The Impact of Augmented Reality Software with Inquiry-based Learning on Students' Learning of Kinematics Graph

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Abstract— **In recent decades, many researches have been done on impact of technology on teaching and learning. However, many such studies were done back in 1990s and to-date technology has since improved by leaps and bounds. Hence, there is a need to look into how schools can tap into the current innovative technology and integrate it into the schools' teaching and learning (T&L).**

This study uses Augmented Reality (AR) software in the T&L of Science. AR has been widely published in Hollywood movie and often used in the making of special effects in movie. This study uses affordable and powerful AR software that is locally developed and applied on a Physics topic known as Kinematics graph analysis – a topic that is difficult for our students to grasp when teaching it.

There is also a call for a deeper research work that is not just based on impact of technology, but how to use pedagogy in information communication technology (ICT) based lesson. This study is both qualitative and quantitative that investigates how the impact of technology on the T&L of a Physics topic designed with a sound pedagogy, in form of Inquiry based Learning (IBL). The focus of this study is on the effect of such integration on 40 secondary 3 students' (15 yrs old) learning attitude and academic achievement, in comparison with 40 controlled students.

Keywords-component; augmented reality, kinematics, inquiry based learning, innovative pedagogy, information communication technology

I. Literature Review

In the past two decades, many researches have been done on finding the various aspect of technology on education. Kulik J.A studies the impact of computer-aided instruction (CAI) programmes. In the study, students score 64 percentile on tests compared to students in controlled conditions without computers at 50 percentile. The study concluded that students learn more in less time when they receive computer-based instruction. Students like their classes more and develop more positive attitudes when their classes include computer-based instructions [1]. In 1998, 219 research studies from 1990 to 1997 was reviewed by Jay Sivin-Kachala to assess the effect of technology on learning and achievement across all learning domains and all ages of learners, [2] and it was found that students in technology rich environments experienced positive effects on achivement in all major subject areas. In addition, students in technology rich environments showed increased achievement in preschool through higher education for both regular and special needs children. The study also shows an impact on students' attitudes towards learning and their own self-conception improved consistently when computers were used for instructions. Blok, Oostdam, Otter and Overmatt examined the effectiveness of computer-assisted instruction (CAI) programmes [3]. Christmann found that computer-assisted instruction is effective in improving the academic achievement of secondary students [4].

Waxmen's [5] findings revealed that more research needs to be conducted in this area on the use of technology in education. The accumulation of research evidences over time and across studies may provide consistent findings that enhance our understanding of the role of teaching and learning with technology. This is the reason why we decided to embark on the research study to investigate the impact of technology on a specific subject.

While there may be many research studies, they are still very knowledge-based and have not provided sufficient information on how to appropriately integrate the use of technology in schools and classrooms. [5] The rapid growth and improvement in technology exceeds current knowledge of how to effectively use technology in schools. Although many studies have been done on the effects of technology on students' outcome, they were conducted more than a decade ago. [6] Hence there is a need to study the impact on using the latest technology in classroom, and how it can be integrated in-line with sound pedagogy.

The diverse range of research in the field has offered many important insights but the many studies that treat technology usage as divorced from the context have been shown to be theoretically and/or methodologically impoverished. Sarah Hennessy stated that pedagogy nevertheless remains under-developed and is not keeping pace with the rapid development of technology applications for school use. While building in pedagogy to software applications is difficult to pull off, a highly promising direction for research is towards the design and evaluation of educational activity around the use of technology 'in pedagogic context'. [7] Referring to her study, there should be a switch of focus from the evaluation of the 'impact' of technology towards a focus on understanding how and why successful approaches work, how technology is used to complement other activities, and how pedagogical strategies have been finely tuned to the Teaching and Learning (T&L) setting. In this study, we have applied the state-of-the-art

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technology in T&L based on sound pedagogy, in form of Inquiry-Based Learning (IBL). In the later part of this paper, the authors will explain the reason for the "adoption" of this pedagogy.

