematics course. It is studied by second-semester students. Among the materials in the course are those concerning argument and deduction methods. The argument method comprises a collection of statements that have expressions of conclusions, while the deduction method explains how to draw conclusions from the general to the specific.

Observations carried out in the Basic Introduction to Mathematics course at STKIP PGRI, West Sumatera, a teacher-training college, show that lectures used the expository method. They started by giving materials and examples and ended with the provision of training. The lecture process and implementation method did not make students active in lectures; instead, the students were found to be more passive in comprehending the knowledge (Siagian, 2016, p. 58). Students only waited for a lecturer's guidance if they got into difficulties. These habits were not effective in increasing students' understanding of teaching materials (Edriati et al., 2015, p. 288). A textbook was used in the Basic Introduction to Mathematics course, which did not allow autonomous learning among students. The textbook was also not able to construct student knowledge, so knowledge was not built by the students and learning was not effective.

Pratiwi et al. (2017, p. 201) stated that the quality of the learning process in higher education can be improved with various strategies and one of the alternatives is through the development of teaching materials. This can be carried out by a lecturer to solve learning problems by paying attention to the target or students and also by adjusting the achieved competencies (Haryanto, 2016, p. 108). This is also reinforced by Ramdani (2012, p. 45), who says that teaching material is the most important part of the overall learning process. The teaching material of a workbook can contain learning objectives, short theories, structured exercises and assignments, practice questions, and discussion materials. It can contain many exercises to help train the students to solve problems.

Fadillah and Jamilah (2016, p. 112) argued that the use of teaching materials should be combined with the use of the learning model, so that they can be used optimally. Hein and Boghossian, in Barlia (2011, p. 344), state that constructivism in learning is a philosophy based on the idea that the process of forming knowledge in a human is the result of mental activities supported by the process of the learning experience. Based on this, it can be concluded that students acquire and construct knowledge naturally through their experiences. This is also in line with Mahmud (2013, p. 238) who states that constructivism is basically a theory based on observation and a scientific study about how people learn. It proposes that people construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences.

Therefore, the workbook developed for this study is a constructivism-based workbook. The characteristics of constructivism are given by Driver and Oldham, in Suparno (1997, p. 69), as follows: (1) orientation, where students are given the opportunity to make observations on the topics to be studied; (2) elicitation, where students are helped to express their ideas clearly by discussing, writing, making posters, etc.; (3) restructuring of ideas, namely, clarifying one's own ideas using other people's ideas or with friends through discussion or through gathering, building, and evaluating new ideas via experiments; (4) using ideas in many situations; (5) review, that is, examining how the idea changed. The constructivism-based workbook is designed to allow students to actively construct knowledge. They are given the opportunity to express ideas and discuss with other friends. The workbook must be adequate for research, which means that it must be validated (Ramdani, 2012, p. 45). The workbook in this study was validated by experts. After the workbook was considered to be validated, it was tested for its practicality. This study aims to find out the practicality of the constructivism-based workbook on argument and deduction method materials.

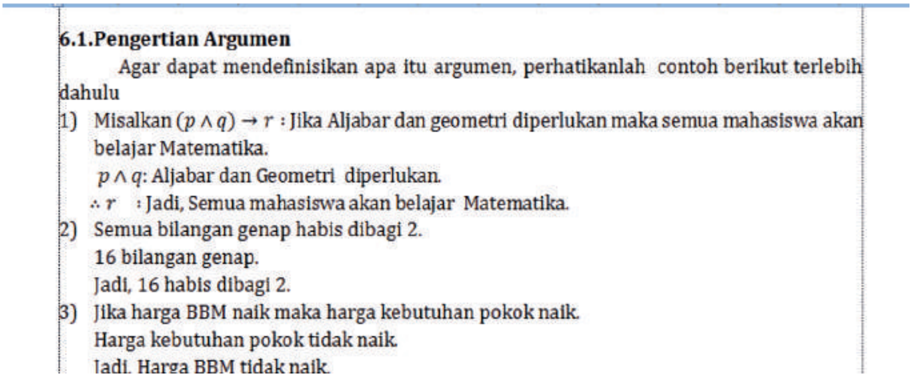
2 METHOD

This was a research and development study. It applied the general model of Plomp's (2013, p. 19) research design consisting of three phases, namely, preliminary research, prototyping, and assessment. The preliminary research phase consists of problem analysis and literature studies. The prototyping phase is the stage of making a prototype. The assessment phase is the stage of evaluating whether students can use workbooks and determining the effectiveness of workbooks. The stage discussed in this study is the prototyping phase, which involve done-to-one and small group evaluations. One-to-one evaluation was conducted on three third-semester students who had studied the Basic Introduction to Mathematics course, while small group evaluation was conducted on nine third-semester students who had studied the Basic Introduction to Mathematics course and each of whom represented high, medium, and low abilities.

The instruments used for data collection were a questionnaire and interviews. The questionnaire used was a closed-type questionnaire containing statements about the time needed, the ease of use of the workbook, and the benefits after using the workbook. Each statement was accompanied by four alternative answers: agree a lot, agree, disagree, and disagree a lot. The results of the questionnaire were analyzed by scoring the answer choices provided for each item statement, with a score range from 1 (LS = Low Score) to 4 (HS = High Score). Then, the mean was determined and confirmed by the criteria specified in Table 1.

Table 1. Practical criteria based on questionnaire.

Average	Criteria
$3.25 < A \leq 4.00$	A lot of practice
$2.50 < A \leq 3.25$	Practice
$1.75 < A \leq 2.50$	Less Practice
$1.00 \leq A \leq 1.75$	No Practice



6.1.Pengertian Argumen

Agar dapat mendefinisikan apa itu argumen, perhatikanlah contoh berikut terlebih dahulu

1) Misalkan $(p \wedge q) \rightarrow r$: Jika Aljabar dan geometri diperlukan maka semua mahasiswa akan belajar Matematika.
   $p \wedge q$: Aljabar dan Geometri diperlukan.
   $\therefore r$: Jadi, Semua mahasiswa akan belajar Matematika.
2) Semua bilangan genap habis dibagi 2.
   16 bilangan genap.
   Jadi, 16 habis dibagi 2.
3) Jika harga BBM naik maka harga kebutuhan pokok naik.
   Harga kebutuhan pokok tidak naik.
   Jadi. Harga BBM tidak naik.

Figure 1. Material description: Argument example.

The interview guide contained the same indicators as the question naire, namely, time, usage, and benefits. Guided interviews were conducted where the questions asked referred to the interview guidelines that had been prepared. Qualitative data from interviews with respondents were collected and analyzed. Qualitative analysis followed three stages: reduction of data, presentation of data, and drawing conclusions. Reducing data involves the activities of selecting, focusing, abstracting, and transforming the raw data.

3 RESULTS AND DISCUSSION

A constructivism-based workbook contains characteristics of constructivism. These are orientation, elicitation, restructuring of ideas, use of ideas in many situations, and review. The initial description of the material contained the constructivism characteristic of orientation. First, an argument example was presented so that students had the opportunity to observe and define the arguments (see example in Figure 1).

Next, students were asked to define an argument in an empty box. For restructuring of ideas, students could also discuss to clarify their current or previous ideas. The results of clarifying the idea could be written in an empty box. Review could also be carried out in an empty box. Figure 2 presents an example.

After making a workbook prototype, self-evaluation of the workbook was carried out. The results of the self-evaluation show that there are still some chapters that do not contain exercises yet support the student in understanding the material. The design of the contents and cover is not interesting and the style of writing in use is not consistent. The revision of the workbook was based on the results of self-evaluation. After revisions were made, the workbook was validated based on expert reviews. The validator provides suggestions and improvements. Revised workbooks are based on validator suggestions. These revised workbooks are re-validated.

A validated workbook was tested in order to find out its practicality through one-to-one and small group evaluations. One-to-one evaluation was carried out by presenting students

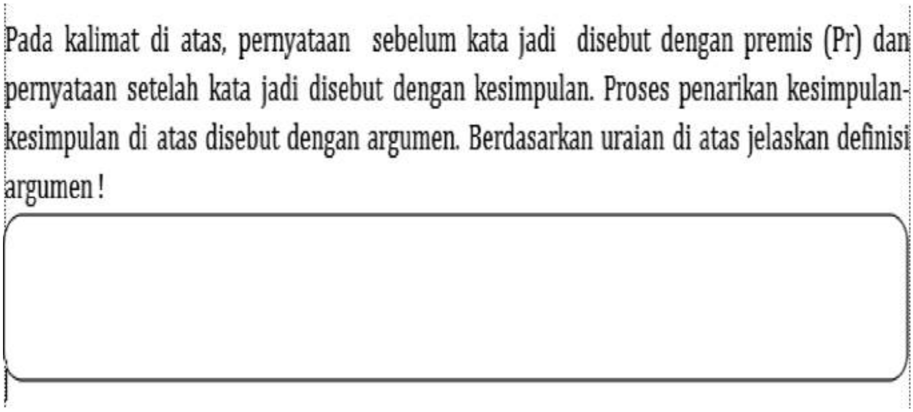

Pada kalimat di atas, pernyataan sebelum kata jadi disebut dengan premis (Pr) dan pernyataan setelah kata jadi disebut dengan kesimpulan. Proses penarikan kesimpulan-kesimpulan di atas disebut dengan argumen. Berdasarkan uraian di atas jelaskan definisi argumen !

Figure 2. Material description: Argument definition, restructuring, and review.

individually at different time ranges from 5th to 16thMarch 2018 in two meetings. Interviews were conducted one-to-one for evaluation of the participant student. The following are some examples from the one-to-one evaluation interviews.

Question 1: "Do you understand the material with the time given?"
Student A: "Yes, I could understand it."
Student B: "Yes."
Student C:"Yes."

Question 2: "Is the explanation of question sample discussion understood?"
Student A: "Yes, understood."
Student B: "Yes, it is understood but the question samples are added."
Student C: "Yes."

Question 3: "Can the material presentation and sample help you to build a concept understanding?"
Student A: "Yes, it could but there are some exercises that are not easy to be understood, such as validity and invalidity testing."
Student B: "Yes, but the question sample should be more."
Student C: "Question sample must be added."

Question 6: "Will the constructivism-based workbook make you independent enough from the lecturers to comprehend the materials?"
Student A: "Yes, agree."
Student B: "Yes."
Student C: "Yes."

Based on the results of the interviews with the three students, it is concluded that students can understand the material within the time provided. They can understand the explanation of the discussion of the sample questions, but examples should be added. Material presentation and sample questions help the students to build concept understanding and they do not really rely on the lecturer's guidance in learning the material. Students also stated that there are some exercises that are not easy yet to understand and examples of questions should be added.

In addition to interview guidelines, one-to-one evaluation also used a questionnaire as an assessment instrument. A questionnaire was given at the last meeting in the one-to-one evaluation. Table 2 shows the results of the questionnaire.

Based on Table 2, the time required indicator is not practical. This is different from the results of interviews. Students argued that the time needed to understand the material is not in accordance with the time provided and the time needed is longer. This difference may be

Table 2. Results of the one-to-one evaluation questionnaire.

No.	Indicator	Average	Criteria
1	Time required	2.33	Less practice
2	Ease of use	3.22	Practice
3	Benefits obtained after using the workbook	3.33	A lot of practice
	Average	2.96	Practice

Table 3. Results of the small group evaluation questionnaire.

