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Does modality principle occur in the learning of C++ computer programming using screencasting?

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Abstract

This study examined whether the modality principle occurs or not in the learning of C++ computer programming using screencasting. According to Mayer and Clark (2011), the modality principle is defined as presenting words as speech rather than on-screen text is more effective in learning. In other words, the learning process will be more effective when information is explained by audio narrations rather than on-screen text. A true experimental pre-test and post-test research design was conducted to determine the modality effects. The experiment consisted of 65 first-year undergraduate students (aged 19-22) who have never attended any formal computer programming course prior to the study. The sample were randomly assigned to two groups: the first group received the screencasting and narration (SN) mode whereas the second group received the screencasting, text, and narration (STN) mode. After that, pre-test was conducted to ascertain their score before being exposed to the treatments. The pre-test results were used as covariate in the two-way ANCOVA analysis. Results showed that the SN mode students outperformed the STN mode students in the post-test. The significant outcome of the result might be due to the effectiveness of the SN mode that supported the Modality Principle.

Keywords: screencasting; modality principle; multimedia principle: C++ computer programming

1. Introduction

In this modern world that fills with technology gadgets and devices, it is undeniable that these devices have become part of our daily life resources. What makes these electronic devices able to function so productive is due to the efficiency of the computer program running within these devices. Thus, it is imperative that in the era of globalisation, manpower with high programming skills are an important factor in enhancing and improving the existing computer system.

Globally, computer programming subjects have been a difficult subject to comprehend. Acquiring the knowledge has been a global problem with high failure rates and withdrawals even at the initial stage of introductory programming courses (Butler & Morgan, 2007; Robins, Rountree, & Rountree, 2003). There are many tools available in the market to assist the teaching and learning of computer programming, but the problem remains unresolved (Tan, Ting, & Ling, 2009). One of the main reasons of difficulty in acquiring the knowledge is due to the static material used in existing teaching material such as books or slides (Bennedsen & Caspersen, 2005; Jenkins, 2002). By nature, computer programming is a subject consists of dynamic concepts that constantly change according to the input and output (Gomes & Mendes, 2007).

Therefore, a more effective and efficient tool that supports dynamic nature of teaching and learning computer programming needs to be ascertained to overcome the

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existing problem. At present, technology has been playing an important role in the field of education technology. One of the education technology tools that emerges and gains popularity is the multimedia technology (Jonassen, 2004; Malik & Agarwal, 2012; Mohorovičić & Tijan, 2011). Multimedia has provided better tools in fostering effective learning in various fields (Berk, 2009; Fluck, 2001). According to Mayer, Dow, and Mayer (2003), multimedia is defined as using both words and pictures as a presentation material.

Screencasting is one of the techniques that use both words and pictures as animation in delivering information. The term 'screencast' has been defined by Udell (2004), as a digital recording of computer screen activity and usually accompanied by audio narrations. Moreover, the Net Generation or Digital Natives we constantly equipped with mobile devices such as laptops and mobile phones that seamlessly connected to the Internet on a daily basis (Beyers, 2009; Oblinger, Oblinger, & Lippincott, 2005). This has created a new generation of learners that prefer to learn using these tools. The conveniences of carrying these devices allowed them to shape their learning experience according to their own learning style and pace rather than the traditional chalk and board method. The learning style preferred by this generation demands greater flexibility in terms of learning location, pace, various types of learning materials, dynamic visual such as animation, and sound elements which enhance their learning experience (Oblinger et al., 2005). Screencasting has gain popularity and potential due to its similarity to YouTube and Vimeo (Mohorovičić, 2012).

In order to develop an effective screencast, there are several principles that need to be considered. Therefore, this research is designed to examine the modality effect in the learning of C++ computer programming using screencasting. According to Mayer and Clark (2011), for learning purposes the modality principle is defined as presenting words as speech rather than on-screen text is more effective in learning. In other words, the learning process is better when information is explained by audio narrations rather than on-screen text.

