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Developing Educational Games for Mathematics Learning to Improve Learning Motivation and Outcomes

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Abstract

This study aims to develop learning educational games as learning media in the mathematics learning process to increase students' learning motivation and outcomes. Educational games are designed to help students understanding a simple geometric shapes such as angles, sides, and nets. The development model was based on the ADDIE model covering Analyze, Design, Development, Implementation, and Evaluation stages. The result of the feasibility assessment by media and material experts reached 94% and 90% of each. Meanwhile, the assessment by the teacher reached 90%. The result of the initial / pilot test and field test reached 87% and 94% respectively. Based on the assessment, it can be concluded that educational games are suitable for supporting mathematics learning. The increase in students' learning motivation reached 84.4%, while the learning outcomes increase from 48.9 to 85.1. Further, the gain score reached 0.71 indicating that the educational games are effective for improving learning outcomes.

Keywords: educational games, mathematics learning, learning motivation, learning outcomes

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INTRODUCTION

The rapid development of science and information technology in this global era encourages individuals to develop their critical and creative thinking skills in responding to all emerging challenges. Along with this development, education also changes. Guzen & Guhan (2010) argue that technology can facilitate problem-solving learning and develop a deeper understanding. Besides, technology provides students more opportunities to explore ideas and allows them to focus on decision making. Further, they added that technology is important in developing a concept in education.

Along with the rapid development of technology, mathematics presents as a systematic and patterned science whose concept is based on real life. Learning mathematics requires students to have certain thinking skills to construct the ideas they have learned and then come up with new ideas. Thus, to come up with new ideas, during the learning process, they need to accommodate as much information as possible. Besides, mathematics is a vital subject because mathematic achievement becomes a determinant factor in formal schools compared to social and emotional skills. Learning achievement in mathematics has always been in the spotlight each year as it becomes one of the subjects tested in the national examination in primary and secondary education levels including elementary school level.

Based on the result of an interview with the fifth-grade teacher, Fidya Etik Irianti S.Pd, on July 22, 2019, regarding the perceptions of elementary school students about mathematics subjects revealed three types of students based on their interest in mathematics. They covered students who have high abilities and like mathematics, students who have the low ability but like mathematics, and students who have low abilities and dislike mathematics. The third group considered mathematics as a burden so they do not have enthusiasm for learning and it affects their learning outcome. Therefore, the teacher has to be able to motivate students in learning mathematics. Then, to change the students' negative mindset towards mathematics, it is necessary to have more attractive learning media to foster the students' learning motivation to improve their learning outcomes in mathematics.

Programme for International Student Assessment (PISA) conducts tests and evaluations of mathematical skills on the topic of geometric shapes in some countries including Indonesia. However, in 2012 Indonesia ranked 64th out of 65 countries with a score of 375 (OECD, 2014). Then, in 2015 there were no significant changes found in the scores and ranks in which this country ranked 63 out of 70 countries with a score of 386 (OECD, 2019).

In 2011, Trends in International Mathematics and Science Study (TIMSS) examined the students' cognitive abilities in mathematics in Indonesia. The percentage of correct answers are knowing 31%, applying 23%, and reasoning 17%. The result is lower than the average international result of knowing 49%, applying 39%, and reasoning 30%. Therefore, it indicates that Indonesian students' cognitive abilities are low. One of the elementary school teachers in Semarang City stated that the fifth-grade students consider mathematics subject difficult, particularly powers and roots, measurement units, as well as cubes and blocks. This study selected one of the topics, namely cubes and blocks.