No.	Indicator	Average	Criteria
1	Time required	3.11	Practice
2	Ease of use	3.14	Practice
3	Benefits obtained after using the workbook	3.08	Practice
	Average	3.11	Practice

due to students being more free to express their opinions in filling out the questionnaire. The indicator of ease of workbook use is practical because it contains clear and easy-to-understand sentences for students, as well as clear presentation of material and discussion of examples of easy-to-understand questions. The benefits after using the workbook are also practical because the use of workbooks encourages students to actively think while solving questions asked and helps to build concept understanding. The mean score is 2.96, which means the workbook is practical for use in lectures.

After the one-to-one evaluation, the workbook was revised. Examples of questions were added and language use was corrected. Then, a small group evaluation was conducted in four meetings in 2018 on March 26th, March 30th, April 2nd, and April 6th for approximately 100 minutes (two credits). Small group evaluation data were collected through a questionnaire. Table 3 shows the results of the small group evaluation questionnaire.

Based on the results of the questionnaire from a small group of students, the mean for each indicator shows that a practical workbook is used. Students stated that the time needed to study the workbook is appropriate, they are easy to use books, and students get benefit from studying the workbooks as it can build concept understanding. The mean is 3.11, which shows that a practical workbook is used.

4 CONCLUSION

Based on the discussion and findings, it is concluded that the workbook is practical in terms of the time needed to study workbooks, ease of use, and benefits after studying. The workbook is ready to be used by students who will take the Basic Introduction to Mathematics course. It contains characteristics of constructivism, including orientation, elicitation, restructuring of ideas, use of ideas in many situations, and applications.

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Decontextualized nature of the mathematics curriculum

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ABSTRACT: This paper explores the secondary-level mathematics teachers' understanding of the mathematics curriculum. The design of this study was narrative inquiry. It is based upon a research questions: "What are the perceptions of the present curriculum from contextualized perspectives?" "Is the curriculum contextualized or not?" On the respective questions, respondents opined that their curriculum is not as contextual as it should be to meet the need of the time. Much content that is taught in the classroom is not applicable in real-life situations. Curriculum should focus on the need of the students. They should be taught to be independent after they pass exams at certain levels. However, the contents are not supportive for this purpose. Further, a pivotal part of this project is examining the applicability of the curriculum and encouraging individual efforts of the students.

1 INTRODUCTION

The purpose of this research is to explore the perception of secondary-level mathematics practitioner-teachers on the present mathematics curriculum from contextualization perspectives. In our context most of the mathematics teachers have been habitual to respond that, it is difficult, abstract, important for the future, etc. to the epistemological questions related to mathematics raised by the students (Luitel, 2019) in which mathematics has been taught from the early days of schooling. Thus, in this situation I consider contextualization of mathematics as a practical, useful curriculum connected to day-to-day activities. The knowledge gained through the curriculum should be applicable in people's (e.g. family members, citizens, and workers) everyday activities (Hudson & Whisler 2007). In this regard, I think that the present decontextualized mathematics curriculum should deal with issues related to the "real-world" situation. First, I introduce the context of the study. Second, I discuss the theoretical orientation for this study in terms of a contextualized curriculum from three fundamental areas of interest based on Habermas' (1972) point of view. Third, I outline the method of data collection, analysis, and interpretation. Fourth, I present the major themes and discuss them in relation to the relevant literature. Finally, I present some points about how our mathematics curriculum is not contextualized, implications of this, and concluding thoughts.

2 THEORETICAL CONTEXT

Curriculum is the descriptive form of what, why, how, and when students should learn. We are the product of a traditional curriculum that was guided by Schubert's image of "curriculum as a subject matter," "as an intended outcome" (Schubert, 1986), where our ontology was that curriculum is like an end in itself. Rather, it seeks both to achieve worthwhile and useful learning outcomes for students and to realize a range of societal demands and government policies. From my experience of learning, our mathematics curriculum does not play an effective role in our society because it is not linked with our social and individual needs. I learned mathematics using methods through which most of the problems were done in the classroom, and I still wonder about how to find the practical implications of that knowledge in my life. As soon as I completed my studies up to the master's level, I was in search of those implications of mathematics education in our society. But I am still left wondering how I could complete my educational journey up to the master's level without understanding the practical implications of the mathematics that I learned throughout my education; I even searched for this during my MPhil.

To address the demand of twenty-first century students, a curriculum should maximize the potential for the effective enhancement of learning, something that has not taken place in our country, Nepal. Good teaching and learning are greatly enhanced by the quality, relevance, and effectiveness of the curriculum. In order to make the curriculum relevant, it needs to be contextualized. One of the burning issues in Nepal is our curriculum which has not been contextualized. The primary notion of contextualization of the mathematics curriculum is to ensure the inclusion of local knowledge traditions in the curriculum content (Luitel & Taylor, 2005). As Gutstein and Peterson (2005) have claimed, helping students to understand their lives in relation to their surroundings and to see mathematics as a tool to help make the world a more equal and just place can be equally applicable in our context too. Belbase (2006) stated that our mathematics teacher was more traditional than our "family pundit," and so he taught mathematics the way he liked: there was no dialog, sharing, or group work in the class.

There are many such cases where students do not understand the connections as they construct the knowledge from their classrooms. The reason behind this can be the faulty process of curriculum making and teaching–learning, in which most of our courses are not connected with real-life situations. Contextual teaching and learning support students for building linkages between experience and implication in real lives or real-world situations (Ohio State University, 1999). I also realize that a contextualized curriculum can help students make sense of quantities and their relationship. Furthermore, a contextualized curriculum can help them interpret the meaning of symbols. Thus, rather than focusing on the lecture method alone if the curriculum can foster interaction among students and teacher as well, the students can make meaning of it.

If we need to understand why learners of mathematics are not interested in their learning, we need to know whether our subject matter is contextualized. We have a funny and realistic example to understand our weakness in making our mathematics education contextualized: "A is A because it is not B and A is A because my seniors said to me so." This is somewhat accepted in language classes, but if we adopt the same logic in the mathematical context it is not enjoyed because mathematics is not exactly like language. Unfortunately, we are still moving forward with the same ideology, so we have failed to contextualize our mathematics and its curriculum.

3 METHOD

Narrative inquiry design was used to obtain the outcomes of this study. This design attempts to capture the whole story of the phenomenon. Similarly, it aims for its findings to be well grounded and supportable. Narrative inquiry is one of the best ways to reflect upon the experiences of study participants (Clandinin & Connelly, 2000). Clandinin and Huber (2010) claimed that there are two possible ways to start with narrative inquiry research: beginning with telling stories and beginning with living stories. The collected information and stories allow researchers to present experience holistically in all its complexity and richness (Mumby, 1996, as cited in Bell, 2002), to explore the hidden realities about study participants.

Data were collected from five teachers selected from three different schools of Lalitpur District in Nepal. I chose five mathematics teachers who are familiar with me. All the participants (teachers) have been engaged in the teaching profession for about 20 years.

In the beginning, I requested the teachers to help me with my research paper on issues in contextualization of the mathematics curriculum. Three teachers were from one school and the other two were from another school. For accumulating qualitative data, I used the narrative research design which enabled me to capture the perceptions of participants about their own experiences. At the beginning of our discussion, some of the teachers talked very informally, saying things like "it's crystal clear, our curriculum is not contextualized." But I thought that, for purposes of this study, it would be better to provide some specific questions related to contextualization on paper for a formal record of perspectives.

I had frequent discussions with five teachers, and they all had the opinion that the mathematics curriculum in the Nepalese context is decontextualized. I realized that we have a lot to do in this regard. So, I decided on this theme as one of the most appropriate issues to address in the present study.

In this regard, the first participant, Mr. Subba expressed his views as follows: “The present curriculum is not cent percent contextual.” He seemed to think somewhat positively about the curriculum. He explained that our curriculum is not totally decontextualized but that if some practical aspects of daily life were considered in the curriculum it could be a milestone in contextualization. Similarly, another participant, Mr. Silwal agreed with Mr. Subba. However, he added that the “present curriculum cannot totally fulfill the demand of the time.” From his statement, gathered that the curriculum needs to be reviewed within a certain timeframe so that it can be made contextual as per the need of the time. The next participant, Mr. Pandey, stated, “I do not have much comment on the present curriculum. “He did not express any opinion as such because his opinion would not be counted at the time of designing the curriculum. Next, Mr. Lamsal had a slightly different idea. He focused on “the inclusion of indigenous ideas in the curriculum.” He meant to say that examples, names, and text in our curriculum should be related to our society and context. The last respondent, Mr. Dongol replied, “Students are unable to understand what they are taught because the mathematics curriculum is not contextual.” The response focused on the contextualization of the curriculum for better performance of the students.

After having conducted the interviews and examining the responses to the questions in the questionnaire, I found that the majority of participants did not see much context in the mathematics curriculum. However, they agreed on some sections in which contextuality seems to have been a perspective. Despite this, they respond that the curriculum is largely based on conventional approaches. As mentioned in the Perin (2011) the practice of contextualization of basic skills can enrich the students to transfer the skills to subject area learning when the instruction is connected to these subject areas rather than taught abstractly.

Our curriculum is influenced mostly by Habermas’s “technical interest,” which is an interest in the technical control of nature and promotes the exploitability of knowledge. It represents human interaction with the physical world. Furthermore, it is driven by the positivist perspective and is rationally goal directed. A goal-directed action can be rational only if the actor satisfies the conditions necessary for realizing his intention to intervene successfully in the world (Habermas, 1972). In this regard, I believe that the present decontextualized mathematics curriculum in Nepal promotes more the technical interest while generating or constructing knowledge.

Habermas’s “practical interest” is the basic orientation toward understanding the human social world. It reflects the dynamic aspects of knowledge. It is a descriptive process of making meaning guided by the interpretive paradigm, which promotes the teaching–learning process in which students are deeply engaged in study through interaction and teachers view their students from the perspectives of the students. Moreover, confidence in an interpretation depends upon agreement with others that such an interpretation is reasonable; hence, Habermas’s claim regarding the necessity for agreement between “at least two acting subjects” who take part actively in interaction. Thus, the notion of consensus is an important one with respect to the interpretation of meaning (Grundy, 1987, p. 10). So, our curriculum should focus on “what ought I to do?” rather than the technical interest of “what can I do?”.

5 THE CURRICULUM IS NOT RELATED TO DAILY LIFE

Mr. Subba expressed his views as, “Some practical problems should be included in the curriculum.” His viewpoint indicates that practical tasks should be considered in the mathematics curriculum. Another participant, Mr. Silwal holding a similar viewpoint, stated, “Our curriculum is not meaningful and does not provide students with a contextual and motivating learning environment." He focused on what a curriculum is planned for and what students are interested in. The next participant, Mr. Pandey, stated, "The present curriculum covers some daily problems of simple interest, home arithmetic, and statistics, etc." He agreed that some chapters are related to daily life but that a majority of the chapters in the curriculum are not connected to the everyday life of students. I also do not deny that the present curriculum is solely decontextualized because, over time, some contextual flavors have been added to this curriculum by comparison with previous ones. Further, Mr. Pandey expressed his views as, "The majority of the students have no genuine mathematical understanding. In order to develop deep understanding of it, mathematical activities need to be open enough such that they can formulate their own meaning rather than following formulated strategies."

Two participants responded that the curriculum is not contextualized because it has not been able to justify the applicable areas of learning. Students are found to lack interest and enthusiasm because they feel that the text doesn't relate to real life. Further, they stated that if the curriculum were focused enough to elaborate the contextuality and scope of the course to the students, then the result would possibly be as desired. Strangman and Hall (2004) showed the constructive view of curriculum design with a student-centered approach and suggested that the process of an effective modification requires deep analysis and assessment of students' needs and their learning contexts where students' needs play essential roles in the process of modification.

