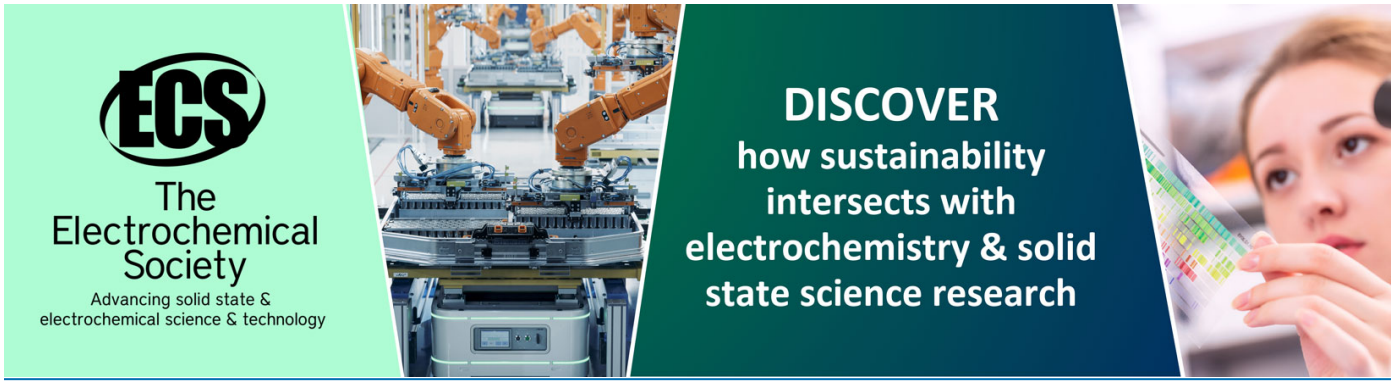
Game-Based Learning: The effects on student cognitive and affective aspects



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Game-Based Learning: The effects on student cognitive and affective aspects

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Abstract. Game-based learning, is one of teaching approach quite populer presently. The existing game, however, merely fun game without particular learning method underpinned it. This study attempts to investigate the effect of game-based learning that developed based on problem-solving method, on students cognitive and affective aspects. Ninety-six students of grade eight (M = 13.5; SD = 0.5 year) from Indonesian school were randomly selected to participated in this study. Performance on cognitive and affective were measured using test and questionnaire. The data were analysed by using qualitative and quantitative methods. Results indicated that students who were exposed to the game-based learning within problem-solving method, obtain positive effect on cognitive and affective aspects. Through this research, it provided evidence that the use educational games could support and increase the mathematics learning outcome.

1. Introduction

Education is one of the fields that affected the most by the rapid development of technology. Even a number of new technologies have emerged in recent years for the use in education. One example is mobile learning where learning can be done anytime and anywhere because of the supports of smartphones, netbooks, and other mobile technologies [1]. This situation leads to a paradigm shift and educational practices needed in the 21st century. This shift will transform a ready-to-use learning paradigm into that of preparing students with the abilities to discover, digital literacy, problem solving, and creativity. Therefore, the development of technology becomes a challenge for the learning problems of the global era.

Dealing with learning challenges in the global era, all parties involved both directly and indirectly, must certainly have the ability to utilize technology as a learning media. Even the Regulation of Ministry of Education and Culture Indonesia number 22 2016 states that one of the principles required in learning is the use of information and communication technology to improve the efficiency and effectiveness of learning [2]. In addition, the National Council of Teachers of Mathematics advocates the integration of technology in mathematics learning [3]. This mandate encourages mathematics education practitioners, including teachers, to create a learning media from the interesting technology for students to understand the concepts of Mathematics subject.

A number of new technologies have emerged in recent years for educational use. One example is mobile learning where learning can be conducted anytime and anywhere because of the supports of

smartphones, netbooks, and other mobile technologies [1]. Furthermore, there is a learning process that utilizes game applications, called game-based learning [4]. Game-content integration aims to create a fun learning atmosphere without neglecting the subject that students must learn. Given that fun learning approaches have a positive impact on learning (e.g., [5], [6]), it seems reasonable to use a game application as a learning facility. In addition, children of around 11-14 years old have started to spend time playing games in mobile devices [7].