2. Literature Review Theoretical Framework

Computer programming subjects have been one of the difficult subjects to comprehend in the education field. High rates of failure and early withdrawals of the course at the foundation stage of introductory programming courses indicate that students were unable to master the subject (Butler & Morgan, 2007; Robins et al., 2003). It has brought the attention of educators around the world to conduct research to determine the difficulties in teaching and learning of computer programming. One of the reasons that impaired the effective learning of computer programming is the usage of contemporary teaching methods and static materials such as books and slides (Barnes, Marateo, & Ferris, 2007; Berk, 2009; Dong & Li, 2011; Malik & Agarwal, 2012). These materials does not seem to be an effective tool and further create confusion among the students. Computer programming is a subject consist of concepts, which are made up of dynamic elements. By using static materials to explain the dynamic nature of computer programming concepts, students were unable to comprehend the dynamic nature of programs (Gomes & Mendes, 2007; Soloway & Spohrer, 2013). The programming language chosen should be based on pedagogical benefits, with elements that are easy to understand and remember (Soloway & Spohrer, 2013). Thus, teaching materials that support explanation of dynamic elements and type of computer programming language chosen should be considered to overcome the problem.

In this modern world of rapid technology development, it has brought changes to the way education is conducted. With the accessibility of internet, software and hardware available to the mass population, the way teachers and learners view education have changed in various perspective. It has been a challenging task for educators to search and produce an effective learning tool to cater for everyone. One of the key tools that have evolved is the emergence of multimedia in the field of education (Jonassen, 2004; Malik & Agarwal, 2012). Many educators have realised

that the rapid growth of computer technology has provided better tools in fostering effective learning (Berk, 2009; Fluck, 2001). According to Mayer et al. (2003), multimedia is defined as using both words and pictures as a presentation material. Furthermore, it can be combined with text, sound, animation and graphic using computer to create an effective instructional material which will enhance the learning experience (Mayer & Clark, 2011).

Plethora of research has been done to prove the effectiveness of multimedia in fostering effective learning. With the combination of audio and visual elements, it has provided an effective stimulation to various human senses (C. Evans & Gibbons, 2007). According to the research done by Seufert, Schütze, and Brünken (2009) it has ascertained that the involvement of all the human senses in learning will increase the students' interest, motivation, and also has a positive effect on the students' understanding. Instructional materials that incorporate multiple modes, such as audio and visual, do assist learners' in constructing knowledge in the mental mode. In order to develop an effective multimedia teaching material, there are several principles guiding the design and organisation of the subject contents that need to be consider. One of the principles that needed attention is the modality principle in the learning of C++ computer programming using screencast.

A lot of research has been done on the modality principle involving different types of subjects. According to past research, the modality effect do occurred in many subjects such as Biology, engineering, training and geometry (Harskamp, Mayer, & Suhre, 2007; McNeill, Doolittle, & Hicks, 2009; Mousavi, Low, & Sweller, 1995; Tindall-Ford, Chandler, & Sweller, 1997). However, there is not much studies pertaining to this effect in the subject of computer programming.

The modality principle was discovered by Moreno and Mayer (1999) and it has been further supported by Mayer's Cognitive Theory of Multimedia Learning. Mayer's Cognitive Theory of Multimedia Learning, made three important assumptions. First, an individual has two separate channels for processing information. Second, each channel has limited processing capacity. And third, the process of learning is an active process. By referring to Figure 1, the active learning involved cognitive process that requires substantial amount of learning materials directing to the sensory memory (Mayer, 2002). Past studies have also provided evidence that the modality principle does affect the short-term memory tasks in terms of recalling, and auditory presentations do result in higher recall than visual presentations (Penney, 1989). Numerous research has investigated the modality effect from the education perspective in terms of multimedia instructional design (McNeill et al., 2009). In terms of teaching and learning of computer programming, there are still many uncertainty pertaining to the modality principle outcome.