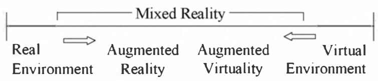

Figure 1. Milgram's Reality-Virtuality Continuum in 1994

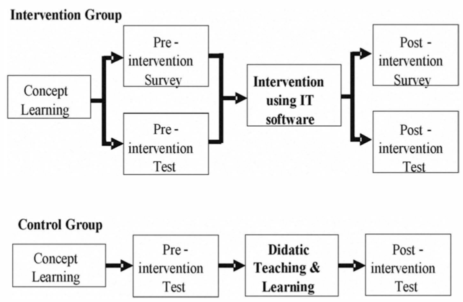

Figure 2. Lesson structure for Intervention and Control Groups

The technology adopted is Augmented Reality (AR) software, developed in Singapore by a team of software developers from Department of School of Sports Health and Leisure, Republic Polytechnic, Singapore. AR is a term used to view a physical real-world environment whose elements are merged with (or augmented by) virtual computer-generated imagery - creating a mixed reality. Azuma [8] defined AR as something that combines real and virtual, it is interactive in real time and is registered in 3D. In another definition by Paul Milgram and Fumio Kishino, they introduced a new continuum for AR known as Milgram's Reality-Virtuality Continuum [9] as shown in Figure 1. They described a continuum that spans from the real environment to a pure virtual environment. In between there are AR (closer to the real environment) and Augmented Virtuality (closer to the virtual environment). The technology used here falls in the AR region. When students learn, they are able to see the graph analysis and data of the physical quantities in the real-time videos recorded. In the process, students are taught how to study and interpret the kinematics graphs. During the lesson, students work in pairs throughout the IBL and ICT based lesson, this is adopted as Lou, Abrami, and d'Apollonia examined the effects of students working in small group versus working individually when students were using computer technology. They found that small group learning had more positive effect than individual learning. [10].

II. METHODOLOGY

In this study, qualitative and quantitative data have been obtained and analysed from 2 groups of Secondary 3 (15 year old) students. 1 group served as the Intervention Group, while the other as the Control Group.

For the Intervention Group, qualitative data has been extracted from surveys to assess the students' level of motivation before and after the use of AR software T&L intervention. Also, quantitative data in form of students' test results in various tests and quizzes conducted before and after the AR software T&L intervention has been extracted. Similarly, such data has also been taken from the Control Group. The notable difference in the Control Group is that the students do not undergo the AR software T&L intervention. Instead, didactic teaching has been used as a control measure to ensure unbiased data collection and analysis. In this study, the term "AR software intervention" is used to denote "augmented reality software teaching and learning intervention".

A. *Background of Students*

The students have some prior basic knowledge of interpreting linear graphs, which has been taught whilst the students were in Secondary Two. Thus, they have been exposed to a fair amount of general linear graph in form of $y = mx + c$. In this study, the students' learning is limited to the interpretation of distance-time (linear) graph and basic calculation of gradient of a linear graph, as the change in y-axis values over the change in x-axis values. They are, however, not expected to understand or learn to derive the relationship between the gradient of a distance-time graph and the instantaneous speed as well as understand the relationship between the area under a speed-time graph and the total distance travelled, as they have not been explicitly taught at this juncture.

B. *Lesson Structure*

The Kinematics lessons had been conducted for a period of 3 weeks, during curriculum time, and have taken a total of 18 periods (1 period = 30 minutes). The lesson structure conducted for the Intervention and Control Groups is shown in Figure 2.

Before the AR software intervention, students have undergone some "refresher" lessons to allow them to make connections on the linear graph knowledge that they have previously learnt in Secondary 2. As the study of kinematics graph requires specific pre-requisite knowledge, the students are also exposed to the definition and understanding of scalar and vector quantities relevant to the study of Kinematics. Some other conceptual knowledge that had been taught also included speed, average speed, distance, velocity, average velocity, acceleration and displacement. Specific formulae pertaining to speed, velocity and acceleration were explained and derived for the students to help them in their understanding when they interpret the kinematics graphs.