Our curriculum can be made contextual by including practical aspects to learning. Instead of limiting to solving the same problems repeatedly, the curriculum needs to be individualized. Ornstein and Hunkins (2009) suggested that although curriculum development models are technically useful, they often overlook the human aspect, such as personal attitudes, feelings, and values, involved in curriculum making. As a curriculum is the foundation and direction for learning, applicability should be the focus. Individual efforts of students should be encouraged and credited. They also found that the evaluation system should grade creative skills and a student's ability to apply their learning. To make the mathematics curriculum contextual we need to connect it with the community and place. Klein (2015) stated that connections of mathematics instruction to a place and community by developing issues of relevance, sustainability, and social-class interaction can enhance the teaching–learning process for mathematics.

A contextual curriculum definitely has an edge over conventional perspectives. Students find more interest in learning activities if there is scope for them to realize their creative potential. Enthusiasm grows and learning deepens if the curriculum is contextualized and focused on applicability.

6 IMPLICATIONS

Implications of a contextualized curriculum depend on the instructor's interest, students' need, culture of the society, and content. Connecting the teaching–learning process with the context can enhance the wide range of activities and professional development as well. By creating appropriate curriculum, instructional materials, and interactive teaching and by involving students with materials students' outcomes can be improved. To guide students towards self-sufficiency and life-long advancement and to create a positive attitude towards mathematics, contextualization can be the milestone and can help in the improvement of the curriculum continually. These considerations have implications for all stakeholders (i.e., faculty, schools, policy makers) to be involved in the process of developing the curriculum. If the curriculum is developed only by "experts," there is a greater possibility of producing a decontextualized curriculum. Therefore, I believe that learner-centered pedagogies, the privilege of engagement with written texts, and the use of contextualized problems can enhance the problem-solving skills of students in general and of those in mathematics remedial classes.

In order to make the curriculum a contextual one, the planners ought to set the foundation for detailed research on the areas that have plausibility for the inclusion of contextuality. The subject should be provided with a practical weightage too. Whether it is arithmetic, geometry, or algebra, things should not just be done through exercises but through out-of-class activities. Students should be encouraged to actively participate in the projects that have a practical output and applicability (Pant, 2017). This transformation in the teaching–learning process will also require acute training of the teaching faculties for desirable outcomes.

7 CONCLUSION

The findings of the present study show that the term "contextualization of the mathematics curriculum" was new for high school teachers on the basis of their teaching and learning experiences, and their perceptions that the mathematics curriculum in Nepal is largely decontextualized although it has some contextual flavor. Moreover, in their professional journey, the teachers had never got such an opportunity to express their views openly on the decontextualized curriculum of mathematics. However, some of the teachers were found to have some knowledge about contextualizing mathematical teaching and learning, and hence they tried their best to apply it in order to help students develop a deeper understanding of what they learn in the classroom.

Through the lenses of the Habermasian theory of interest, it was found relevant that the curriculum should be guided more by practical interest than technical interest. This inquiry reveals that most of our present mathematics curriculum is not contextualized. Consequently, the achievement level of students is also not satisfactory (Education Review Office, 2018). Being a mathematics teacher-educator, I believe that the views of mathematics teachers should be considered while developing the mathematics curriculum in Nepal in the days to come.

Further, I think that the major reason behind the lack of contextualization of the mathematics curriculum in Nepal is the faulty process of designing the curriculum mostly via "experts." Stakeholders such as students, teachers, and guardians are not considered as valuable contributors to its design. The practicality of the curriculum is not given priority at the time of designing it. The curriculum is prepared as per the personal understanding and feeling of the experts. This ultimately makes the curriculum decontextualized.

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Evaluation of implementation of the hypothetical learning trajectory at the thesis of mathematical education

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ABSTRACT: This research focuses on analyzing and evaluating the final assignment of a master's program in Mathematics Education using the Design Research (DR) approach. The thesis is analyzed and evaluated in order to determine the feasibility of planned learning activities in the Hypothetical Learning Trajectory (HLT) in the real classroom environment. Evaluation was based on Retrospective Analysis (RA) and used the logic model that has four stages: inputs, activities, outputs, and outcomes. From 69 theses, only eight (11.6%) used the DR approach and thus were selected for this study. In the inputs stage, all DR theses contain the correctly planned HLT. In the activities stage, many differences exist among the theses, especially regarding the context that is conveyed to students depending on the subject matter. The suitability of context and subject matter was very well managed by the students, but some implementations in the field were not in accordance with the plan. In the outputs stage, RA revealed only two theses that conveyed the change of HLT during research. In the outcomes stage, it was noted that students' attitudes changed because they became more familiar with mathematics as a subject and their social abilities developed, allowing them to convey the reasons for change through good communication skills.

1 INTRODUCTION

Design Research (DR) is a type of research approach first developed by Hans Freudenthal in the Netherlands. The difference between DR and comparative empirical research is the purpose of research, that is, evaluating theory and teaching materials (Kizito, 2012). DR aims to develop theories and teaching materials, and, according to Bakker (2004), the purpose of DR is to develop local instructional theories about the stages of the learning process and how to support it. Kizito (2012) explained that the development of local instructional theories is done by anticipating the task of learning, the desired dialog, the norms of class participation, and the tools and resources needed to regulate teaching.

In addition, DR is a type of qualitative research that is quite complex and requires carefulness, accuracy, and creativity in compiling contextual and realistic mathematics learning. DR's emphasis is on the process of delivery of the subject matter by the teacher to students and the products that are produced in the form of learning design, which is part of the Hypothetical Learning Trajectory (HLT) with a realistic mathematical approach. The basis of why the DR approach was developed is partly because mathematics must be properly mastered by students. This can be achieved only by the success of the teacher conveying the mathematics lesson material properly and correctly. Only if the teacher correctly understands and teaches the material can the students be expected to have a certain standard of mathematical ability after learning from and understanding the lessons, as stated in the Ministry of National Education Regulation No. 23 of 2006 concerning Competency Standards for Graduates. Students are expected to be able to recognize and use various information about the surrounding environment logically, critically, and creatively, have a high sense of curiosity, and be able to solve simple problems in their daily lives and in the surrounding environment.

Realistic mathematics learning adopts Realistic Mathematics Education (RME) in terms of delivering subject matter to students and adapting RME to contextual problems that exist in Indonesia in carrying out learning for the subject of mathematics. According to Treffers (Bakker, 2004: 6), there are five characteristics of the RME approach: (1) phenomenological exploration, (2) using models and symbols for progressive learning, (3) using students' own constructions and productions, (4) interactivity, and (5) intertwinement.

The focus of this evaluation research is to observe the implementation of HLT in the theses of students of the DR-type master's program in the actual learning process in the classroom that is arranged in the Lesson Plan (RPP). The formulation of the problem in this evaluation research is as follows: (1) Is the HLT in each thesis compiled in accordance with the material to be taught in the classroom? (2) Is any mathematics learning activity planned to fulfill the five characteristics of RME, namely (a) phenomenological exploration, where learning is delivered contextually and realistically, (b) learning that begins with the model of the student so that students independently find the model for the material taught, (c) learning that contains student activities so that students can construct and produce their own knowledge, (d) learning that encourages interactivity between students, and (e) an intertwinement that links mathematics materials with other subject materials? (3) Is there a discussion in Retrospective Analysis (RA) about the implementation of HLT in each thesis? (4) What is the exposure and discussion in RA about the implementation of HLT in each thesis? (5) Is there an increase in students' mathematics learning outcomes?

From the results of this evaluation research, it is expected that clearer information will be obtained about the implementation of HLT from each thesis. This study is also expected to provide benefits in the form of advice and input to the supervisors so that they can guide students to make HLT in accordance with the subject to be taught.

2 METHOD

This study uses a qualitative evaluation approach to determine and represent quality that can thoroughly describe the actual condition of the implementation of the hypothetical learning trajectory in the design research of each thesis from students of the master's degree in the Mathematics Education Study Program. This evaluation research uses a logic model with stages of inputs, activities, outputs, and outcomes.

3 RESULTS AND DISCUSSION

All eight theses selected for this study contained HLT planned in a number of meetings and used contextual daily events around students. Table 1 lists the title, subject, and context of the theses.

After obtaining data about the material and context, an analysis of the relevance between the material and the chosen context is carried out (see Table 2). The right context enables students to create their own construction of the concept, so that there is a change from "model of" to "model for" mathematics learning based on findings and work of the students themselves.

In order to produce the students' own constructions and productions, teachers are required to make RPP for implementation of interactivity and intertwinement (Table 3).

After the research activities were conducted, retrospective analysis was carried out and included research sustainability analysis and research implementation suitability with the existing HLT (see Table 4).

All theses showed that students' mathematics learning outcomes improve. Students' attitudes changed because they became more familiar with mathematics as a subject and their social abilities developed, allowing them to convey the reasons for change through good communication skills.

Table 1. Title, subject, and context of theses.

No.	Thesis title	Subject	Context
1	Learning Development with Indonesian Realistic Mathematics Education Approach to Build Relational Understanding of Students in Integral Subject at XI-IPS, MAN 4, Jakarta	Indefinite and definite integrals	Covering wall ar0ea with wallpaper
2	Learning Development with Indonesian Realistic Mathematics Education Approach to Build Students' Relational Understanding of Logarithm Subject in Class X AP of Prudent School, Prudent School, Tangerang	Exponent and logarithm concepts	a. Amoeba growth b. Family Planning Program (KB) c. *Planaria* growth d. Multi-level marketing (MLM)
3	Development of Realistic Problem-Oriented Mathematics Learning Design with Inquiry Model to Develop Mathematical Creative Ability in Circle Subject in Junior High School	Circumference and area of a circle	a. Look for treasure to find the concept of a circle b. Use a re-allotment system to find the area of a circle
4	Application of Indonesian Realistic Mathematics Education (PMRI) Approach with Eggen Kauchak's Integrative Model on Learning about Surface Area and Volume of Pyramid to Build Representative Ability of Students in Class VIII, SMP Utama Citra	Surface area and volume of pyramid	Make a pyramid with origami paper
5	Surface Areas and Volumes of Cubes and Cuboid Learning to Develop Mathematical Problem Solving Abilities Using the PMRI Approach with the Student Teams Achievement Division (STAD) Model	Surface areas and volumes of cubes and cuboids	a. The making of a souvenir box in cube shape video b. Cube nets from a souvenir box made of soft drink bottle
6	Development of Learning with the Indonesian Realistic Mathematics Education Approach to Build Relational Understanding of Circle Subject in Class XI, IPA Al Azhar 1, Islamic High School, Jakarta	Position of point and line to the circle	a. The safe zone in the disaster of the Mount Kelud eruption b. Disaster relief center location
7	Application of PMRI Approach to Surface Area and Cone Volume Learning to Improve Students' Mathematical Problem Solving Ability in Class IX, Seram Barat Junior High School	Surface area and volume of cone	Traditional Buton cooking tools named Kukusang
8	Developing Mathematical Literacy Ability through Realistic Mathematics Approach Generative Model in the Concept of Permutation and Combination in Class XI, Fransiskus Jakarta High School	Permutation and combination	a. Mix and match clothes with pants b. Sitting formation c. Travel route d. Modified traditional game of *bekel*

Table 2. Subject and context relevance.