A game application can be designed in various ways to create a fun playing experience using challenging activities [8]; competition and goals [9]; rules [10]; and choices [11]. For learning designers, these characteristics can be used in different ways because each characteristic offers a number of opportunities for innovative game designs that facilitate learning. This means there are also opportunities in designing games by following the stages of a particular learning method. Applying appropriate method will also determine the effectiveness and efficiency of learning [12]. Moreover, in mathematics learning, learning methods facilitate students' understanding of the material [13] which ultimate goal is to improve their learning outcomes [14]. The students' ability to apply mathematics in everyday life is one of the main goals of mathematics education [15]. The effectiveness of students' applying mathematics in daily life is depend not only on performing mathematical operations, but also on the extent to which they are able to understand mathematical topics. The most important thing is that they are given access to any contextual problems in the learning material. Indeed, it has been recommended that mathematics should be learned using problem-solving method.

Curriculum 2013, used in Indonesia, required student centred approach however many teachers still in favour with teacher centred approach due to many reasons. In this approach, student lean mainly from books and teachers' explanations [16]. This study tried to explore the effect of game-based learning on students' especially on their cognitive and affective aspects. Previous research studies have been pointed out the positive effect of game-based learning in mathematics classroom. This study, in particular, aimed to examine the effects of game-based learning in mathematics learning on students' conceptual understanding (cognitive) and learning interests (affective).

2. Method

2.1. Participant

Ninety-six students of grade eight (M = 13.5; SD = 0.5 year) from two Junior High School in Indonesia were selected using purposive sampling to participated in this study. Each school followed the national curriculum, and the students recently learned the geometry plane as the prior knowledge to teach solid geometry in this study. The national curriculum of Indonesia requests teachers to use student-centred learning rather than teacher-centred methods [17].

2.2. Treatment

In this study, students learn mathematics based on problem solving approach through educational game. The educational game called "GeoGame Adventure" has passed several revisions from expert judgement as well as field assessment in the real classroom. This game consists of several levels, where each level followed problem-solving procedure developed by Polya (Polya, 1987). Students were taught to *identify* the problem in general form (stage 1), *devising* a plan about how to solve the problem (stage 2), and *apply* the plan gained in solving problem (stage 3). The treatment is carried out for 6 meetings (80 minutes for each meeting). The material learn by the students is geometry particularly solid geometry

2.3. Testing and Measurements

The measurement consisted of two phases: a test phase and questionnaire phase. The questionnaire phase was done at the beginning of the meeting (before using GeoGame Adventure) and after the treatment ended. The test phase was carried out only once in which the students have been experiencing GeoGame Adventure.

Test phase was carried out to measure students' conceptual understanding about solid geometry. There are 15 test-items divided into three categories: identifying a concept; distinguishing examples and non-examples; and applying the concept into an algorithm. Each category was measured using 5 items of test. The score for correct response is 20 and 0 (zero) for incorrect one. Therefore, the total score for each category ranging from 0 to 100. The scores of each student were then compared with the minimum criteria set which is 75. Kuder Richardson reliability coefficient was $\alpha = 0.86$.

The questionnaire phase used to gain information about the students' interest in participating in game-based learning. Two questionnaires were used in this study, one for assessing prior of students' interest (pre-test); and post-test for knowing students' interest after being given the treatment. The questionnaires consisted of 25 questions with five-point Likert scale: 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree. The data form the questionnaire was then categorised based on Table 1 to determine the level of students' interest in learning mathematics using game-based learning.

Table 1. category score of students' interest

Interval Score	Category
$X > 105{,}06$	Very High
$85{,}02 < X \leq 105{,}06$	High
$64{,}98 < X \leq 85{,}02$	Medium
$44{,}94 < X \leq 64{,}98$	Low
$X \leq 44{,}94$	Very Low

3. Result and Discussion

From the test, it was found that 87.88% of students have achieved the minimum mastery criteria in learning the material of three-dimensional geometry. If analysed based on each indicator of conceptual understanding, the results obtained are as shown in Table 2 below.