In addition, students were taught briefly that the gradient of a distance-time (or speed-time) graph represents instantaneous speed (or instantaneous acceleration) and that the area under speed-time graph represents the total distance travelled by an object.

To further enhance the study, so as to ensure that the process employed in this study is fair, the Physics teachers involved in this study used the same set of resources like the Kinematics Powerpoint™ slides and stopped at the exact same slide before conducting the pre-intervention test (pre-test).

C. Intervention Tests and Surveys

Both groups of students participated in a pre-test and post-test. The pre-test contains two sections: the first section consists of 10 multiple choice questions and the second section consists of questions that require short responses to 3 typical Kinematics conceptual questions to gauge students' pre-existing knowledge.

The post-test is similar to the pre-test. To prevent students from merely regurgitating the answers with little or no understanding, the questions in the post-test are randomly rearranged and different numerical values have also been used.

Furthermore, in this study, a pre- and post-survey have been conducted for the Intervention Group. The purpose of the pre-survey is to study the students' academic motivation level. Questions have been extracted and adapted for use from [11]. This is to give some insights into students' use of subconscious statements to motivate themselves, to demonstrate understanding, to be academically competent or to improve their performance relative to self-established standards.

D. Topic for Intervention

In line with Singapore Ministry of Education (MOE) Physics syllabus [12], teachers and students are encouraged to use Information Communication Technology (ICT) as a tool in Physics learning, which can include experimental and theoretical results interpretation. Thus, the topic on the analysis of kinematics graphs had been chosen for the intervention study. This topic had been selected as generally teachers find it difficult to teach and most students do have difficulty understanding the learning concept.

The learning objectives of the lesson are for students to be able to 1) deduce from the shape of a displacement-time graph when a body is at rest; moving with uniform velocity; moving with non-uniform velocity; and having negative displacement; 2) deduce from the shape of a velocity-time graph when a body is at rest; moving with uniform velocity (or zero acceleration); and moving with uniform acceleration; 3) calculate the area under a speed-time graph to determine the distance travelled for motion with uniform speed or uniform acceleration; 4) understand the relationship between a displacement-time graph and a velocity-time graph.

III. AUGMENTED REALITY SOFTWARE INTERVENTION

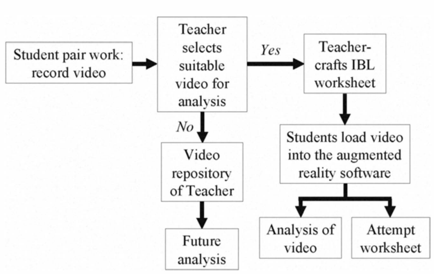

Figure 3. Key stages in augmented reality software intervention.

The students in the AR group work in pairs and have been tasked to submit their own "live" videos of moving objects such as a train, a trolley or a ball being thrown. They were given a week to accomplish the task. Subsequently, the teacher selected and used one common video for students to learn the Kinematics graph analysis. Figure 3 shows the key stages in the AR software Intervention Group.

The AR software intervention sessions last about 4 periods. During the session, the teacher of the Intervention Group conducts a period of tutorial on the basic features of the AR software. Following that, for the subsequent 3 periods students work in pairs to use the software to analyze the video, with some guided assistance from the worksheet prepared. An excerpt of the software screenshot is shown in Figure 4.

The AR software has a powerful processing capability to track moving object in real-time and derive real-time data from the video. This includes velocity and displacement in the horizontal and vertical directions. The strength of this software intervention learning is that it gave students the power of real-time graphing [13] — simultaneous collection, analysis and display of experimental data. Although there were some similarities to a datalogger, this AR software, however, allows for better experimental data analysis where it is not possible for a datalogger to be deployed. For example, the study of the projectile motion of a basketball being thrown into the basketball net is more feasible using the AR software as opposed to a datalogger.

