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Android-based Educational Game: The design to improve students' understanding in learning Geometry

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Abstract

This study aims to develop and investigate the effectiveness of android-based educational games on students' understanding of solid geometry objects. This is a research and development study using ADDIE model. The experimental (implementation) stage of this study employed *one group pre-test and post-test design.* This study involved 32 junior high school students in Yogyakarta District who were selected using cluster random sampling. The game is designed and packed similarly to the game that available in Playstore so that the students familiar to the students. The students were asked to play educational game as a complement of formal learning in the class conducted by teacher. The data obtained from pre-test and post-test show that students' understanding of the solid geometry increase significantly. The design of the game is discussed in paper as an example of the effective game design to support students understanding of the learning materials.

Keywords: educational game, solid geometry, students' understanding

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INTRODUCTION

The learning process in the post COVID-19 pandemic continues finding a new effective form of learning. After almost two years of studying at home, the implementation of learning at school requires students to be able to adapt well because the time provided for learning is very limited with the same amount of material that must be learnt. Interviews with several junior high schools in Yogyakarta, it was stated that the amount of time for mathematics lessons had decreased due to government policies on school-time cutting in the post pandemic. With this limited time, it is hoped that students can make the best effort to learn, pay attention to the teacher's explanation, note the important points, and do assignments.

Geometry is one of the materials that perceived to be difficult by students in many country (Gal & Linchevski, 2010; Fabiyi, 2017; Ubi, Odiong, Igiri, 2018; Salifu, Ibrahim, & Yakubu, 2020). Similar issue happens in Indonesia. Based on national exam results obtained from the Ministry's Education Assessment Center Education and Culture, the average scores in Geometry of junior high school in 2017, 2018, and 2019 respectively are 48.57; 41.40; and 42.27 out of 100 (Puspendi, 2018). In addition, the level of students' understanding on Geometry is below the minimum competency ranging from 1.40 to 1.79 which indicates less than 50% of students achieve the minimum competency based on educational reports by the Ministry of Education (Pusmendik, 2022).

On the other hand, many researchers have attempted to develop technology-based learning instruction. For example, Luthfya (2020), she developed a digital quiz to facilitate students' understanding of concepts. The quiz is merely a drilling, students are asked to solve a combination of questions from all material and there is no other activities than answering bulks of questions. Another

research studi developed a spatial learning media for fifth grade students (Herawati, Wahyudi, & Indarini, 2018). The media, named Baratika, presents material alternately without providing a menu of options for each shape so that it seems ineffective because if the user wants to study a geometric shape, he has to search one page at a time.

Previous research studies prove that educational games have a positive influence on students' cognitive and affective (Pratama & Setyaningrum, 2018a). Moreover, students who were exposed to educational games significantly outperformed their counterparts who were exposed only on textbooks (Pratama & Setyaningrum, 2018b). Evidence from the teachers' views presented by Setyaningrum and Waryanto (2018) stated that a good quality educational game could help students learn mathematics. In a broader scope, games could enhance learning activities and increase motivation (Huang, Tsai, Diez, & Lou, 2014) and improve spatial abilities in geometry (Chung, Yen-Chih, Yeh, & Lou, 2017).

Many articles have suggested that educational games have a positive impact on students, either cognitive, affective or psychomotor. These articles, however, have not explained the design of the game that could help students in learning mathematics in detail. This current article, therefore, explores and explains the design of educational games to learn geometry in junior high school. It is then followed by a discussion on the effect of the game on students' understanding of solid geometry.

METHODS

The game developed in this study is an android-based interactive learning media. The model employed a Research and Development research method, which is a research method used to produce certain products and test the effectiveness of these products (Sugiyono, 2018). The development model used is ADDIE which stands for the Analysis, Design, Development, Implementation and Evaluation stages.

Participants

This study involved 32 students grade eight of junior high school in the implementation stage. The students were selected in clustered random sampling method in one public school in Yogyakarta.

Procedure

The development model employed in this study is ADDIE.

1. Analysis
   A needs analysis is carried out prior to developing media/game. The analysis aimed to find out the conditions in the classroom related to the learning process of mathematics for class eight junior high school. The activities in this stage include:
   a. Material analysis
      Material analysis aims to determine the learning materials that will be used in this study. It referred to current curriculum used in Indonesia particularly it referred to the core and basic Competencies. This information is used to determine the learning objectives that were obtained by the students after using the media or after playing the game. The learning objectives are used to direct the scope and the structure of learning material in the game.
   b. Needs analysis
      Needs analysis aimed to find out the problems faced and what kind media have been used and what media expected to use by intended users in this case students and teachers when learning geometry at grade eight. Analysis was carried out through interviews with teachers and students to obtain information on the ability of students to achieve predetermined learning objectives as well as a literature review on the results of national exams and national assessments as well as the results of research that support the development of this learning media.
   c. Analysis of the character of students
      Character analysis was carried out to determine the responses and attitudes of students towards learning mathematics. Analysis was carried out through interviews by identifying issues

in learning geometry, especially during pandemic and post pandemic, such as abilities and skills in understanding material, distance learning experiences, and attitudes of students. At this stage it will be known the level of ability of students and the obstacles that are often faced so that it will be facilitate in developing appropriate and appropriate learning media

d. Software analysis
Software analysis is carried out to find out which software can be used in assisting the process of developing interactive learning media and can adapt to technological developments that are of interest to students. The analysis was carried out by observation and discussion with the supervisor and the teacher concerned.