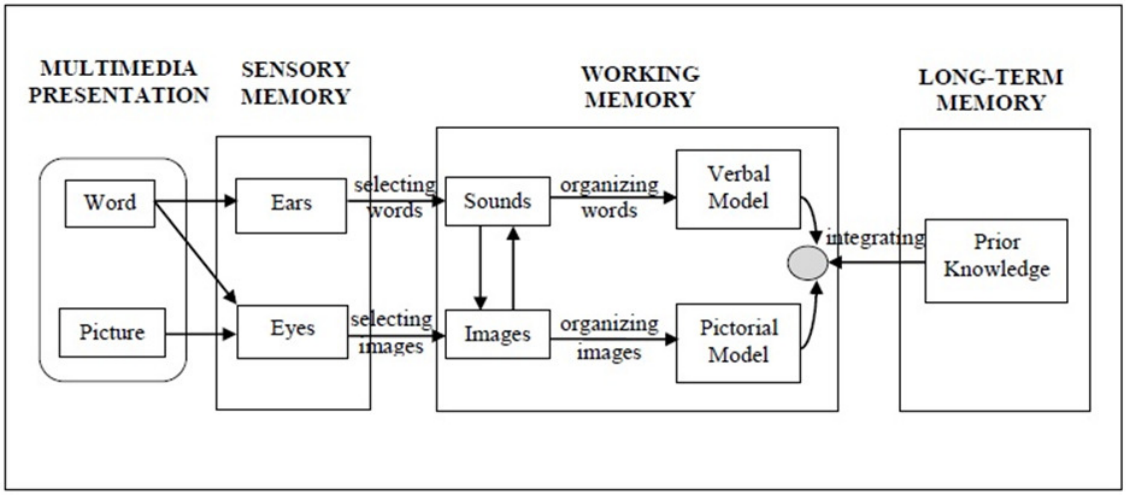

Fig. 1. Cognitive Theory of Multimedia Learning (Mayer, 2002)

Based on the research conducted in explaining the operation of a car's braking system (Mayer & Moreno, 1998) and the learning of the lightning formation process (Moreno & Mayer, 1999), it was found that the group that was presented with animation together with concurrent audio narrations outperformed the group that was presented with animation together with concurrent on-screen text. The same outcome was obtained as well in the learning of geometry (Mousavi et al., 1995). The reason behind the drawbacks of having animation and on-screen text simultaneously is that it overloads the visual processing channel (Mayer & Clark, 2011; Mayer & Moreno, 2010).

Nevertheless, some studies showed conflicting results. In the research done by McNeill, Doolittle, and Hicks (2009) to investigate the effects of training, the modality effect has contrary results. Students were divided into three groups and there were three different multimedia treatment modes. The first mode was graphic and simultaneous audio narration. The second mode was graphic and simultaneous on-screen text and the third mode was audio narrations, graphics, and on-screen text. The results showed that there was no significant difference on all the three treatment modes on the modality effect. In another study by Tabbers, Martens, and Merriënboer (2004), the modality effect can be dismissed by minimising the use of visual text in terms of sentence length and the ability to control the pace of the presentation. Narrative descriptions written in brief and concise text such as journal articles were found to be as effective as spoken explanations (Tabbers, 2002).

Based on past research results, there were mix outcomes pertaining to the effect of modality principle in various types of subjects taught. However, not many studies have proven this effect on the subject of computer programming. Therefore, the objectives for conducting this research is to determine whether the modality effect does occur or not in the learning of computer programming.

Besides that, screencasting was chosen as it fulfils all the criteria needed to develop an effective multimedia teaching material. Plethora of research has been done to investigate the effectiveness of screencasting in the education field. One of the early adoptions of using screencast in education is the teaching of Dewey Decimal Classification by Peterson (2007).

Furthermore, it has been used as a solution to homework problems, and teaching of procedural processes by Carr and Ly (2009). Several studies pertaining to the usage of screencast in the field of mathematics courses (Jordan, Loch, Lowe, Mestel, & Wilkins, 2012; Trenholm, Alcock, & Robinson, 2012) have also proven to be effective. The effectiveness of screencasting is further enhanced by showing animated handwritten step-by-step solutions involving complex calculations and equations (Jordan et al., 2012). In the field of engineering, screencasting has been used for demonstrating the use of MATLAB software (Ashdown, Doria, & Wozny, 2011). Besides that, medical practitioners have incorporate images accompanying the anatomy and embryology (Evans, 2011) or ophthalmology (Razik, Mammo, Gill, & Lam, 2011) for explanatory purposes used in lectures to enhance the students' understanding.

Research done by Mohorovičić (2012), shown that screencasting has received overwhelming acceptance from students. This is due to the reason that screencasting has provided flexibility for students to learn outside the classroom environment whenever they want at their preferred learning pace and time. Moreover, they were are able to control the screencast by selecting the options available such as pause, rewind, forward and even adjusting the volume according to their preferences. Besides that, students were allowed to select a specific lesson where they require more attention and time to understand whenever they face problems. In fact, students can jot down notes at their own pace, and explanations can be repeated infinity times. Additional to that, the replacement of lessons in the event of the students' absence due to unforeseen circumstances can be conducted without incurring additional time and money. In terms of learning styles, the visual and auditory elements of screencasting complement various types of learning styles among the students.