Table 2. Average Score from each indicator of conceptual understanding

Indicator	Score
identifying a concept	94,7
distinguishing examples and not examples	98,48
applying the concept in an algorithm	80,34

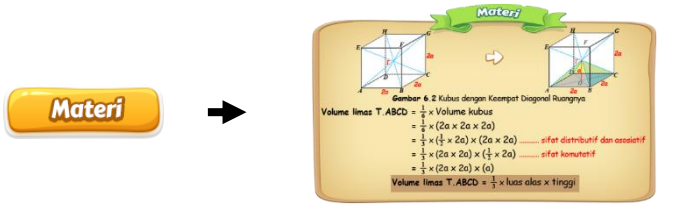
Based on the Table 2 above, each conceptual understanding indicator obtain an average score of above the minimum criteria after the students are taught using GeoGame Adventure learning media. The indicators that differentiate examples and non-examples get the highest score in the students' achievement in working on the conceptual understanding test of the three-dimensional geometry. In addition to the indicators of distinguishing examples and not examples as the basis for conceptual understanding [19], the features of the media also help obtain the highest score; for example, choosing images of nets, the geometry that meets the specified criteria, and the geometry according to the specified area and volume. In doing this, there is a reward and punishment in the game that force students answer every question thoughtfully and carefully. Through the selection of the images specified in the game rules, students are trained to be able to distinguish examples and non-examples of conceptual understanding indicators.

The material presented in GeoGame Adventure might also contribute to the effectiveness of understanding the concept of the three-dimensional geometry. For example, in teaching surface area, the students were guided to understand the concept of surface area that is refers to the area of the entire side of a three-dimensional geometry. This means that students will not be fixated on the formula,

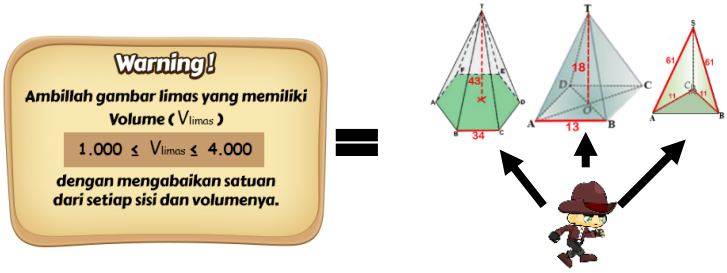
because they know that adding up all the sides of the geometry can determine its surface area. Through this concept, students were not confused in working on surface area questions that are different from those that have been exemplified during learning [20]. The same approach was used to teach volume of 3D shapes, the game emphasizing the volume concept first and then finding the same formula to find volume in each shape. The advantage of this approach in understanding volume concept is that students do not need to memorize the formula too much so that it is easier for them to work on the problem. It is through this game activity that students are facilitated in gaining the conceptual understanding of the three-dimensional geometry.

The design of the game might also help students understand the mathematical concepts. GeoGame Adventure was designed based on the stages of problem solving. Problem solving facilitates students to interact with problems to help students in determining certain mathematical concepts contained in the problems that could increase conceptual understanding [21]. Table 3 is some description related to the interface of the GeoGame Adventure used in this study.

Table 3. Description of GeoGame Adventure (just sample one of the level)

Figure	Information
	It begins with the *identify* stage through characters touching check-points to present the initial problems presented in the game
	*devising* stage through a plan about how to solve the problem in the game. This stage was done through the Material button on tap. Then, the material review provides present summary concepts needed to solve the problem
	*Apply* the plan gained in solving problems. Character touch problem-points for presents various problem-solving questions.
	Tahapan *Apply* stage was carried out through answering questions. If the student is wrong (*SALAH*) in the answer, then it will reduce the *life of the character*. Otherwise if they correct (*BENAR*), then will get *points of problems*. Finally, in this game must collect 3 *point of problems* to get continue next level.