IV. INQUIRY BASED PEDAGOGY

In line with MOE's Science Curriculum Framework, the recommended pedagogy to teach Science is through inquiry. Hence in this study, the authors have adopted the Inquiry-Based Learning (IBL) approach to integrate the AR software intervention and the learning of Kinematics graphs. The lesson design uses the IBL 5E cycle of Engagement, Exploration, Explanation, Elaboration and Evaluation. [14]

The productive activity of using the AR software in kinematics data collection and analysis allowed the students the opportunity to seek answers to their own questions raised. Consistent to the students' reference knowledge, students were continually tested and challenged in the process of learning. As a result, the teacher worked as a

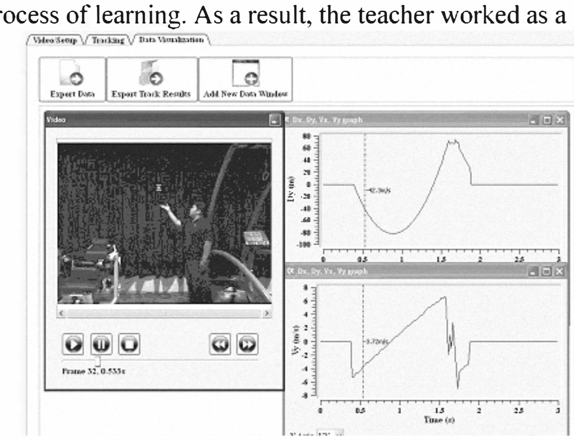

Figure 4. Screenshot of the augmented reality software used.

facilitator to the students, to come together to co-construct knowledge, where both parties participated in elaborating and validating the student's reference knowledge [15]. This led learners to re-examine the validity of their proposals and attempt to gain a true and deeper understanding of the kinematics graph concept. Overall, this socio-cognitive regulation promoted a higher level of cognitive processing. In other words, the use of reference knowledge as the basis for the knowledge exchange prompted the teacher to move into the students' zone of proximal development [15]. This enables the teacher to "decenter" himself/herself during the data interpretation phase in order to see things from the student's perspective and be in a position to point out the flaws.

V. RESULTS AND DISCUSSIONS

A. *Qualitative Data and Discussion*

Table I shows the effect size from the qualitative pre- and post- surveys conducted. Statements with effect size more than 0.2 is shown in Table I.

The qualitative result revealed that the use of ICT has positive effect on students' learning attitude. This is consistent with many other researches like Kulik J.A (1994) and Jay Sivin-Kachala (1998). However as Table I showed that there are a few statements with effect size between 0.20 and 0.49, this showed that the intervention has a small effect on the students.

Survey statements 1, 4 and 6 showed that there is an increase in students' motivation to learn Physics. This is due to the meaningful fun that the students had during the lessons. This increase in motivation arises due to the 'Engage' part of the IBL lesson, where students get to work in pairs to produce the brief 10 to 60 seconds video(s) of their own choice prior to the lesson. Eventually, students get to study the physical quantities of the video in real time, thus increasing their level of interest. Such positive feedback also showed that the AR software is simple and user-friendly, which can be easily picked up within 30 minutes, and thus, students do not fear a lack of competency in using it.

Statement 5 showed an increase in students' perception on the relevance between what they have learned and their daily lives. The AR software allowed students to study their surroundings and the captured video motions in a few simple steps. The students were now able to reproduce what they can see on virtual applets, in reality, thus adding realism to their learning. Such Physics learning through use of ICT definitely related to our students well.

Statement 3 has an effect size of 0.50. This is considered as large effect size. The students felt that they were challenged to complete the assignment and learn from it. This is due to the purposefulness and nature of the lesson. Through the IBL-based designed worksheets which posed them critical questions, students were now able to think deeper and generate more thought-provoking questions. The teacher being the facilitator throughout the lesson did not provide students direct answers to their questions asked; instead more critical thinking questions were asked to lead them to understand the concept at hand. In the process, students learnt to explore and explain what data they have obtained from the video and arrived at the learning objectives of the lesson. Such inquiry approach in Science learning had helped in challenging the students, and served as a motivating factor.