No.	Subject and context relevance	Model for
1	Resolving the challenge of determining the area of wallpaper needed to cover the walls of the exhibition; then using relational understanding to link the process of closing the area as an integral draw	a. Understanding the area in the $a \leq x \leq b$ interval is the sum for infinite n (many rectangles) and $\Delta x \to 0$ the width of each rectangle is close to zero. b. Determining the area between the curve and the x axis in the $a \leq x \leq b$ interval with algebraic manipulation and using a relational understanding of the concepts that already possess function definitions; if $F(x)$ is a polynomial function, then $F(a)$ is the result of substituting a to each variable x on $F(x)$ c. Determining the area's broad shading between two curves and the area between two curves with integrals d. Using a working-backward strategy with contextual functions resulting from integral drawing e. Discussing partial integral using a working-backward strategy in the context of the differential drawdown of the two-times function
2	Growth of amoeba and the KB program explains the occurrence of the principal number 2 in the logarithm, followed by main number 3 on *Planaria* and main number 10 with calculators	a. Building the concept of exponent patterns 2^n with the relevant context with logarithm b. Building the concept of exponents as a prerequisite for the concept of logarithm c. Building the concept of logarithm d. Finding the nature of logarithm e. Finding the nature of logarithmic operation
3	The concept of the circle is introduced by using the context of finding treasure; for the circle area, the activity uses the re-allotment method using other forms of the plane figure	a. Rediscovering the definition of circles and circle elements b. Finding the value of the approach π c. Finding and using circumference of the circle d. Finding and using the circular area formula with re-allotment activity
4	The surface area and volume of the pyramid using origami paper in the context of the rectangular and triangular pyramids	a. Building student enactive stages of representation to make their own teaching aid b. Building iconic stage representation capabilities to draw rectangular pyramid origami from various points of view c. Determining the surface area and volume of the pyramid
5	Through observation by watching videos, the concept about cube nets is embedded in students; each side of the cube nets is colored differently and it is expected that students can find their own characteristics in the cube	a. Cube nets b. Bloc nets c. Cube surface area d. Cuboid surface area e. Cube and cuboid volume

(*Continued*)

Table 2. (*Continued*).

No.	Subject and context relevance	Model for
6	The concept of the circle is introduced by using the safe zone context for the victims of the volcanic eruption; the relief center is used to explain the position of the two circles	a. Discovering circle concepts b. Finding the equation of circle with the center *P*(0,0) and *P*(*a,b*) c. Positioning point to circle d. Line positioning to circle e. Finding the equation of the tangent circle through a point on the circle and of circles that are known gradients
7	Kukusang is a tool for cooking cassava or cone-shaped sangkola	a. Finding cone elements and nets by observing the Kukusang cooking tool b. Finding the formula for cone surface area and volume
8	Contexts a, b, and c are used to explain the concept of multiplication rules; the *bekel* game, with the terms *ngecrek* and *ngeraup*, is used to explain the concept of permutation and combination	a. Formulating the concept of multiplication rules b. Building factorial concept c. Formulating the concept of permutation and combination d. Finding differences in the concept of permutation and combination e. Formulating a formula in the concept of permutation and combination f. Formulating the concept of cyclical permutation and identical permutation

Table 3. Interactivities and intertwinement.

No.	Interactivities	Intertwinement
1	Shade the area of $\int_0^b f(x)dx$, with $b \geq 0$, and the area of $\int_a^0 f(x)dx$, with $a \leq 0$	a. Formula b. Polynomial c. Rectangle d. Unit of length e. Cartesian diagram f. Differential
2	Fill out tables that contain sequential numbers and have patterns to finally find the logarithm concept from activity finding the concept of exponents 2^n, 3^n, and logarithm with base numbers 10	a. Amoeba, *Planaria*, KB, MLM and member addition in parties b. Flow chart, tree diagram, and family tree c. Usage of calculator
3	a. Determine the definition of a circle by making the area as an area that may be a treasure place within a certain radius b. Find the value π from the circumference of the circle c. Use a re-allotment system to find the circle area with a plane figure	a. "Treasure" term b. Radius c. Re-allotment system d. Plane figure, triangle, square, rectangle, parallelogram, rhombus, trapezoid
4	a. Make a pyramid from origami paper b. Draw a pyramid from various sides c. Find the concept of pyramid surface area d. Find the concept of pyramid volume	a. The characteristics of a plane figure, square, and equilateral and isosceles triangles b. Pythagoras
5	a. Observe cube nets and cuboid made of soft drink packaging b. Observe cube nets to get the concept about surface area and cuboid	a. Souvenir box b. Measurement process c. Checkered paper d. STAD technique

(*Continued*)

Table 3. (*Continued*).

No.	Interactivities	Intertwinement
6	a. Make a circle by determining the city points that considered cities inside or outside the safe zone due to volcanic eruptions b. The location of the relief center clarifies the concept of the position of the points on the circle and the lines in the circle	a. Mount Kelud b. Disaster relief center c. Radius d. Skala e. Maps
7	a. Observe the cone-shaped Kukusang b. Draw Kukusang parts; circle sector c. Find the concept of cone surface area and volume	a. Kukusang cooking tool b. Kasuami c. Woven leaves of Kukusang d. Kukusang without lid
8	a. Fill out tables so that permutation patterns can be observed b. Play *bekel* to get the concept about permutation and combination c. The *bekel* game leads to the concept of identical and cyclic permutations	a. The *bekel* game b. *Ngecrek* and *ngeraup* term c. Circles (for cyclic permutation)

Table 4. Retrospective analyses.

No.	Retrospective analysis
1	The thesis started by explaining from where the constant number C was added to complete the indefinite integral. Students managed to understand that polynomials are always complete to the last term with a zero-level variable (x^0). To calculate the curve area, the context was used to calculate the wall area that will be covered by a rectangular wallpaper. This explains the concept about calculating area by using specifics internal to the students. HLT ran well according to plan.
2	The use of the growth of amoeba and *Planaria* enables students to understand that mathematical material about logarithms is something that exists in everyday life. Continued with other contexts, if the Family Planning Program is successful and each family has only two children, the logarithm principal number 2 is noted. For other basic numbers, the development of multi-level marketing can show a lot of possible principal numbers in logarithms. The logarithm material begins by recalling the exponent subject. HLT went well according to plan, but when principal number 10 was introduced, the teacher used a calculator as a tool.
3	The creative abilities raised in this thesis include how students are able to find their own area of the circle formula; students have even already used the formula in elementary school. Students are given some activities to use a re-allotment system to find the area of the circle using other flat buildings. At first, students found some difficulties because of the curvature of the circle that could not cover the flat-build area used by the students, so the meeting frequency was increased because students had to understand the new ways the teacher asked to develop the students' creative abilities.
4	The use of Eggen Kauchak's Integrative Model in this thesis helps to develop representational capabilities of enactive and iconic stages in students. Building student representations at the enactive stage is to develop students' ability to make their own teaching aids, while building student representations at the iconic stage is to develop the ability to draw a square pyramid from various points of view. In this study HLT went unplanned, so the research meeting reached 12 meetings. This theory was applied by the researcher for the success of applying the student representation ability to find the pyramid surface area formula and pyramid volume.

(*Continued*)

Table 4. (*Continued*).

No.	Retrospective analysis
5	Making cube-shaped souvenirs from used mineral water packaging bottle is a creative and innovative idea to explain the cube surface area. The sides of the cube can be filled with different colored paper, so students can see the top–down, right–left, and front–back sides clearly as parallel sides. Furthermore, the props are opened into nets of colorful cubes to make various possibilities from the shape of cube nets. Hence, nets of cubes are used for students to imagine the area of the cube surface. The same thing is repeated for the cuboid.
6	The context was the eruption of Mount Kelud and the establishment of a disaster relief center within a certain radius. The circle as a mandatory subject, including the position of the point on the circle and the position of the line in the circle, followed by the tangent to the circle and the placement of the equations of the tangent circle. HLT ran well according to plan because the subject of the circle at the high school level was not new, but the position of points and lines on the circle and tangents is the material to be delivered.
7	To find the formula of the cone surface area, a traditional cooking tool of the Buton community was used, named Kukusang, which is cone-shaped. Kukusang was split into cone-shaped nets in the form of a circle to preserve the knowledge of Kasuami or Sangkola, dishes that are cooked in Kukusang. Problems arose when determining the surface area of the cone, because Kukusang did not use a lid; the surface area of the cone was included in the wide circle of the cone base. Students became confused because no part of Kukusang was in a full circle. After an explanation by the teacher about how that matters, HLT ran well according to plan because students could determine the surface area of the cone with the help of a circle, and could find the cone volume formula from the results of Kausami or Sangkola made by students.
8	Traditional games were reintroduced as a context to introduce permutation and combination. The traditional game *bekel* that uses a small ball was applied by researchers with several modifications, so the students can learn about cyclic permutation and identical permutation. The terms in the game, such as *ngecrek*, *ngeraup*, *pit*, and *rho*, decorated mathematics learning at that time. Modification of the game was made in order to make students understand the difference between permutation and combination. HLT activity went well according to plan, even though it ran slowly, because students were "playing" and the *bekel* ball went everywhere. Game modification was greatly helped by the student worksheet directing students to fill in matters relating to permutation, combination, cyclic permutation and identical permutation.

4 CONCLUSION

1. Inputs stage: All DR theses contain the correctly planned HLT.
2. Activities stage: Many differences exist among the theses, especially regarding the context conveyed to students, depending on the subject matter. The suitability of context and subject matter was very well managed by the students, but some implementations in the field were not in accordance with the plan.
3. Outputs stage: RA revealed only two theses that conveyed the change of HLT during research.
4. Outcomes stage: All theses showed that students' mathematics learning outcomes increase. Students' attitudes changed because they became more familiar with mathematics as a subject and their social abilities developed, allowing them to convey the reasons for change through good communication skills.

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Empowering Science and Mathematics for Global Competitiveness – Rahmawati & Taylor (Eds)

Chronic Obstructive Pulmonary Disease (COPD) detection using cough sound analysis based on machine learning

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ABSTRACT: Chronic Obstructive Pulmonary Disease (COPD) is one of the largest causes of death in the world. This chronic lung disease is caused by lung damage that can no longer be cured. This disease is very closely related to cigarette smoke that is inhaled either by smokers or by those around them who inhale the smoke for a prolonged time as passive smokers. There are many symptoms for COPD, such as shortness of breath especially after exercise, wheezing, cyanosis, cough, and cough with phlegm. Our data consist of 20 patients with COPD and 15 healthy control patients. Cough sound was recorded for 10 minutes using a clip-on microphone. Then, we separated every cough into one-second segmentations and extracted the Mel-Frequency Cepstral Coefficient (MFCC) feature vectors. We trained the data using two machine-learning algorithm classification models: support vector machine and multi-layer perceptron. We achieved 0.94 as the best result of both sensitivity and specificity.

1 INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a leading cause of chronic morbidity and mortality. It is one of the major public health problems, with a lifetime risk in smokers of 35–36% (Vestbo, 2007). It is estimated that more than 200 million people will have COPD by 2020, and it will be the third-leading cause of death worldwide (Sumner et al., 2013).

COPD is a common, preventable, and treatable disease characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar abnormalities usually caused by significant exposure to noxious particles or gases. The chronic airflow limitation that is characteristic of COPD is caused by a mixture of small airway disease (e.g., obstructive bronchiolitis) and parenchymal destruction (emphysema) (Vestbo et al., 2013). Diagnosis of COPD should be considered in any patient who has symptoms of a chronic cough, sputum production, dyspnea (difficult or labored breathing), and a history of exposure to risk factors for the disease (World Health Organization, 2004).