for choosing correct figure



There is some obstacle in this game. Character must be choosing correct figure about calculation of surface area and volume. It will train students' understanding of the content of the *Materi*. Moreover, some monsters which should be avoided because it will reduce the *life of the character* if crashing it.

some monsters

The problem-solving stage in the game, for example in the evaluation stage, students answer various problems that have been reviewed. In Table 3, it has been explained that if the user makes mistake in solving a problem, it will reduce the character's life. If the life has run out, it will return to the previous material (material review). The activity was carried out because material review was the main role in strengthening the students' conceptual understanding. In addition, there are also several indicators of conceptual understanding in the game, for example distinguishing examples and not examples through choosing images of nets and three-dimensional geometry according to the specified area and volume. In addition, the presentation of the material dominated by images, texts, and animations in GeoGame Adventure can visualize the concept of the three-dimensional geometry. These features make this media different from printed media such as textbooks that are commonly used by students.

In the questionnaire phase, there was an increased interest in learning before and after using GeoGame Adventure media. In summary, the results of the student-interest questionnaire can be seen in Table 4 below.

Table 4. Data on students' learning interests

Score interval	Category	Pretest		Posttest	
		Percentage	Average score	Percentage	Average score
$X > 105{,}06$	Very High	0%		18,18%	
$85{,}02 < X \leq 105{,}06$	High	3,03%		66,67%	
$64{,}98 < X \leq 85{,}02$	Medium	54,55%	65,36	15,15%	98
$44{,}94 < X \leq 64{,}98$	Low	36,36%		0%	
$X \leq 44{,}94$	Very Low	6,06%		0%	

The questionnaire revealed that game-based learning succeeded in making students' learning interests increase. Initially, their interest in learning mathematics had a score of 65.36 which is in the medium category. After using GeoGame Adventure media, there was an increase in the score of learning interest to 98 which is in the high category. In addition to the final results, 84.84% of students have learning interests in the minimum high category after using GeoGame Adventure media. This result is in line with the previous researchs (e.g., [22], [23]) which stated that Mobile Game Based Learning is very helpful for teachers to increase students' learning interests. Previous research also pointed out that mobile learning combined with certain learning methods can increase students' learning interests [24] therefore GeoGame Adventure that was developed based on problem solving method might increase students' interest.

The combination of colours, animations, and presentation of material using images in the media has a strong effect on students' interests in learning. As suggested in the previous research that interest can be triggered by colour, movement of images, and instructional materials that utilize the potential of information technology in the learning process [25]. These features make this media different from

printed media such as textbooks that are commonly used by students. Another factor that might causes the GeoGame Adventure media to be effective in terms of students' learning interests is that the geometry topic is presented through pictures and problems they often encounter in everyday life making them interested in learning. Learning related to everyday life (real-life context) can increase students' interest in learning (e.g., [26], [27]), which is also embedded in the problem-solving method (e.g., [28], [29]).

4. Conclusions and Future Work

This study provides evidence that the use of games (especially educational games) in mathematics learning has a positive effect on cognitive and affective aspects. Therefore, it is expected that the learning developers and mathematics educators can develop materials with educational games to provide a different learning environment for students.

However, there are several limitations that should be acknowledged. First, every students has different speed at playing games thus they have different speed to complete the game. This makes students who are less adept at playing games can not the learning process maximally. However, this problem will be resolved if they continue to be given learning facilities with game-based learning. Another issue is that GeoGame Adventure might not appropriate to be use by students in other countries. This is because the context and presentation of the material like those in GeoGame Adventure may not always be experienced by the students in other countries.

Notwithstanding the aforementioned limitations, the result of this study provide a basis for further research. First, this research was only tried out in the mathematics class especially for geometry lesson. On the other word, it could not be implemented for other subjects although they had similar problems in learning process. It could be interested if the game application contained some different subjects and consisted all of the academic year. Second, this research was already success to implement the game-based learning that was facilitated by the problem-solving method. Besides, this research also showed for the learning developer to make all of learning media certain learning methods game-based learning by using other methods of learning.

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