Generally, the concept of geometry in the fifth grade is crucial to master. However, it is not easy to instill the concept of two-dimensional geometric shapes to elementary students, so that it cannot meet the objectives of motivating students in learning geometry. Furthermore, the National Education Standards Agency (2013) states that students do not like mathematics particularly for the concept of three-dimensional geometric shapes. Most of them think that this concept is abstract, even though they are concrete. Students have not been able to capture a real picture of the problems in geometric shapes as most of them found it difficult to solve questions about two-dimensional geometric shapes in which their understanding of the nature and aspects of geometric shapes reached 38.88%. Therefore, it requires a learning innovation to help teachers visualize the abstract materials into concrete ones, to attract and motivate students to learn mathematics, particularly two-dimensional geometric shapes, to help students understand the concept of two-dimensional geometric shapes better, and able to improve their learning outcomes.

The presence of technology as learning media is beneficial to increase students' interest in learning mathematics. In this case, technology can be used to strengthen students' motivation and to assist them in understanding certain concepts. Besides, technology can support them in drawing connections both inside and outside of learning, and allow them to focus on decision making and reflection (Guzel, 2010). Thus, it can be said that learning media is a technology that facilitates students in the learning process, especially in mathematics, both inside and outside the classroom.

One of the learning media that can attract students' interest and attention in learning is games. Games are one of the children's favorite. Sherryl and Pacheco (2006) state that games have great potential to keep students' attention during the learning process. Further, Sudargo, et al. (2017) states that games have some elements that can encourage someone to play it for a long time. The element includes a good appearance, interesting content, and fun in completing a level or to go to the next level.

Different from games for entertainment, games for learning or educational games are designed to achieve certain learning outcomes. Besides, educational games can be used as media to train students' skills in solving problems, finding solutions, thinking quickly, and competing (Ardiningsih, 2019). The main objectives of educational games are to achieve learning objectives in accordance with the expected results, to produce meaningful learning through a game process, and to produce a real picture through a game simulation. A previous study conducted by Bernard (2015) found that someone prefers to play until they understand how the game run. However, if the game process is replaced with the educational game and the students understand the mathematical concepts in the game, they may be able to master mathematics and are motivated to learn.

The form of the game that suits the concept of geometric shapes is adventure games. Cahyo (2011) states that adventure games are a type of game where the player is assumed to be the main character in an interactive story supported by exploration and puzzles. Further, Anggraini, et al (2016) added that this adventure game emphasizes the completion of the storyline. This game is not like action which requires quick reflex. It only requires sharp analysis and memorization. In this game, the player is required to solve obstacles or conclude a series of events from character conversations or the use of objects in the right place. The adventure-type games provide students with geometric shapes materials in more interesting visualization and easy to be a learner. After students get the material, the obstacle emerges and the students have to solve them first to proceed to the next level. Thus, the students are not only interested in playing this adventure game, but also learning mathematics from the game.

Based on research conducted by Morsi and Jackson (2007), most students argue that when playing games, they got positive feelings, such as "happy" and "interested". Bernard (2015) found that educational games for mathematic are fun in which students can provide ideas and appreciate mathematics. Further, they have a great curiosity about technology. Thus, the development of educational games for mathematics can change the students' mindset about mathematics as a fun lesson in which its concepts can be easily understood, attractive, and motivating for learning mathematics. Therefore, students' learning outcomes can also increase.

METHODS

This research is a Research and Development (R&D). R&D is research to produce certain products and test the effectiveness of the product. This type of research is different from other educational research because the goal is to develop a product based on trials and then revise it to produce a suitable product for use. The development model referred to the ADDIE model as proposed by Dick and Carey (1978) which covered Analysis, Design, Development, Implementation, and Evaluation.

The use of R&D and ADDIE model is considered appropriate because (1) the focus of this study is to design and develop an educational game product as media for learning mathematics, particularly the concept of cubes and blocks; (2) Feasibility of educational quiz game products based on the experts' judgment and respondents' assessment; and (3) The effectiveness test to determine the improvement of learning motivation and outcome of fifth-grade students.

The development of the educational games using the ADDIE model was started from stage 1) Analysis. This stage was to determine the suitable educational games for overcoming student difficulties in learning mathematics, particularly the concept of two-dimensional geometric shapes adjusted to the characteristics of the fifth-grade students. The analysis stage covered observation and interviews. The second stage was 2) Design.