The main cause leading to its occurrence is exposure of the lungs to toxic substances in the form of gases and vapors that are in the air and that are the result of industrial and technical processes, combustion products, and substances contained in the smoke.

A previous report revealed that tobacco use is one of the major risk factors for the development of COPD (World Health Organization, 2015), especially in developing countries where there are so many tobacco smokers and the number continuously increases every year. However, more evidence is becoming available to suggest that other risk factors such as air pollution, respiratory infections, poor nutritional status, chronic asthma, impaired lung growth, poor socio-economic status, and genetic factors are also important for disease development. Another study also revealed that chronic respiratory diseases represent a challenge to public health because of their frequency, severity, projected trends, and economic impact (Aït-Khaled et al., 2001). For these reasons, we want to propose a method to simplify the diagnosis process of COPD by analyzing cough sounds.

Analyzing a large variety of sounds requires calculating a larger number of parameters from sound signals, and using automatic methods like machine learning to differentiate between various types of sounds. Most computational analysis systems dealing with realistic sounds are based on the supervised machine-learning approach, where the system is trained using labeled examples of sounds from each target sound type. The supervised learning approach requires that there is a set of possible scene categories or classes, defined by the system developer, and that there are good enough amounts of labeled examples available to train the system.

One study claimed that quantitative cough analysis can differentiate healthy and asthmatic subjects, and those with COPD with an accuracy of 85–90% (Amrulloh et al., 2018). It is well known that cough sounds carry information related to respiratory diseases. In our study, we propose a method to analyze cough sound as an alternative to detecting COPD, without the need of medical equipment, by using a machine-learning algorithm.

2 METHOD

2.1 *Data collection*

Cough monitoring was undertaken in the Persahabatan Public Center Hospital for a month. We used a Raspberry Pi 3 as the platform, with a BOYA BY-M1 Lavalier clip-on microphone attached. The audio was recorded by the microphone and analyzed using a machine-learning algorithm. We collected data by observing 20 patients with COPD and 15 healthy patients. The age range was 40–80 years. The recording duration was 10 minutes per patient. The total number of coughs recorded was 170. The ratio of coughs from patients with COPD to healthy patients was 1:1. We recorded the sample at 44,100 Hz, in mono, using a WAV format. Figure 1 shows a cough recording sample of a patient with COPD, which was plotted using Python software.

2.2 *Preprocessing*

We processed our data using audio-editing software to manually segment the cough sounds to one-second audio files. From each segment of coughs, the Mel-Frequency Cepstral Coefficient (MFCC) feature vector was extracted to be later processed using machine learning. We used all 13 MFCC feature vectors.

Mel-Frequency Cepstrum (MFC) is a representation of linear cosine transformation of a short-term log power spectrum of a speech signal on a non-linear mel scale of frequency. MFCCs together make up an MFC. In MFCC extraction, all the characteristics of the speech signal are concentrated in the first few coefficients (Kishore & Satish, 2013).

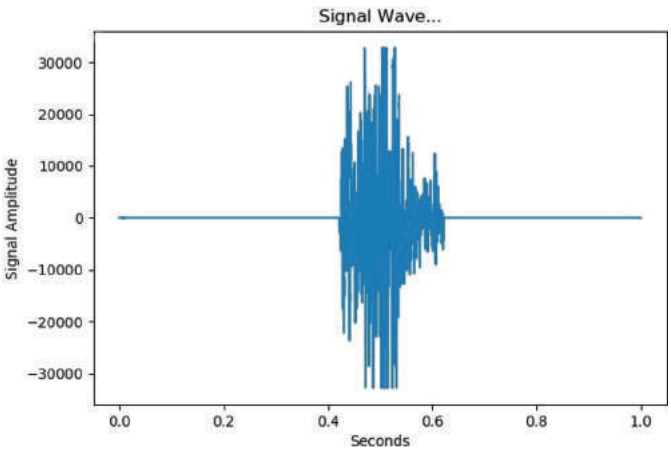

Figure 1. Cough recording sample of a patient with COPD.

2.3 *Machine-learning classification*

We used two machine-learning algorithms to classify the data: Support Vector Machine (SVM) and Multi-Layer Perceptron (MLP). SVM is a machine-learning algorithm used for non-probabilistic testing as a regression and classification technique. It can also be called Support Vector Network. Through SVM we put items based on data samples on n-dimensions space, where n is a feature that is considered.

Then, classifications were done using a hyperplane to separate class. Every hyperplane is characterized by direction w; (b) is the proper position in space and threshold value; and x_i is an input vector by n dimension or text content and shows the class. One set of training labels is as follows:

$$(x_1, y_1), (x_2, y_2), \ldots, (x_k, y_k), XR^d \tag{1}$$

where d is a dimensionality of vector: y_i $\{-1, +1\}$; $i = 1, 2, \ldots, k$.

We considered the decision function with $f(x, w, b) = \mathrm{sgn}((w.x_i) + b)$, $w \in R^d$, $b \in R$. Then, the area between the hyperplane if and only if separates each classes, is called margin. The margin width is equal to $1/2\|w\|$ and the maximum value of the margin might be based on the idea of the SVM algorithm. Maximizing margins involves minimization; that is,

$$f(w,b) = \frac{1}{2}\|w\|^2 \tag{2}$$

with

$$wx_i + b >> 1, \text{ if } y_i = 1;$$
$$wx_i + b << 1, \text{ if } y_i = -1.$$

K is a constant value defined by the user and ε is a margin error. Margin error occurs if the data are included in one class and on the wrong side of the hyperplane. Minimizing the costs is a problem between a large margin and a small number of margin errors. The solution to this optimization problem was obtained as follows:

$$w = \sum_{i=1}^{N} \lambda i\, \gamma i\, \chi i \tag{3}$$

This formula is a weighted average of training features, where λi is the Lagrange multiplier of the optimization assignment and γi is the class label. The value of λi is not zero for all values inside the margin when it is on the right side of the classifier (Rahmansyah et al., 2018).

One of the advantages of SVM is that, with limited training data, it may generate comparable or even better results than other methods. The SVM algorithm is used for automated object detection and characterization. Specifically, SVM is applied in its basic form as a binary classifier where it distinguishes two classes, namely, object and background (Wardaya, 2014).

A multi-layer perceptron is the part of the perceptron algorithm also called feed forward network. The perceptron algorithm was formulated by Rosenblatt in the late 1950s (Murtagh, 1991). It has one or more hidden layers between its input and output layers, the neurons are organized in layers, the connections are always directed from lower layers to upper layers, and the neurons in the same layer are not interconnected. The number of neurons in the input layer equal the number of measurements for the pattern problem, and the number of neurons in the output layer equal the number of classes. The choice of number of layers, neurons in each layer, and connections is called the architecture problem (Ramchoun et al., 2016).

The multi-layer perceptron is used to approximate some function of f. The multi-layer perceptron network is composed of many functions chained together. A network has three functions or layers.

$$f(x) = f^{(3)}(f^{(2)}(f^{(1)}(x))) \tag{4}$$

Each of the layers is composed of units that perform an affine transformation of the linear sum of inputs. Each layer is represented as

$$y = f(Wx^T + b) \tag{5}$$

where f is the activation function (covered below), W is the set of parameters or weights in the layer, x is the input vector, which can also be the output of the previous layer, and b is the bias vector.

We optimized the result by tuning the parameter for both algorithms. For SVM, we tuned the parameter to kernel = linear, C = 1,000, $\gamma = 0.01$. For MLP, the hidden layer = (250, 200, 150), max iteration = 200, solver = lbfgs, learning rate = 0.01, and activation = tan$h$.

2.4 *Statistical evaluation*

We used sensitivity, specificity, and Receiver Operating Characteristics (ROC) area to evaluate our method. Sensitivity is a statistical method that measures the percentage of actual positives that are correctly identified. Specificity measures the percentage of the actual negatives that are correctly identified. The ROC curve is created by plotting the true positive rate (sensitivity) against the false positive rate (1–specificity). The curve can be represented with the area under the curve.

3 RESULTS AND DISCUSSION

Our dataset consists of 170 coughs, where 85 coughs were from patients with COPD and 85 were from healthy patients. We used a ratio of 8:2 for splitting the data into training and testing datasets. The results we got using the parameters mentioned are listed in Table 1.

From the results in Table 1, we can see the difference between both algorithms. We achieved 0.99 sensitivity when using SVM and this decreased when using MLP to 0.94. While the sensitivity decreases when using MLP, there is a high improvement in specificity from 0.83 to 0.94. The ROC area for MLP is slightly higher than that for SVM, which makes MLP slightly better overall. The ROC curves for both algorithms SVM and MLP are shown in Figures 2 and 3, respectively.

Table 1. Statistical evaluation results.

Algorithm	Sensitivity	Specificity	ROC area
SVM	0.99	0.83	0.97
MLP	0.94	0.94	0.98

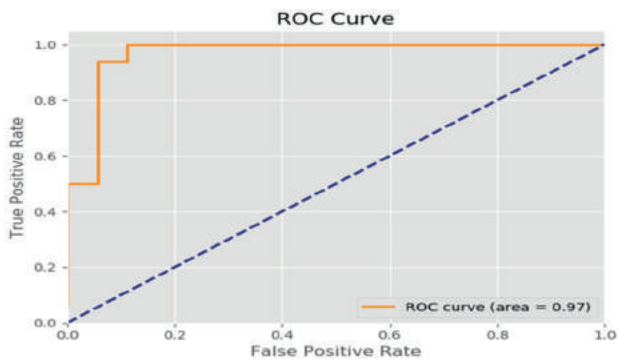

Figure 2. ROC area for the support vector machine algorithm.

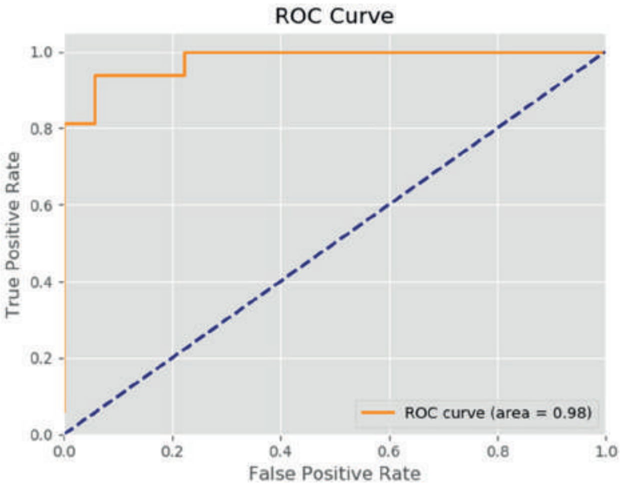

Figure 3. ROC area for the multi-layer perceptron algorithm.

The results obtained prove that cough sounds can differ between healthy patients and those with COPD. One of the problems of this research is that within the time of the recording there may not be any natural coughing, so we sometimes had to ask the patients to let out voluntary coughs. It is recommended that recordings are done for a longer duration, for example two hours, to increase the possibility of acquiring more non-voluntary coughs. With some improvements, this method may be used for an early diagnosis of COPD.

4 CONCLUSION

From the research done, we can conclude that the use of machine learning to analyze cough sound is viable as the alternative method for detecting chronic obstructive pulmonary disease, with a sensitivity, specificity, and ROC area of 0.94, 0.94, and 0.98, respectively.

In the future, we hope to also apply machine learning to data preprocessing to change the manual segmentation with a cough-detection algorithm to improve the data quality.

