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CRISTAL: A Game based Intelligent Tutoring System for Learning Mathematics in Malaysian Polytechnics

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Multimedia technology in the form of a learning game can be an interesting instructional tool that can make learning more interactive and increase student performance. A game based application that was designed using learning style theories and applied suitable learning strategies have the potential to help the students learn mathematical concepts. Previous studies showed that the students that were presented with the multimedia game-based learning materials have higher achievement in test results as compared to the group with traditional non-game learning materials. Thus, this study has developed an intelligent tutoring system that intelligently assigned the students to the most suitable multimedia learning materials based on their learning profile. The result showed shows that the students that were given the learning materials in the form of game-based have statistically significantly higher means of learning gains (mean =11.76) than the group with learning materials that were non-gamed-based (tutorial). The results from this study can be used by instructional and game developer as a guideline and reference for creating more personalized and interactive learning materials for learning mathematics.

Keywords: game-based; mathematics; application; learning materials; game design

I. INTRODUCTION

Multimedia has been used as one of the most prominent technologies in today's classroom. This technology is found able to increase students' understanding and making learning fun and enjoyable and has played a major role in education (Silverman, Kim, Hartranft, Nunn, & McNeish, 2016). An application that utilized the concept of multimedia must have the correct combination of sound, animation, text, and graphics (Frey & Sutton, 2010). However, the multimedia technology that incorporated the game-based technologies is found to be more effective than the non-game based designed as suggested by Cicchino (2015) and Mclaren, Adams, Mayer, & Forlizzi (2017). Thus, the potential of the game-based multimedia application in supporting learning should be given full attention by learning material developers.

The development of games based-learning has been on the rise since the blooming of the game industry in the form of desktop and mobile around the world. There is various type of educational games that can be obtained and downloadable every day. An analysis for over 1000 studies by Clark, Tanner-Smith, & Stephen Killingsworth (2014) on the games-based educational development application proved that game-based have 0.33 standard deviation improvement than non-game-based application. This is supported by a survey done by Gameandlearning.org in 2014 which concluded that educators do use game-based education applications at least once a week and they found out that the technology works. However, there is still a lack of empirical studies on the effectiveness of the game application development on the teaching and learning process of mathematics as concluded by Sosnovsky, McLaren, & Aleven (2014). This is supported by an intensive study on the published researches on the comparison of educational game development with the non-game application found that only five of those studies were on the domain of mathematics. Thus, it is important to do a more

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rigorous study methodically of the game-based learning application for the domain of mathematics learning.

II. LITERATURE REVIEW

Instructional technology has been used to achieve educational objectives since the early 1960s (Arroyo *et al.*, 2014). The Intelligent Tutoring System (ITS) is one of the products of instructional technology that try to replicate the ability of a human tutor in delivering instructional learning material to specific learners. The technology of ITS was introduced in the 1970s and developed progressively in the 1980s (Anderson, Corbett, Koedinger, & Pelletier, 1995; Sierra, García-martínez, Cataldi, Britos, & Hossian, 2006). The function of ITS is to personalize learning by using the information on the students' attributes (Barbhuiya, 2013). This personalization is important to ensure the learning material presented is suitable and able to increase the students' achievement in the specific topic.

Mathematics is one of the most discussed subjects in educational studies around the world (Ganal & Guiab, 2014; Hodgen & Marks, 2013; Jasni & Zulikha, 2013; Samkange, 2015). For Malaysian polytechnic students, passing the subject is important to ensure graduation and job opportunities (Education & Training Foundation, 2015). However, a survey done by Mokmin & Masood (2015a) proved that the achievement of polytechnic students in mathematics is just above the minimum requirement and below the specific expectation. As suggested by Hodgen & Marks (2013), mathematical competence is very much needed for engineering studies. The products of Malaysian polytechnic were expected to fill the semi-technical jobs in the country after graduation and the low achievement in mathematics can impact the process of producing workers or engineers that competent for the engineering fields. Thus, educators and curriculum developers in Malaysian polytechnics have to allocate potential technologies that can be a game-changer in the teaching and learning of mathematics.

A study by Tokac, Novak, & Thompson (2019) concluded that students that learned with game-based learning materials have higher learning gain in mathematics when compared with the traditional class. This is supported by Brezovszky *et al.* (2019), where the result showed that the game-based design mathematics learning material can enhance the arithmetic skills and mathematics knowledge. However, there is a lack of studies done on the effectiveness of learning materials that utilized both ITS technology and game-based design. By utilizing the benefits of both technology, personalized game-based learning material for mathematics education can be utilized to increase mathematics achievement, especially for slow learners.

Thus, this study compared the effectiveness of two design of learning materials: (i) Game and (ii) Non-game (tutorial) toward the mathematics learning in Malaysian Polytechnics by using an ITS application. For that specific objective, an intelligent tutoring system coined CRISTAL is developed and tested. The application design and development were described further in the next sections and the comparison result is discussed in the result section.

III. METHODOLOGY

The study is carried out in three phases (i) application development, (ii) application testing in the actual setting and (iii) evaluation of the students' performance.

A. Design and Development

CRISTAL was developed using theories of Alessi and Trollip's Instructional Design Model (Alessi & Trollip, 2001) and guided by Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2014). The Intelligent tutoring engine for this application was constructed from Nwana (Nwana, 1990) and the Case-based Reasoning algorithm was selected as the Artificial Algorithm for this application. More studies on CRISTAL were discussed by Mokmin, Masood, & Nur Effatul Fairuz Zainal Apandi (2014).

