INTERACTIVE GAME APPLICATION FOR LEARNING MATHEMATICS: AN INTELLIGENT TUTORING SYSTEM DEVELOPMENT AND STUDENT ACHIEVEMENT EVALUATION

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Abstract
Multimedia technology in the form of learning game can be an interesting instructional tools that can making the learning more interactive and increase student performance. A games based application that were design using learning style theories and applied the suitable learning strategy have the potential in helping the students learns mathematical concepts. Previous studies showed that, the students that were presented with the multimedia game-based learning materials have higher achievement in test result 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 into the most suitable multimedia learning materials based on their learning profile. The result showed that the group that learned with game-based multimedia learning material has a significantly higher means in the learning gains marks as compare to the traditional non-game group. 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.

CCS Concepts
• Software and its engineering→Interactive games

Keywords: Multimedia, Game, Intelligent Tutoring System, Algebra, Mastery, Self-Expressive, Understanding, Interpersonal, Instructional, Mathematics.

INTRODUCTION
Multimedia has been used as one of the most prominent technology in today’s classroom. This technology is found able to increase students understanding and making learning fun and enjoyable and has play major role in education [1]. An application that utilized the concept of multimedia must have the correct combination of sound, animation, text and graphic [2]. 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 [3], [4]. Thus, the potential of the game-based multimedia application in supporting learning should be giving 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 obtain and downloadable every day. An analysis for over 1000 studies by [5] 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 survey done by Gameandlearning.org in 2014 which concluded that educators do used game-based education application at least once in a week and they found out that the technology really works. However, there is still lack of empirical studies on the
effectiveness of the game application development on the teaching and learning process of mathematics as concluded by [4]. 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 more rigorous study methodically of the game-based learning application for the domain of mathematics learning.

Instructional technology has been used to achieve educational objectives since the early 1960s [6]. 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 [7][8]. By the year 2016, ITS technology takes the form of facial recognition tutors [9], emotion recognition [10], games [11] and computer applications [12]. ITS originates from the theories of computer science, education and training as well as psychology [13]. This combination has provided various ITS products that have proved to be effective in facilitating the learning process in various studies [14], [15]. The function of ITS is to personalize learning by using information on the students’ attributes [16]. 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 subject in educational studies around the world [17]–[20]. For Malaysian polytechnic students, passing the subject is important to ensure graduation and job opportunity Education and Training Foundation (2015). However, a survey done by [22] proved that the achievement of polytechnic students in mathematics is just above the minimum requirement and below the specific expectation. As suggested by [18], a 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 a 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.

With the emergence needs for more effective learning material for learning mathematics, this study compared the effectiveness of two mode of learning materials: (i) Game and (ii) Non-game(tutorial) toward the mathematics learning in Malaysian Polytechnics. 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.

**METHODOLOGY**

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

**DESIGN AND DEVELOPMENT**

CRISTAL was developed using theories of Alessi and Trollip’s Instructional Design Model [23] and guided by Mayer’s Cognitive Theory of Multimedia Learning [24]. The Intelligent tutoring engine for this application were constructed from [13]Nwana (1990) and the Case-based Reasoning algorithm is selected as the Artificial Algorithm for this application. More studies on CRISTAL were discussed by [22], [25]

This application teaches the subtopic of simplify algebraic fraction, one of subtopics of algebra. The students will be presented with one of the four learning materials that were design based on the study of the theory of mathematics learning style. Based on studies by [26], [27], a mathematics students usually
have four different learning style when learning mathematics. When giving the correct learning material that suited their learning preferences, their learning performance can be increased.

For the purpose of this study, the four learning materials were divided into two groups of treatments. The first group contains the learning materials that were non-game, where tutorials methods were used. The selected learning materials were Mastery Learning Material (MLM) and Interpersonal Learning Material (ILM). The design and development of both learning material were discussed by [28], [29] respectively. For the second group, which is the game-based group, the Self-Expressive Learning Material (SLM) and Understanding Learning Material (ULM). The SLM is discussed in depth by [11] and ULM is discussed by [30]. Figure 1 shows the snap shot of the MLM, where the Graduated Learning Strategy is used. The tutorial is divided into three phase: (i) Beginner, (ii) Intermediate and (iii) Expert. The students is free to choose which learning phase they wanted to learn.

Figure 2 shows the snapshot of ILM, where the concept of Real-life example is applied. All the videos and tutorial used in the application were based on activities that the students usually go through daily and related to real-life experience. Figure 3 displayed the snap shot of ULM, where the students learn mathematical concepts using Concept Attainment learning strategy. In this game, the students were given eight checkpoints on a map that they have to complete for each lesson. The students learn the mathematical concept by differentiating between the correct and incorrect mathematics statements. The last learning material, which is Figure 4 displayed the Inductive learning strategy activities. In the SLM application, the students need to go find clues in three different scenes, similar to a searching game.
testing

In order to test the effectiveness of the application in giving the right learning experience to the students, the application is tested in actual setting. A group of 309 students were selected from this 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. Figure 5 displayed the flow of the application. The students were asked to complete a set of pretest and enter their basic information such as matrix number, mathematics prior knowledge and answer a mathematics learning style inventory. After each of the information has been entered, the application calculated the best learning material that most suited to the student. The students will then learn mathematics using the learning material that has been selected by the application. After each session, the students need to answer a set of posttest. The learning gain is calculated by subtracting the pretest from the posttest.
RESULTS

From the 309 data, about 60% of the respondent were in the group one, where majority of them (142) in were assigned with MLM. The ILM were presented to a group of 40 students. The second group with contains 127 number of students and majority of them (87) were presented with SLM. The remaining number of students were presented with ULM. Table 1 shows the numbers of students for each treatments 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 shows that the students that were given the learning material in the form of game-based have statistically significantly higher means of learning gains (means =11.76, standard deviations=17.38) than the group with non-gamed-based (tutorial) (means 7.03, standard deviations: 19.63), with t (307) = 2.23, p = 0.26

<table>
<thead>
<tr>
<th>Table 1. Group Statistics</th>
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<tbody>
<tr>
<td><strong>Treatment</strong></td>
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<tr>
<td><strong>Game</strong></td>
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<td><strong>Tutorial</strong></td>
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### Table 2. The Independent T-test Result

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game</td>
<td>182</td>
<td>11.76</td>
<td>17.374</td>
<td>1.288</td>
</tr>
<tr>
<td>Tutorial</td>
<td>127</td>
<td>7.03</td>
<td>19.629</td>
<td>1.742</td>
</tr>
</tbody>
</table>

### DISCUSSION AND CONCLUSION

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 application that were designed and developed in this study were based on the researches on the area of mathematics learning style, intelligent tutoring system, game based learning and instructional learning theories.

The positive result also signifies the potential of game-based learning as a learning material in engaging students towards learning. As mathematics is often view as a difficult and boring subject, a game-based multimedia learning material can be an added item on the list of successful technologies in mathematics classroom.

For Malaysian polytechnics, the result from this study can be a reference in the process of formulating the most suitable learning material for mathematics learning. [31] have stressed in their study on the importance of mathematics educators in formulating the most effective learning strategies to achieve the international benchmark standard. As [32] concluded in his report, for a country to be in the same league as the leading countries in mathematics education, all aspects that can contributed positively toward the education must be fully considered by all the stakeholders involved in the education process.

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### REFERENCES