The educational game design was started by designing flowcharts and storyboards, and the type of assessment to be carried out.

The next was 3) Development stage to realize the design and validation were carried out by media experts, material experts, and the fifth-grade teachers. Next, the 4) Implementation stage was to determine user responses through 3 tests, namely pilot test (3 people), field test (10 people), and operational field tests (36 people). The last was (5) Evaluation stage in which it was based on the assessment of material experts, media experts, and respondents.

The data were collected through observation, interviews, questionnaires, and tests. Observations and interviews were carried out during the preliminary test to determine students' learning conditions. Meanwhile, the questionnaire in the form of an evaluation sheet was used for experts' judgment and respondents' assessment. The test was carried out in 2 stages, namely the pretest and posttest to identify the differences in students' learning outcomes before and after using the developed product. The obtained data were analyzed by compiling and grouping data, describing data, and drawing conclusions. Data analysis was carried out descriptively to explain the respondents' responses to tests, questionnaires, interviews, and observations.

The result of the questionnaire for learning motivation assessment was processed using a formula proposed by Purwanto (2010). The result of the pretest and posttest used the normalized gain or gain score technique to measure the difference in the same sample which experiencing two treatments, namely before and after.

RESULTS & DISCUSSION

The mathematics educational games were developed through several stages, namely, analysis, design, development, implementation, and evaluation. The analysis stage was carried out through observation and interviews. Based on the results of observations in mathematics learning in the fifth grade, the teacher used lectures and practice learning methods. The teaching materials were from textbooks and worksheets. Besides, the teacher provided other learning resources in the form of instructional videos. However, some students were still not interested in watching the video, because they only see it without directly operating the devices. Then, based on the result of interviews with fifth-grade students, some of them considered mathematics difficult with many confusing formulas and difficult questions to be solved. It resulted in a low interest in learning mathematics and finally, it affected the learning outcomes. One of the materials considered difficult by students was the concept of cubes and blocks as they still have difficulty in understanding other shapes of the nets.

In the design stage, based on the result of observations and interviews, the researcher designed the learning materials, learning media, and evaluation. The material used in this study was the concept of cubes and blocks. The basic competencies were the students 'ability to find angles, sides, and nets of cubes and blocks, and students' understanding in solving problems about the volume of cubes and blocks. Then, the next stage was determining the media sources or application for educational games media design. The software used in developing this product was Unity 3D and supported by other tools such as Photoshop CC to edit the background and characters in educational games. This study used a questionnaire for validating the product with 24 indicators of media experts, 18 indicators of materials experts, 14 indicators of teachers' response indicators, and 13 students' responses indicators. Then to find out student learning outcomes, the research used to pretest and postest with 10 multiple choice questions and 5 description questions. Meanwhile, to determine the increase in students' learning motivation, it used a questionnaire for motivation consisting of 20 statements.

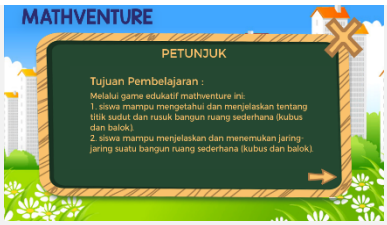
In the development stage, it was started with creating flowcharts and storyboards, determining character, creating interfaces and layouts, and determining the font type and size, namely "Montserrat" with a size of 14. The back sound music for this educational game was "Depapepe-Start". The developed games consisted of 2 levels, where each level consisted of 3 stages.