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A proposed model for predicting stock market behavior based on detecting fake news

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ABSTRACT: Stock market is an important area of research due to its higher earnings. The higher earnings for the stock market also imply higher risks, so a large amount of data generated by the stock market is considered a treasure of knowledge for investors. There are several aspects that affect stock market fluctuations; the most important of them is news data. News data have an influential effect on the investors' thoughts and beliefs. Using machine learning and textual data processing are considered a significant part of the stock market analysis. Researchers have been concerned with designing a suitable model to predict the future behavior of the stock market to avoid investment risks. A strong relationship has been found between stock news and changes in the stock prices. This study aims to propose a framework for detecting stock market fake news that helps in avoiding higher investment risks and improves stock market prediction accuracy. The study also aims to determine the best combination of machine-learning algorithms that lead to the best performance of the prediction model that is designed according to news sentiment and numeric data analyses. Different experiments have been applied to uncover algorithms that lead to the best performance and raise the prediction accuracy to 92%.

1 INTRODUCTION

The stock market has many factors that affect market behavior; the main factor among them is news data. Detecting news credibility and authenticity is considered an important area of research unlike stock market research that has lower interest (Sahal, Khafagy & Omara, 2016). Incorrect news content has led to more fluctuation in the stock market through many buying and selling signals that cause large financial losses by misleading content of stock market news, which affects the investors' behavior and decisions. Social media and knowledge-sharing platforms are large-scaled as a source of information for investors. This information includes the stock market news data as well as the tremendous number of social media users who bias investors' thoughts and decisions about specific stocks. In the stock market the cost of information is very high, so detecting news credibility is a major task to avoid large financial losses which requires effective solution (Shenouda, Khafagy, & Senbel, 2014). Investors usually wish to achieve higher profits on their investments by determining stocks of interest and the best time to buy or sell; this is achieved by designing an accurate prediction model for the stock market behavior. Machine-learning techniques are used to explore the stock market pattern.

Machine learning includes supervised and unsupervised approaches (Witten et al., 2011; Kaseb et al., 2018) is applied in different directions (Sarhan, Ghalwash & Khafagy, 2009; Sahal, Khafagy & Omara, 2018; Mahmoud, Hegazy, & Khafagy, 2018). Text mining is a process of handling unstructured data and is considered a step of knowledge discovery. Text preprocessing techniques include tokenization, stemming, and stopping word removal. Sentiment analysis is the process of determining people's attitudes, opinions, evaluations, appraisals, and emotions toward entities such as products, services, organizations, attributes using Natural Language Processing (NLP), statistics, or machine-learning methods from text data.

2 RELATED WORK

There are a number of researches that have been conducted in the area of prediction in general (Sahal et al., 2016) and specifically in stock market prediction. Some of them aimed to predict the future price based on historical stock prices (e.g., see Witten et al., 2011; Desai & Gandhi, 2017; Bing et al., 2014), others aimed to predict the stock market behavior by analyzing news sentiment (e.g. see Vijayarani & Janani, 2016; Tan et al., 2006; Kannan et al., 2010), and another study aimed to build a prediction model based on news and some historical stock prices (see Shriwas & Farzana, 2014). The literature on stock market prediction includes studies by Desai and Gandhi (2017), Mazen et al. (2018), and Khedr et al. (2017) and the literature on fake news detection includes the study by Granik and Mesyura (2017). In the field of the stock market and fake news detection, few studies till now aimed to detect the credibility of stock market news despite its importance and impact on investment decisions and investor behavior.

3 METHOD

Fake news detection is considered an important task for stock market prediction because of the effect of fake news on the investor's thoughts and beliefs. Fake news also has a great effect on the stock market prices according to a number of studies, as shown in the previous section, that proved there is a strong correlation between news releases and stock market prices. The aim of our proposed model is to detect stock market fake news and enhance the prediction accuracy of the stock market by combing stock market news and historical stock prices. The analysis of stock market news is based on analyzing different types of news every day and determining their effect on the stock market along with historical stock prices (Open-High-Low-Close; OHLC). Our proposed model is implemented based on three steps: The first step detects fake news and then filters it from our dataset to avoid non-factual news, thus avoiding unauthenticated sources of information that cause stock market fluctuation and higher investment risks to improve the performance of the stock market prediction model.

The second step compares different machine-learning algorithms to discover the best combination of algorithms that leads to the enhanced performance of stock market news based on sentiment analysis as positive or negative news. The third step determines the best combination of machine-learning algorithms to enhance the performance of the prediction model that is designed based on news sentiment analysis and numeric data analysis to predict the stock market's future behavior as a fall or rise.

3.1 *Data description*

Our proposed model is implemented based on United States market data. NASDAQ is the largest stock market in the United States that combines stocks for the largest companies in the United States. The stocks for Yahoo!, Facebook, Inc., and Microsoft Corporation have been used in our experiment. We collected different types of news along with historical stock prices for each of these companies. For our news dataset, we collected news from different authenticated data sources, including *The Wall Street Journal*, Reuters, company websites, Google Finance, Yahoo! Finance, Nasdaq.com, Economics.com, and share market updates. Other news for the news dataset was collected from social media (Twitter) along with stocks news from knowledge-sharing platforms such as Seeking Alpha and Motley Fool. The second type of dataset collated for this study was the historical stock prices for the chosen companies, which included opening and closing prices along with the highest and lowest stock prices for the company stocks during a day.

3.2 *Description of the proposed model phases*

3.2.1 *Fake news detection model*

Fake news detection is considered an important task to determine factually incorrect and misleading news for investors. Stock market fake news aims to affect the investors'

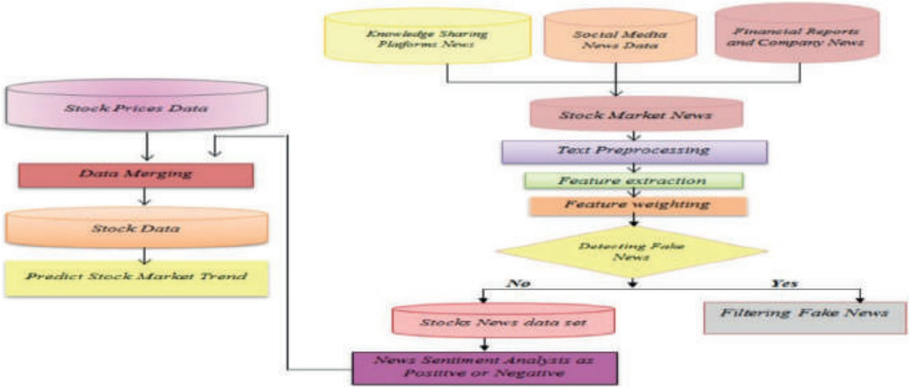

Figure 1. Proposed model.

opinions and decisions about their investment portfolio, so it can cause large financial losses. The stock market fake news detection model is shown in Figure 1. Stock market news was collected from different authenticated data sources and from different knowledge-sharing platforms such as Seeking Alpha and Motley Fool. The text preprocessing techniques in this study include using tokenization, stopping words and stemming, and text normalization. Text normalization techniques were applied for the news corpus by transforming different forms of text into a common standard format through the modification of all letters in the news into lowercase. After this, N-gram was used for the news corpus as a syntactic analysis technique in order to extract features from the news corpus as a series of tokens for length *N*. Our model generated bi-grams from the news corpus. N-gram has a robust performance in extracting features from text because of automatic capturing of the most frequent roots in news data. Also, good representation that is provided by N-gram does not require using a specific dictionary, as noted in its tolerance for spelling errors (Lyon & Cedex, 2009).

The vector space model was used for document representation to represent terms as a vector model and capture the extracted features from the stock market news corpus. Term Frequency–Inverse Document Frequency (TFIDF) is a feature-weighting method used for weighting each term in news articles to indicate the importance of a word in news documents or in the corpus. TFIDF is used to replace each token with a weighted value (Loke, 2017). TF is the term frequency for term *t* in document *d*, weighting terms based on the occurrence of a term in the document. Inverse Document Frequency (IDF) weight is based on the documents that contain the term *t* in the collection of news articles.

Our proposed model has two main classes of news: “fake” and “correct” news. After features were extracted and weighted, a random forest classifier was applied to classify the stock market news as fake or correct news. The fake news detection model is implemented using the random forest classifier. The random forest classifier is a supervised classification machine-learning algorithm that is an ensemble classification method. This technique builds multiple decision trees and combines these decision trees to produce a random forest (Assaf et al., 2013; Elagamy et al., 2018). The output of several independent decision trees is combined and the majority vote is used to produce the optimal predictive model. For stock news data, the random forest builds multiple decision trees and combines the output for these trees based on the majority vote to produce the optimal classifier and determine the class label (i.e. which news articles are fake and which ones are correct). The random forest classifier was implemented for detecting fake or correct stock news. It is an extremely flexible method and has higher accuracy. We noticed that there are common features to distinguish fake news from correct news. The former usually has shorter news content and a lower authenticity score.

3.2.2 *News sentiment analysis phase*

Fake news will be filtered because it is considered misleading for stock market prediction and the correct authenticated news are maintained. The maintained correct stock market news used to perform sentiment analysis to investigate its impact on the stock market as positive or negative impact. The objective is to determine the stock market news polarities as positive or negative news. In this phase we perform the following steps for text normalization techniques along with previous text prepressing techniques that performed for news data in the fake news detection component. For each news article we process acronyms and abbreviations by constructing list of abbreviation for replacing of substrings by original token or term. Performing abbreviation replacement because of abbreviation is meaningless in context and in sentiment analysis such as 'US' replaced by United States. After processing the abbreviations all token that is less than two letters ignored because it does not have semantic contribution in news context. Sentiment analysis for stock market news to be either positive or negative for the stock market behavior has been implemented using different machine learning algorithms and compare their performance to uncover which of them have higher performance and more suitable for the nature of stock market news dataset. In sentiment analysis model we explored various machine learning methods such as support vector machine (SVM), K-nearest neighbor (k-NN), naïve Bayes and logistic regression in order to improve the classification accuracy.

SVM is one of the classification methods that has its roots in statistical learning theory. SVM is based on the idea of separating two datasets by enforcing a margin and train to find the maximum margin. It also, find the distance between the point and hyperplane that has the maximum distance of the closest point to the margin called support vector.

Naïve Bayes is based on simple probability classifier that is belonging to Bayes theorem, which is based on conditional Independency between features. Conditional Independency considers each attribute is an independent attribute from other attributes thus it does not consider the relation between attributes or features.

Logistic regression one of the popular classification algorithms that are used logistic function to estimate the probabilities between data labels (as positive or negative) and the extracted features form news data. This means that the logistic function represents that the probability of class label occurrence is a linear function combination between independent predictor variables and the extracted features. The classifier used logistic function to calculate the likelihood that "positive" class label will occur with the specific group of features and will not occurs with another group of features that belongs the "negative" class label. Logistic regression considers the dependency between features and performed well with binary classification. Logistic regression similar to naïve Bayes in extracting a set of weighted features.

4 RESULTS AND DISCUSSION

Here, we discuss the experimental results in three sections. The first section represents results for fake news detection through sentiment analysis for news content as fake or correct news. The second section is concerned with the experimental results for stock market news sentiment analysis as having a positive or negative effect on the stock market or on investors' decisions, using different machine-learning algorithms to find the best performance. Finally, the third section describes the results for predicting the stock market's future behavior as a fall or rise.