This application taught the subtopic to simplify an algebraic fraction, one of subtopics of algebra. The students were presented with one of the four learning materials that were design based on the study of the theory of mathematics learning style by Silver (2013). From this theory, mathematics students usually have four different learning styles when learning mathematics. When giving the correct learning material that suited their learning preferences, their learning performance can be increased.

In this study, the theory of personalized learning using ITS is implemented through the Artificial Intelligent algorithm that was programmed in the app. This algorithm worked by using information from the users to determine the most suitable learning material from the group of four different learning materials. The selected learning material was then presented to the user and the pre and post-test results were recorded and compared.

These four different learning materials can be grouped into two types of design: (i) the non-game design, where tutorials methods were used and (ii) the game-based design. The selected learning materials for the non-game design were Mastery Learning Material (MLM) and Interpersonal Learning Material (ILM). The design and development of both learning material were discussed by Mokmin & Masood (2014) and Mokmin & Masood (2016a) respectively. For the second group, which is the game-based design, the Self-Expressive Learning Material (SLM) and Understanding Learning Material (ULM). The SLM is discussed in depth by Mokmin & Masood (2015b) and ULM is discussed by Mokmin & Masood (2016b). Table 1 shows the types of learning materials used in this study and the learning strategies associates with each learning material.

Table 1. The design and strategy of each learning materials

Learning Material & Strategy	Design
MLM & Graduated Difficulty	A mini bookstore design where students can choose any books, they want
ULM & Concept Attainment	Checkpoints in map design. Eight checkpoints need to be cleared to reach the end of the road on the map.
SLM & Inductive Learning	Finding clues in scenes. There are three screens provided, the students have to find the clues from the scenes and make them own conclusions
ILM & Real-life Learning	A real-life example of mathematics by representing the information in situations related to them

B. Testing

A group of 309 students was selected in this experimental study. They were the first-semester engineering students from two polytechnics in the northern part of Malaysia. The actual test was carried out for about an hour in a computer laboratory. The students were asked to complete a set of pre-tests and enter their basic information such as matrix number, mathematics prior knowledge and answer a mathematics learning style inventory. After the information was entered, the application calculated the best learning material that most suited to the student. The students would then learn using the learning material that has been suggested by the application. After each session, the students need to answer a set of post-tests. The learning gain is calculated by subtracting the pre-test from the post-test. Table 2 displays the respondents for each group of treatments. Figure 1 is a screenshot of the SLM as one of the game-based treatment group and Figure 2 is a screenshot for the tutorial group.

Table 2. Group Statistics

Treatment	Learning Material	N
Game	MLM	142
	ILM	40
	Total	182
Tutorial	SLM	87
	ULM	40
	Total	127
	Total	309

Figure 1. Screenshot from SLM

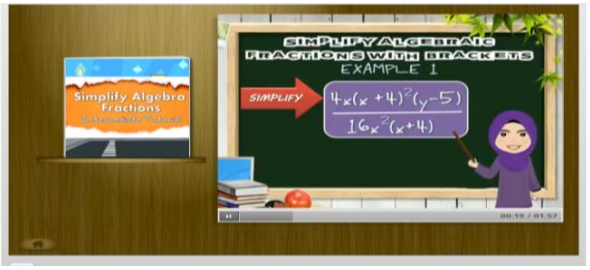

Figure 2. Snapshot of MLM

IV. RESULT

From the 309 data, about 60% of the respondent was in group one, where the majority of them (142) were assigned with MLM. The ILM was presented to a group of 40 students. The second group contains 127 number of students and the majority of them (87) were presented with SLM. The remaining number of students were presented with ULM.

Table 2 shows the numbers of students for each treatment and learning materials.

An Independent T-test that was used as the statistical test to compare the means between the two treatments group. The group statistics in Table 3 shows that the students that were given the learning material in the form of game-based have statistically significantly higher means of learning gains (mean =11.76) than the group with non-gamed-based (tutorial) (mean = 7.03), with t (307) = 2.23, p = 0.26.

Table 3. Result

Group	Numbers	Mean	Std. Deviation	Std. Error Mean
Game	182	11.76	17.374	1.288
Tutorial	127	7.03	19.629	1.742

V. DISCUSSION

The result from this study proved that, when designed and developed thoughtfully, the game-based multimedia application can be an effective tool in mathematics learning. The positive result signifies the potential of game-based learning as a learning material in engaging students towards learning. As mathematics is often viewed as a difficult and boring subject, a game-based multimedia learning material can be an added item on the list of successful technologies in the mathematics classroom.

For Malaysian polytechnics, the result of this study can be a reference in the process of formulating the most suitable learning material for mathematics learning. Patrick, Kennedy, & Powell (2013) have stressed in their study on the importance of mathematics educators in formulating the most effective learning strategies to achieve the international benchmark standard.

The result of this study also proved that the utilization of ITS for learning mathematics is one of the options that can be considered to be implemented in mathematics learning in polytechnics setting. Various developments of ITS by researchers around the world have proven the ability of ITS as one of the instructional technologies that can help students in learning mathematics. The learning material that has been developed by using a suitable learning strategy in this research can help curriculum developers to include variations of learning that will increase student's achievements. Variation of learning materials can increase students understanding of the learning topics. Therefore, this result can give additional input to developers of learning materials in their quest for the most effective learning materials.

This study also has constructed learning materials that are focused on giving an understanding of the Algebra topic. Since this topic has been referred to as the gateway to mathematics (Gomez, 2012). The learning materials in this study are an added instructional materials that can be used to increase learning achievement in algebra.

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