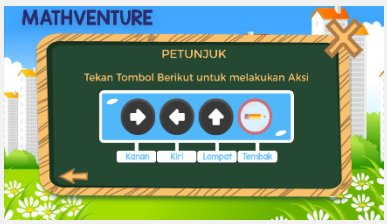
At level 1 stage 1, players were required to collect at least 50 "pencils" to eliminate enemies in the form of "snakes" and to collect 8 "stars" where at the end of stage 1 the player was asked to place the "stars" at the corner point of the cubes. If the player was hit by a "snake", went into a cliff, or the number of pencils or stars did not meet the requirements, then the player must restart stage 1. On stage 2 and stage 3, players were required to do the same, but they collected "rulers" not “stars” which represent the edge on stage 2 "squares" which represent sides and cube nets on stage 3. At level 2, the player was required to find out the angle, sides, and nets of the cubes. At each level, there was also a button that can connect to YouTube about the explanation of the cube materials for level 1 and block materials for level 2.

After the educational game media has been developed, the media must be validated by media experts and material experts as well as the assessment of the fifth-grade teacher. Based on the result of validation, the product was revised so that it was suitable for use.

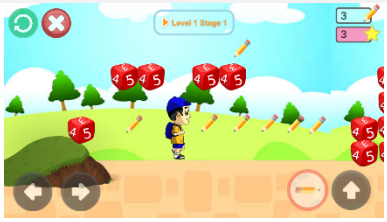
Table 1. Revisions of Educational Games

Before Revision	*After Revision*	*Notes*
	 	1. Added target users on the interface 2. Made the character look more polite by wearing the cap correctly 3. Added select ‘character’ button to choose the gender of the player
		1. Revised the font from “Kristen ITC” to “Montserrat” 2. Replaced the words “Play” and “Setting” to Bahasa Indonesia “*Mulai*” and “*Pengaturan*” 3. Replaced the word “*About*” to “*Developer Profile”*





Added learning objectives and navigation button on the Instruction



Replaced the dots on the dice with number 1-6

After revising the developed product, the next stage was the implementation stage. At this stage, there were 3 tests. The pilot test or initial field test involved 3 fifth-grade students on August 23, 2020. The field test involved 10 fifth-grade students on August 25, 2020. In the field test, the assessment was carried out using students' response questionnaires. Then, the operational field test was conducted in real conditions on August 31 - September 11 2020 with a total of 36 fifth-grade students. The students were participated in mathematics learning using educational games. The pretest and posttest used 10 questions about cubes and blocks material and 5 descriptive questions to see an increase in students' learning outcomes. After carrying out learning activities, students filled out a learning motivation questionnaire to see an increase in learning motivation after using educational games.

Overall, all students experienced game over on different stages, but the more often they repeated, the more curious they were to play the games. This was intentionally done where the enemy was created in the form of "snake" and "mouse" so that the player who loses has to start over from the beginning. It aimed to train the player's memory on materials to be collected to find out the angle, edges, sides, and nets considering the evaluation through this game was developed to measure the cognitive domain by emphasizing the memory aspect. Most of the respondents considered the game fun, intriguing, and interesting.

The evaluation stage was carried out using a questionnaire and test. Based on the results of the assessment by media experts using a questionnaire covering aspects of software engineering, design and appearance, and programming. The total percentage was 94% or **Very Appropriate**. Media experts suggested considering replacing the dots on the dice with the number to make them more meaningful.

Table 2. Assessment of Media Experts

No	Rated Aspects	Percentage	Interpretation
1	Software Engineering	100%	Very Appropriate
2	Design and Appearance	95%	Very Appropriate

3	Programming	90%	Very Appropriate

Based on the results of the assessment by material experts using a questionnaire covering aspects of learning objectives, content quality, and feedback, and motivation, it reached a total percentage of 90% or Very Appropriate. Material experts suggested that instructions must be clarified by added learning objectives and navigation buttons. Then, it was suggested to add select 'character' to select the gender of the player.