4.1 *Results for detecting stock market fake news*

The experimental results demonstrated that fake news has a strong effect on stock market behavior because of its impact on investors' beliefs and decisions. The random forest algorithm was used to detect the credibility of stock market news as fake or correct news for three companies: Yahoo!, Facebook, Inc., and Microsoft Corporation. The algorithm demonstrated a reasonable accuracy for fake news detection. The results showed that accuracies achieved are 66.6%, 69.2%, and 61.1% for Yahoo!, Facebook, Inc., and Microsoft Corporation, respectively. The model performance was measured by kappa statistics and the results demonstrated that the proposed model is acceptable. From our experimental results it was found that fake news has common features, such as it usually has shorter content, fewer self-references, higher insight words (think, know) and discrepancy words (think, should), that help differentiate it from correct news. These general features are consistent with previous studies for fake news detection models.

4.2 *Results for stock market news sentiment analysis*

The stock market news sentiment analysis was performed based on different algorithms to find the best performance. The overall experimental results are represented in Figure 2. Empirically, logistic regression achieved higher accuracy than K-Nearest Neighbor (K-NN), Naïve Bayes, and Support Vector Machine (SVM) algorithms; this means that logistic regression is more suitable for textual data analysis than other models. Figure 2 shows logistic regression achieved accuracy for the sentiment analysis model 88.24%, 86.21%, and 81.82% for Yahoo!, Facebook, Inc., and Microsoft Corporation, respectively. Logistic regression obtains a higher accuracy of results because it considers the dependency between features and has higher performance in the case of binary classification. The experiment also used the random forest classifier for news polarities, but it did not achieve reasonable accuracy because of the large size of data compared with that for fake news detection and because of the sentiment features that are not adequate to give the news a label. The sentiment feature was evaluated because split decisions are not informative and therefore produce imbalanced decisions as well as because of the complexity of building multiple classifiers on large text data.

4.3 *Results for predicting stock market behavior*

In this section, we describe the experimental results for predicting the stock market's future behavior as a fall or rise. The performance of different algorithms was compared. The results for all are promising. The performance of the following three supervised learning algorithms was compared: SVM, random forest, and K-star algorithm. It was found that the random forest algorithm has a better performance than the others because it achieved an accuracy up to 92.3% for Microsoft Corporation. The training and testing files were shuffled to measure the validation of our proposed model.

The experimental results demonstrated that the random forest model outperformed SVM and K-star with accuracies of 83.9%, 92.3%, 91.3% for Yahoo!, Microsoft Corporation, and Facebook, Inc., respectively. The accuracies achieved for predicting the stock market's future behavior based on the SVM algorithm are 82.9%, 84.6%, and 79.2% for Yahoo!, Microsoft Corporation, and Facebook, Inc., respectively. Finally, the prediction model based on the K-star algorithm's performance achieved accuracies of 70%, 80.6%, 82.9% for Yahoo!, Microsoft Corporation, and Facebook, Inc., respectively.

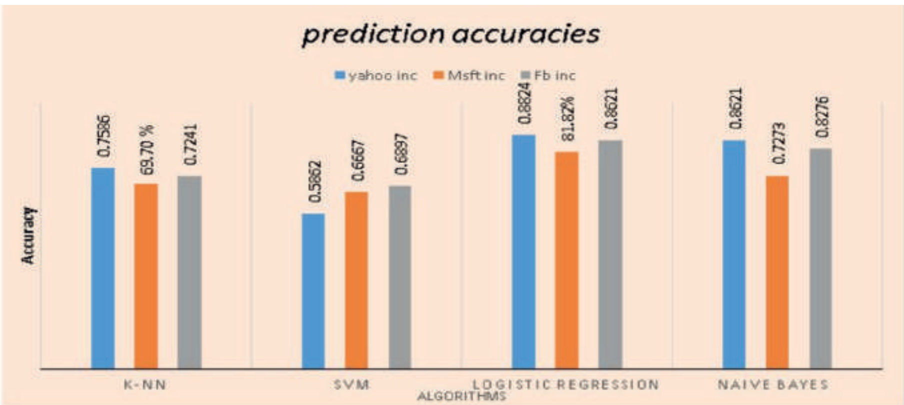

Figure 2. Results for the performance of algorithms for news sentiment analysis.

The experimental results proved that our proposed model is an effective way to predict the stock market based on stock market news detection, analyzing different types of news, and historical stock prices. Our model was tested using kappa statistics to compare the observed accuracy with the expected accuracy to determine the degree of acceptance and approval for the proposed model. The values in Figure 2 demonstrate that our model achieved a higher degree of acceptance using the random forest algorithm.

5 CONCLUSION

Stock market prediction is considered an essential area of research because of higher earnings and its importance in the economic growth of countries. There are several factors affecting the stock market. News release is considered a significant factor that causes stock market fluctuations because of its great impact on investors' thoughts and decisions about their investments. Detecting news credibility is a new growing area of research in stock market prediction. Detecting the authenticity of news has a great impact on improving stock market prediction and avoiding large financial losses. The proposed model in this study detected stock market news releases using the random forest algorithm with reasonable accuracy. News sentiment analysis as positive or negative news was performed using logistic regression. Logistic regression is more suitable for sentiment analysis data through the comparison of three popular machine-learning algorithms by achieving an accuracy up to 88.24%. Comparison between three machine-learning algorithms was performed to find the best combination of algorithms for higher prediction accuracy of the stock market. The random forest algorithm achieved the best performance and higher accuracy compared with other algorithms. For future work, this model can be enhanced by considering larger sample size of fake news and some technical analysis features.

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Comparative study of stream, block, and hybrid cipher techniques in the Hadoop distributed file system

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ABSTRACT: Big data streaming is the most trending term nowadays, collecting a stream of data from different places and devices that need to be processed in real time. Hadoop is the suitable framework for this large stream of data because it supports handling of big data storage with the Hadoop Distributed File System (HDFS) and real-time processing with MapReduce functions. Big data streaming needs a security model to achieve data confidentiality. Here, a comparative study has been done among different security approaches (i.e. block, stream, and hybrid) that have been applied for Hadoop. The implementation of these approaches is based on the performance and the output data for each approach. The results of the comparative study show that the streaming security approach outperforms other approaches (i.e. block and hybrid).

1 INTRODUCTION

Cloud computing has become a critical technology for e-business and is used for processing large-scale data. It helps save costs by sharing hardware and software resources. Managing cloud computing is not a challenge for users because it is easy to use. Pay per use is the best solution for saving cost, as users only pay for the hardware resources, software applications, and services that they use (Sun Microsystems, 2009; Nwobodo, 2015).

The vendors of cloud commuting offered support and management of the back-end to help the users make use of the services that are scalable with user demand.

Cloud computing is not just the best way to reduce information technology costs. Nowadays, it is also a business's solution for interacting in real time directly with the customers. The challenges of cloud computing are shown in Figure 1.

1. Authentication: This is the process of proving one's identity. It means that before the system sends and receives data, the receiver and sender identity should be verified.
2. Confidentiality: This ensures that only the intended receiver reads the message and no one else does. This is usually how most people identify a secure system.
3. Integrity: This ensures that the message received by the user is not altered or manipulated. The basic form of integrity is packet checksum in IPv4 packets.
4. Performance: Different models can decrease performance time if there is no probable plan that negatively impacts performance.
5. Service reliability/availability: Since the main problem with most systems is getting hacked by an intruder, who can cause a downtime in availability, such systems provide a way to provide their users with the quality of service they expect.

This study focuses on cloud computing security, especially data confidentiality.

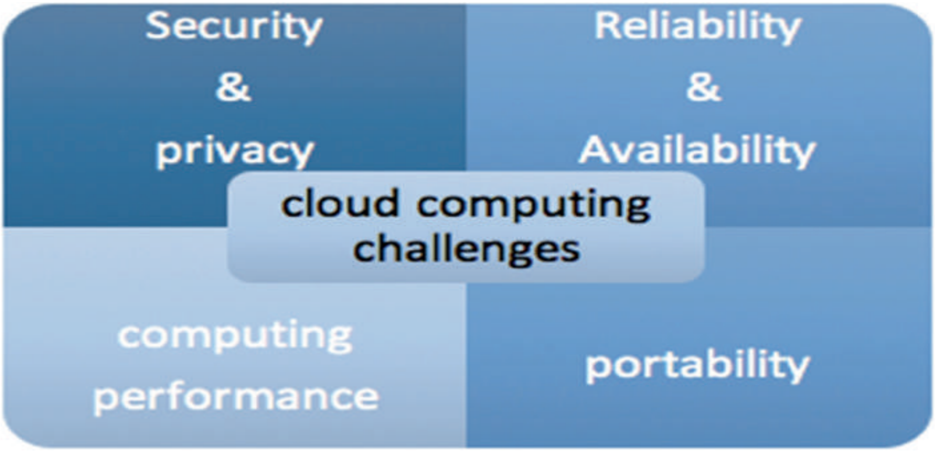

Figure 1. Cloud computing challenges.

1.1 *Hadoop architecture*

Hadoop (Borthakur, 2007) is an open-source platform for managing large datasets and distributed storage. It supports distributed data processing. Hadoop consists of two components: the Hadoop Distributed File System (HDFS) and MapReduce.

1.2 *Hadoop distributed file system*

HDFS is responsible for storing large datasets through multi-clusters that consist of a single name node as a master server and multiple data nodes for storing data blocks. Figure 2 describes the HDFS procedures for uploading a file. The user can upload a file in HDFS through the distributed file system module that uses a load-balance technique (Sarhan et al., 2009) and reserves the data blocks on metadata that is located at the name node server. The stream of data is uploaded to HDFS on data node servers (Abdel Azez et al., 2018; Kaseb et al., 2018).

1.3 *Big data streaming*

Massive datasets are a big challenge for data management tools and data processing in real time. Big data streaming is used to quickly process continuously generated data. Data analysis in real-time streaming data is a single-pass analysis (Namiot, 2010).

Big data consist of four vectors (Srinivas, 2010): velocity, variety, volume, and value:

1. Velocity is the speed of generating data;
2. Variety is the different types of data;
3. Volume is the size of data generated;
4. Value is the output for gains from massive data.

1.4 *Big data challenges*

Tole (2013) highlights some of the issues facing big data:

1. Limited availability for skilled clients to manage big data;
2. Data development timing;
3. Security to protect big data from unauthorized users;
4. Performance of processing big data (Sahal et al., 2016, 2018; Shanoda et al., 2014);
5. Scalability of resources for processing data.

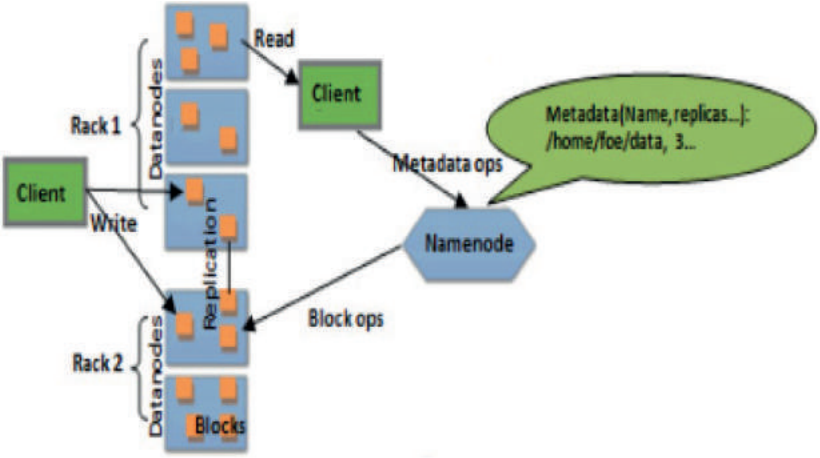

Figure 2. HDFS procedures for uploading a file.