Screencasting is an ideal multimedia tool that can be used as scaffolding for education which meets the criteria of the Net Generations (Barnes et al., 2007). It has

the dynamic element of visual and spatial capabilities that supports the explanation of computer programming. Thus, it accommodates the learning of logic reasoning due to the nature computer programming (Bennedsen & Caspersen, 2005). These elements enable the students to have a mental representation of a problem and assist them in understanding the process control and data flow. Therefore, screencasting contains methods and capabilities that meet the requirements in delivering information for learning computer programming purposes (Bennedsen & Caspersen, 2005).

There are various ways to utilise the effective use of screencasting. It can be used as an additional teaching material to complement existing traditional teaching materials such as books, slides and written instructions. Moreover, the availability of audio narrations and step-by-step visual queue of explanations, further enhance their learning experience when it comes to subjects like computer programming which require visualisation and spatial imaginations. Furthermore, screencasting is available to the mass population anywhere, anytime, 24/7 and can be viewed an infinite number of times (Mohorovičić, 2012).

3. Methodology

The self-learning tool used in this research was developed using Camtasia 2018.0.7 to produce the screencast. Screencasting is defined as recording of the screen activity and accompanied by narration and audio (Udell, 2004). The screencasting used in this research consists of animation such as images, text effects and control options. Control options to manipulate the screencast such as play, stop, fast forward, rewind, pause, volume, and timeline selection are also available. These animations and control options are available to ease the use of the screencast and to enhance the learning experience.

The research participants were made up of students' age between 19 and 22, and the total number were 65 first-year undergraduate students from a university. Criteria to select the right participants were individuals who have never attended formal computer programming course before. There were two types of learning modes, and participants were randomly assigned to the two modes. Group one received the screen and narration (SN) mode, whereas group two received the screen, text and narration (STN) mode.

The C++ Computer Programming Pre-test was used to assess the level of understanding in C++ Computer Programming before the sample was exposed to the treatment modes. Students in both groups sat for a pre-test. The pre-test consisted of 30 multiple-choice questions. Each correct answer was given one mark whereas each incorrect answer was not given any mark. Table 1 shows the specifics for the total number of questions corresponding to each topic. The total number of questions for each topic were equally divided between seven to eight questions. The test items consist of various types of questions such as tracing of the final output result, usage of variables, definition of programming terms and error detection. This is to ensure that the students' were tested on all the relevant topics from various aspects of problem solving methods.

Table 1. *Specifics for the C++ Computer Programming Pre-test*

Topics	Total number of questions
Overview of Program Development Life Cycle	7
Input and Output Operators	8
Program Control	8
Introduction to Functions	7
Total questions	30

The experiment took five weeks to conduct and each week a new topic of introduction to C++ computer programming was introduced to the students. During the experiment, each group was given one hour to view their respective screencast. In the final week, a post-test was given to all the students. Both groups conducted their viewing at different locations and time. This is to prevent contamination between the two groups and to increase the reliability of the research outcome. Sample gropus were not allowed to communicate during the viewing session and the only material they were allowed to refer to is the screencasting. The post-test questions were identical to the pre-test. However, the question number and sequencing were jumble up. The purpose of doing this is to avoid the possibility of students remembering the answers from the pre-test. In order to determine the reliability of the test instrument, the test was tested according to the Kuder-Richardson, KR20, and has the internal reliability value of 0.78. The results proved that the reliability of the pre-test instrument was at an acceptable level.

4. Results

Table 2 shows the mean and standard deviation of the C++ computer programming pre-test and C++ computer programming post-test scores. The samples were divided according to the SN mode, and STN. The mean and standard deviation obtained for the SN mode are (M = 24.27, SD = 2.6), whereas the mean and standard deviation obtained for the STN mode are (M = 23.63, SD = 3.09.