In conclusion, while the effect size of some statements are small, the use of ICT in learning of Science do have a general positive effect on students' learning attitude which have been shown in previous researches in Kulik J.A (1994) and Jay Sivin-Kachala (1998). Moreover, to apply ICT with a sound pedagogical approach (in this case IBL) in the lesson design, this is likely to cause students to feel more motivated and challenged (through their inquiry process).

B. *Quantitative Data and Discusssion*

A random sample of 40 students has been selected from each of the Intervention Group and Control Group. Both groups' selected students have the same pre-test results. The selected students' post-test results are analyzed using small mean difference. Both pre- and post-tests were based on a maximum possible score of 19 marks. The results are tabulated in Table II, III and IV.

For the post-test, the students in the Intervention and Control Groups have been randomly selected based on identical pre-test scores. The ranges of scores were evenly spread from a score of 4.5 to 10.5. Such selection ensured a common ground for fair comparison in the post-test. Hence

TABLE I. EFFECT SIZE OF QUALITATIVE TEST

S/N	Survey Statement	Effect Size	Effect
1	I am motivated to study Physics.	0.32	Small
2	I enjoy doing my Physics assignments.	0.21	Small
3	I challenge myself to complete class work and learn as much as possible.	0.50	Large
4	My class looks forward to almost every Physics lesson.	0.27	Small
5	I try to make Physics seem more useful by relating it to what I want to do in my life.	0.27	Small
6	If I have a choice on what subjects to study, I still want to study Physics.	0.46	Small

TABLE II. RESULTS OF PRE AND POST TESTS FOR INTERVENTION GROUP (N=40)

Type of Test	Mean Score	Standard Deviation
Pre	7.025	1.811
Post	12.975	2.378

TABLE III. RESULTS OF PRE AND POST TESTS FOR CONTROL GROUP (N=40)

Type of Test	Mean Score	Standard Deviation
Pre	7.025	1.811
Post	10.788	2.557

TABLE IV. EFFECT SIZE OF PRE- AND POST- TESTS (N=40)

Type of Test	Effect Size	Effect
Pre	0.000	N.A.
Post	0.856	Large

from Tables II and III, the effect size of the pre-test is zero and the standard deviation is equal at 1.811. From Table IV, it is evident that the effect size is large for the post-test. This led to the consistent findings that the use of ICT can help improve students' academic achievement [2] [3] [4].

VI. CONCLUSION

The qualitative result showed that the AR intervention had a positive effect on students' learning attitude. Firstly, students had higher motivation to learn Physics. Secondly, results showed that students find themselves relating better to Physics concepts as they are now able to connect the concepts to their daily living and routines. Although the two results do not have large effect size, they remain consistent to the findings found in the previous researches. A large effect size of 0.50 was seen in the area where students had been positively challenged during the lessons, as such it became a motivation for them to inquire and solve questions.

The quantitative result showed that the AR intervention had positive effect on students' academic achievement up to a large effect size of 0.856. However, since the post tests had been carried out a day after the AR intervention, it is possible that students' memory is still fresh from the earlier learning experience, thus further post tests can be carried out to investigate the effect of such AR intervention in students' understanding of the Kinematics graph skills in long term.

A. Limitations and Challenges

The effectiveness of a using ICT in T&L requires various skills. Teachers must not only understand the content and effective pedagogy, they are also required to know how to use the ICT tool appropriately to teach and learn the content better. Quoting [16] that technology use can play an important role in enhancing the critical role of a skillful teacher, yet all the evidence shows that the crucial component still remains to be the teacher.

There may be occasions where ICT may fail, or do not respond well. In this situation, such delays may cause students to lose focus and their engagement during the lesson. Thus, teachers do also need to have the basic knowledge of how to carry out simple ICT troubleshooting or even has the presence of mind to be able to switch the lesson appropriately to a "low tech" lesson when ICT seems to malfunction.

B. Future Development

Looking forward, more interviews can be carried out to substantiate the results found in the qualitative test. Also, further research can be done on the impact and effectiveness of such AR intervention on other Physics topics like the Principle of Conservation of Energy as well as on other subjects in education like Sports Science, Humanities and Mathematics.

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