1.5 *Big data security*

Big data security (Wang et al., 2014) is becoming a critical issue. All companies and banks need to protect data, so a big data security analytics solution is required to secure data that consists of three characteristics of scale, performance, and flexibility (Focardi, 2001).

1.6 *Hadoop security*

The original Hadoop system was designed without any security. Data in Hadoop were not secure and not protected from hackers. A previous work has tested techniques to secure data in the Hadoop distributed file system (O'Malley, 2010).

The rest of this paper is organized as follows: Section 2 describes related work regarding the stream, block, and hybrid cipher techniques. Section 3 describes a comparative analysis of HDFS security techniques and experimental results. Section 4 concludes the work.

2 RELATED WORK

Some previous studies used the block or stream cipher by new mechanisms to secure data in Hadoop. It requires a lot of techniques to achieve security features like confidentiality and authentication. Here, we show the performance and complexity that affects each mechanism.

2.1 *Stream cipher*

In this section, we examine the related works on the use of the data stream in HDFS using new techniques to secure data.

Pardeep and Peteriya (2012) used different stream ciphers to secure data over transmissions in different ways, to ensure that there is no unauthorized access and to achieve the integrity of data. Enhanced implementations of RC4 were also shown in the paper, which also discusses the difference in the performance between the RC4 stream cipher algorithm and the stream cipher algorithm.

Jayan (2017) implemented a secure Hadoop using RC4 as a stream cipher to enhance the performance of encryption/decryption. The MapReduce functions were used to ensure the confidentiality of data and allow users to protect their data. In this study, the RC4 encryption algorithm was modified to use in parallel to enhance the security of data on Hadoop and reduce the cost algorithm utilizing MapReduce. RC4 depends on the resource of the nodes.

2.2 *Block cipher*

In this section, we examine the related works on the use of the data block in HDFS using new techniques to secure data. Park and Lee (2013) and Yang et al. (2013) implemented the Advanced Encryption Standard (AES) encrypt/decrypt class and added to the compression codec in Hadoop to secure the HDFS architecture. The testing and results in Hadoop showed that the use of MapReduce on encrypted HDFS generates an affordable computation overhead of less than 7%. Files were encrypted and decrypted before being written or read in the HDFS. A client's request to encrypt or decrypt file I HDFS blocks at each data node used 128-bit AES in ECB mode with HDFS blocks.

Yang et al. (2013) implemented the triple encryption scheme using HDFS file encryption. They used three algorithms, DEA, RSA, and IDEA, to encrypt the file using an RSA private key, and then integrated it into the Hadoop-based cloud data storage. The hybrid encryption method used a symmetric cipher to encrypt data with a unique key and the key used asymmetric cipher encryption with the user's public key. Hybrid encryption used symmetric and asymmetric ciphers to encrypt files with the DES algorithm to get the data key. The data key was encrypted using the RSA algorithm, where the user keeps the private key in order to decrypt the data key.

Adluru et al. (2015) used random encryption techniques that achieved authentication of distributed data access. They discussed the issues of security and privacy of big data. The Hadoop ecosystem provides security and privacy as the name node and the data node in Hadoop. This system is a need for trust between the client and the name node used hashing and Encryption techniques on the data are implemented using random algorithms like RSA, AES, and RC6.

2.3 *Hybrid cipher*

Hybrid data are used in some of the related works when using the data stream combined with the data block to enhance data security in HDFS. Mahmoud et al. (2018) presented a new approach that consists of two algorithms: a block cipher AES algorithm with ECB mode and a stream cipher One-Time Pad (OTP) algorithm to achieve data confidentiality in HDFS using encryption/decryption data. Their approach enhanced the encrypted file size that increased by 20% of the original file, and the performance in encryption/decryption data was improved in Hadoop compared with other related works.

Lin et al. (2012) designed and implemented the integration of HDFS-RSA and HDFS-Pairing to achieve data confidentiality in Hadoop. The result of the integration showed an overhead on reading and writing operations. They designed the fuse-DFS module to modify the reading and writing operations, and described the two implementations to achieve this module: First, HDFS-Pairing used the Pairing-Based Cryptography (PBC) library; second, HDFS-RSA used OpenSSL. The hybrid data used a block cipher and stream cipher to encrypt the data.

3 RESULTS AND DISCUSSION

3.1 *Experimental environment*

For the performance evaluation of encrypted HDFS, we configured Hadoop 1.2.1 as a single-node cluster to use the HDFS and MapReduce functions. Each node has an i7 core with four processors, 8 GB memory, and 750 G hard disk.

3.2 *Dataset*

We use the TPC-H benchmark (www.tpc.org/2018) dataset to evaluate our implementation with the original Hadoop.

Table 1. Summary of the classification study on security techniques.

Work/Year	Cryptography cipher	Method	Strength	Weakness	Security property
1-Mahmoud et al. (2018): An approach for big data security (Yang et al., 2013)	Block cipher with stream cipher	The AES algorithm with the OTP algorithm is implemented	Hybrid encryption algorithm used enhances the performance of encryption/decryption data	The encrypted file size increases by 20% of the original data	Confidentiality, integrity
2-Jayan (2017): RC4 in Hadoop security using MapReduce (O'Malley, 2010)	Stream cipher	The RC4 encryption algorithm is modified	Encrypted file size is the same as the original file	The key is not secure	Confidentiality, integrity, and authentication
3-Big data security and privacy (Park & Lee, 2013)	Block cipher	Random techniques like RSA and AES are implemented to encrypt data; there is a trust mechanism between the user and the name node	Privacy and security is achieved in HDFS	The connection between the user and the name node takes a lot of time to achieve trust, which affects performance	Authentication
4-Lee (2013): Encrypted HDFS (Pardeep & Peteriya, 2012)	Block cipher	The AES algorithm with ECB mode is implemented to encode and decode the data in HDFS	Encrypted HDFS generates an affordable computation overhead less than 7%	Different blocks are used independently of each other because ECB mode is used; the size of the encrypted file increases to approximately 50%	Confidentiality and authentication
5-Triple encryption scheme for Hadoop data security (Jayan, 2017)	Block cipher	Three algorithms, RSA DEA, and IDEA, are implemented to encrypt data using an RSA private key	Data encryption with high security data	Encryption and decryption affect the performance using the triple encryption scheme	Confidentiality, integrity, and authentication
6-Pardeep & Peteriya (2012): Pragmatic study on different stream ciphers (Focardi, 2001)	Stream cipher	The RC4 algorithm is implemented	RC4 has faster encryption and decryption among the other stream cipher algorithms	The RC4 algorithm needs improvement to be more secure	Confidentiality and integrity
7-Integrating hybrid encryption schemes and HDFS (Adluru et al., 2015)	Block cipher with stream cipher	HDFS-Pairing and HDFS-RSA integrations are implemented	Data confidentiality is provided in HDFS by using data encryption	Asymmetric encryption is used by RSA and pairing algorithms are slower and not suitable for encryption and decryption data in Hadoop	Confidentiality and integrity

3.3 *Comparative analysis of HDFS security techniques*

The summary of the classification study on security techniques used to secure the data in HDFS is described in Table 1, including the method, strengths, weaknesses, and security properties.

In previous works, the performance comparison with AES (Park & Lee, 2013), RC4 (Jayan, 2017), and the hybrid approach (Mahmoud et al., 2018) show algorithms compared with generic files in HDFS with different file size by megabyte. File write performance comparison is shown in Table 2 and file read performance comparison is shown in Table 3.

Figure 3 shows the comparison of the write performance between related works (Jayan, 2017; Park & Lee, 2013; Mahmoud et al., 2018) and the generic file in Hadoop in the chart. Figure 4 shows the comparison of the read performance between the same related works and the generic file in Hadoop. These results show that the use of stream cipher algorithms to secure the Hadoop distributed file system has the best performance in reading and writing data in HDFS.

Table 2. File-writing performance comparison.

File size (MB)	Generic HDFS (minutes)	AES algorithm (minutes)	RC4 algorithm (minutes)	Hybrid algorithm (minutes)
64	0.3146	0.7604	0.5347	0.6324
128	0.7007	1.7214	0.9914	1.2790
256	1.5385	2.6378	2.0234	2.4335
512	2.9045	6.4622	3.9850	4.7789
1024	6.8923	12.7654	10.4457	11.0539

Table 3. File-reading performance comparison.

File size (MB)	Generic HDFS (minutes)	AES algorithm (minutes)	RC4 algorithm (minutes)	Hybrid algorithm (minutes)
64	0.3292	1.2077	0.8920	1.0850
128	1.0239	2.0843	1.4982	1.5980
256	1.7502	2.7878	2.2099	2.5332
512	4.1879	8.8221	5.3652	6.4801
1024	11.1232	13.8540	12.2805	12.9877

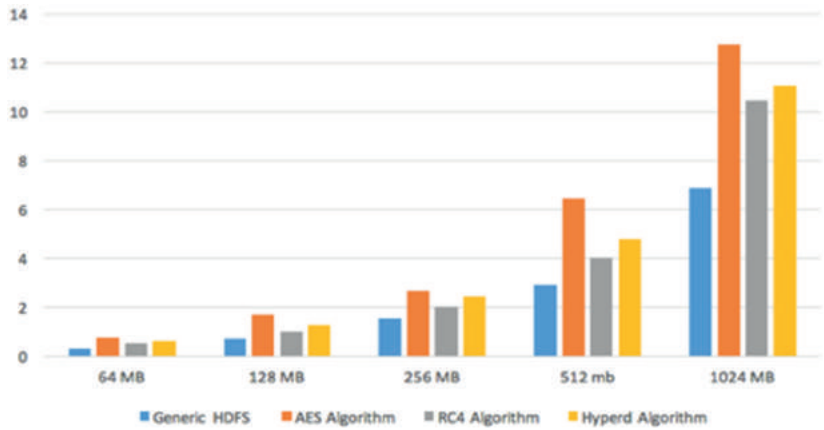

Figure 3. Comparison of file-writing performance.

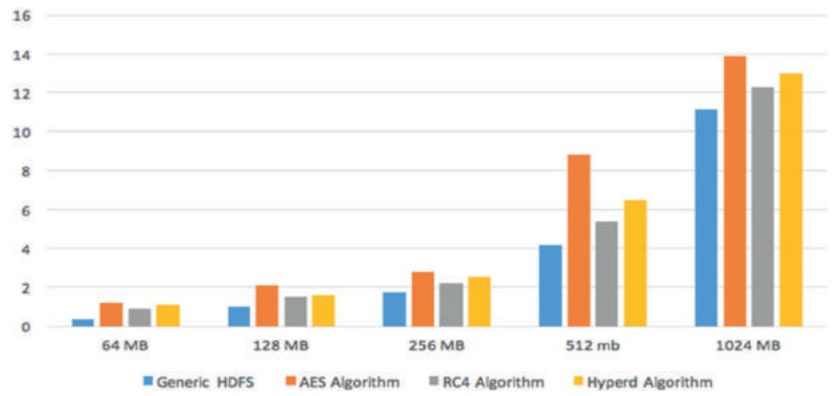

Figure 4. Comparison of file-reading performance.

4 CONCLUSION

This study introduced phases to secure the data in HDFS. It identified the difference between stream and block ciphers that were used by the latest techniques in previous works. Big data security is the critical issue in Hadoop, so a new mechanism needs to be implemented using different stream or block cipher techniques to secure data.

We believe this study will better support the latest security techniques for big data in order to enhance them in the future.

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