Table 3. Experts' Judgment/Assessment

No	Rated Aspects	Percentage	Interpretation
1	Learning Objectives	90%	Very Appropriate
2	Content Quality	86%	Very Appropriate
3	Feedback and Motivation	100%	Very Appropriate

The feasibility of educational games also required an assessment from the fifth-grade students. The assessment was carried out using teachers' response questionnaire covering aspects of functions and benefits, program presentation, and language and typography. The result of the teacher response showed a total percentage of 90% or **Very Appropriate.**

Table 4. Assessment of teachers' responses

No	Rated Aspects	Percentage	Interpretation
1	Functions and Benefits	96%	Very Appropriate
2	Program Presentation	87%	Very Appropriate
3	Language and Typography	87%	Very Appropriate

Then, the initial field or pilot test was carried out. This assessment was carried out to determine students' responses by involving 3 students as respondents. The questionnaire covered aspects of function and benefits, program presentation, and language, and typography. The results of the questionnaire in the initial field test showed a percentage of 87% or **very appropriate**. Then, it was proceeded with the field test by involving 10 students and using the same questionnaire. The result showed a percentage of 94% or **very appropriate**.

Table 5. Initial Field Test

No	Rated Aspects	Percentage	Interpretation
1	Functions and Benefits	85%	Very Appropriate
2	Program Presentation	88%	Very Appropriate
3	Language and Typography	92%	Very Appropriate

Table 6. Field Test

No	Rated Aspects	Percentage	Interpretation
1	Functions and Benefits	94%	Very Appropriate
2	Program Presentation	95%	Very Appropriate
3	Language and Typography	95%	Very Appropriate

The operational field test was conducted to 36 students as respondents. It was conducted to determine the increase in students' learning outcomes from the pretest and posttest scores. The mean score for the pretest was 48.9, while the mean

score for the posttest was 85.1. Based on the mean score of the two tests, it can be seen that there is an increase in the pretest and posttest. Then, the gain score was calculated using the two mean scores which resulted in 0.71. As the gain score is $0.71 \geq 0.70$, it is considered **high**, so the use of educational games in learning mathematics of the fifth-grade students can be said **effective**.

Table 7. Effectiveness Test

Minimum score	35	75
Maximum score	65	100
Mean	48,9	85,1
Gain Score	**0,71**	
Interpretation	**High**	

Moreover, to find out an increase in learning motivation, an assessment was carried out using a questionnaire by involving 36 students as respondents. It consisted of 7 indicators divided into 20 questions. The indicators covered 1) Passion and desire to learn mathematics, 2) Learning needs, 3) Learning rewards, 4) Diligent in completing tasks, 5) Resilient and never give up in facing difficulty, 6) Showing interest in various problems, and 7) Finding and solving problems in learning. It showed a percentage of 84.4% with Good interpretation. Therefore, the use of educational game media for mathematics learning particularly cubes and blocks can increase learning motivation of the fifth-grade students.

Table 8. Percentage of Learning Motivation Improvement

Indicators	Percentage	Interpretation
Passion and desire to learn mathematics	86,8%	Very good
Learning needs	84,7%	Good
Learning rewards	84,7%	Good
Diligent in completing tasks	80,7%	Good
Resilient and never give up in facing difficulty	86,6%	Very good
Showing interest in various problems	84,0%	Good
Finding and solving problems in learning	85,8%	Good

CONCLUSION

Based on the result of the development of educational games for learning mathematics, it can be concluded that: 1) The assessment of media experts and material experts reveals that the educational games are very appropriate to be used for learning mathematics in the fifth-grade of elementary school with a percentage of 94% (media experts) and 90% (material experts). 2) The assessment of the fifth-grade teacher, the educational games are very appropriate to support the teaching and learning process with a percentage of 90%. The teacher added that there is a need for the development of educational games for other materials. 3) In the initial field test conducted to 3 students, the percentage was 87%. Then, the field test conducted to 10 respondents showed a percentage of 94%. Thus, the educational games can be said Very Appropriate to help students learning mathematics particularly cubes and blocks. 4) The use of educational games in learning mathematics can improve students' learning outcomes. The mean pretest and posttest scores showed an increase from 48.9 to 85.1 and gain score was 0.71 with a

high interpretation. Therefore, learning mathematics using this educational game is effective, and 5) the increase of students' learning motivation reached 84.4%.

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