Table 2. *Mean and Standard Deviation of the C++ Computer Programming Pre-test and C++ Computer Programming Post-test*

Group	N	C++ Computer Programming Pre-test		C++ Computer Programming Post-test	
		Mean	**Std. Deviation**	**Mean**	**Std. Deviation**
SN	33	14.24	4.98	24.27	2.60
STN	32	14.03	5.63	23.63	3.09

The distribution of sample according to the levels of logic which are Low level logic and High level logic, classified into the two treatment modes is shown in Table 3. There were 33 students in the SN group and 32 students in the STN group. The total number of participants is 65 students

Table 3. *Distribution of Low/High logic group based on the treatment mode*

Group	N	Logic		Percent (%)	
		Low	**High**	**Low**	**High**
SN	33	14	19	42.42	57.57
STN	32	13	19	40.62	59.37

An analysis of two-way ANCOVA was conducted to determine the significant difference in the students' achievement in the learning of C++ computer programming between participants using SN and STN mode. The covariate for this analysis is the C++ Computer Programming pre-test score, and the results are shown in Table 4. The results show that there is a significant difference in the students' achievement in the learning of C++ computer programming between those using SN and STN mode, $F(1,60) = 19.28$, $p = .00$, $\eta 2 = .24$.s

Table 4. *Two-Way ANCOVA of C++ Computer Programming Post-test score among students using different modes of Screencast (SN & STN)*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	300.047[a]	4	75.012	12.158	.000	.448
Intercept	3192.356	1	3192.356	517.401	.000	.896
Mode	118.984	1	118.984	19.284	.000	.243
C++ Computer Programming Pre-test	90.414	1	90.414	14.654	.000	.196
Error	370.199	60	6.170			
Total	35378.000	65				
Corrected Total	670.246	64				

a. R Squared = .448 (Adjusted R Squared = .411)

5. Discussions

Based on the results of this study, it shows that participants attending the SN mode performed better on average in the C++ Computer Programming Post-test compared to the students who attended the STN mode. The effectiveness of the SN mode might be caused by the Modality Principle. Based on plethora of past studies, modality principle has proven that learners' learn better when on screen-text is presented as narration. This is to prevent the cognitive overload from happening in the visual channel. As mentioned by Mayer's Cognitive Theory of Multimedia Learning (CTML), it was developed to assist educators, trainers, and developers in designing effective multimedia courseware (Mayer & Moreno, 2002). The outcome does align with the modality principle that presenting words as speech rather than on-screen text is more effective in the learning process.

In the SN mode, the cognitive load was reduced and minimised because of the images in the screencast were directed to the eye while the narration was directed to the ear. As a result, there were balance between the auditory and visual channels. Moreover, it has also prevented the overloading of the extraneous cognitive load from occurring. The working memory capacity which was not overloaded, allows it to have substantial resources to select, filter, and organise the visual and verbal information. It is vital that the corrected information were absorb before converting it into meaningful verbal and pictorial model, (Mayer, 2005). Thus, accurate information processing were achieved in the learning process.

Contrary to the SN mode, the STN mode has the text and images appearing simultaneously on the screencast. This causes both elements having to be absorbed by the visual channel, the eye, which is limited in capacity. Therefore, the visual channel was overloaded and created split attention due to the text and images appearing simultaneously (Mayer & Moreno, 1998). Moreover, the working memory has limited capacity for temporarily holding and manipulating information in active process. Hence, parts of the information were left out and unprocessed. As a result of that, information were not effectively absorb and rejected, and therefore learning fails.

Thus, the result indicated that the SN mode is more effective compared to the STN mode.

6. Conclusion

The results obtained from this research shows that there is significant difference in the students' achievement in learning C++ computer programming between the SN and STN modes. It has supported the Mayer's Cognitive Theory of Multimedia Learning in terms of modality principle. The cognitive theory of multimedia learning states that the human information processing consists of dual channels. These two channels were the visual which are the eyes and auditory channels which are the ears. Moreover, the two channels have limited capacity to process the information at any one time during active processing of information. Thus, information which is presented as images or text, were processed by the visual channel, whereas information which is presented as audio or narration, were processed by the auditory channel. In order to achieve the optimum level of effective learning to occur, there should be a balance between these two channels (visual and auditory). If either one of these two channels were overloaded with information, it will impaired the learning process.

Furthermore, the effectiveness of the screencast might be due to the demonstration of step-by-step procedures showing the flow of the C++ computer programming codes. Besides that, effective use of cueing animations which further guide the learners' learning process. The outcome of this study has also provided further insight and guidelines to instructional designers when designing and creating a multimedia learning courseware. This research has discovered insight and information to provide guidance to future courseware developer in developing effective teaching materials. The important aspect that a courseware designer needs to take into consideration is the modality effect to ensure an effective courseware is produced.

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