2. Design
In making interactive learning media, several things are prepared at this design stage, including designing concepts to be used along with flowcharts and storyboards, learning materials and questions or mathematical problems, collecting assets such as images, animations, audio, and designing assessment instruments in the form of questionnaires and achievement test pretest posttest.
3. Development
At this stage the media design plans on flowcharts and storyboards were used as a guideline to develop media and prototypes. All assets are arranged in accordance with the desired concept, then convert it into an apk file so that it can be played on Android. If the learning media can be played well without problems, this means that the interactive media is ready to be tested.
4. Implementation
At this stage everything that has been prepared by taking into account input from the validators both media and content validators. The media then was tested to grade eight students. The students were asked to play the game along with classroom teaching and learning process.
5. Evaluation
The evaluation stage is the final stage to determine the effectiveness of the learning media that have been developed. The data obtained from the implementation stage are analyzed to obtain a conclusion about the effectiveness of the media. In addition to evaluation at this last stage, evaluation is also carried out at the development stage after the validators provide an assessment and the data from the implementation stage, to improve the media that is being made.

Data Analysis Method

The data of students understanding obtained from pre and posttest are analyzed in descriptive and inferential statistics. Using the one group pretest posttest research design, the effectiveness criteria based on student score of both tests. The game is effective if the average score of the post-test was higher than the pre-test and the average score is different significantly. Pre-test and post-test are ten items of multiple-choice questions about surface area and volume of solid geometry objects.

Prior to the statistical test, the effectiveness of the game is measured using N-gain score. The N-gain score obtained was then converted into percentages to determine the effectiveness of interactive learning media based on pre and posttest. The categories for interpreting the effectiveness of N-Gain are shown in Table 1 (Suharsimi, 2006).

Table 1. N-gain criteria

N-gain Score (%)	Interpretation
< 40	Ineffective
40 - 55	Less effective
56 – 75	Nearly effective
> 76	Effective

The statistical analysis begins by looking at the results of the normality test with Kolmogorov-Smirnov on the basis of decision making, that is, if the Asymp. Sig. (2-tailed) > 0.05 then the data is normally distributed and if the Asymp. Sig. (2-tailed) < 0.05, the data is not normally distributed. Then proceed with the paired sample t-test if the data is normally distributed or the Wilcoxon test if it is not normally distributed on the basis of decision making, that is, if the Asymp. Sig. (2-tailed) < 0.05 then H_o is rejected and if the Asymp. Sig. (2-tailed) > 0.05 then H_o is accepted. The H_o is that there is no significant differences between the average score of pre-test and post-test.

RESULTS AND DISCUSSION

This study aims to develop an educational game for grade eight students and investigate the effectiveness of the game toward students' understanding. The phases in developing the game are Analysis, Design, Development, Implementation and Evaluation. This article discussion of the article, however, focused on the design and the effectiveness of the game.

Analysis Phase

The initial stage carried out in development is in the form of aspect analysis including analysis of material, needs, student character, and software. From this activity it was found that learning flat solid geometric material with a short time allocation requires learning media to help students understand the elements, surface area, and volume by using time outside of class hours in a fun and attention-grabbing atmosphere.

Design and Development Phase

The game is developed based on the Indonesian Curriculum 2013 therefore the menus in the first page (see Figure 1) of the game consists of: 1) *Deskripsi*: contains information about the scope of the material and the competencies that should be acquired by students through the game; 2) *Materi*: provides learning material that should be learnt by the students according to the curriculum; 3) *Permainan*: contains a game that integrate learning material and adventure; 4) *Petunjuk*: gives instruction on how to play the game; 5) *profil*: informs the developers of the game.

Figure 1. Menus on the game

In *Materi* menu, the learning material is presented sequentially and interactively. The order of the material presentation is definitions of solid geometry objects (see Figure 2(i)), their characteristics (see Figure 2(ii), surface area (*luas permukaan*) and volume (see Figure 2(iii)), as well as examples of problem solving related to the objects (see Figure 2(iv)). The material covers cube (*kubus*), cuboid (*balok*), prism (*prisma*) and pyramid (*limas*).

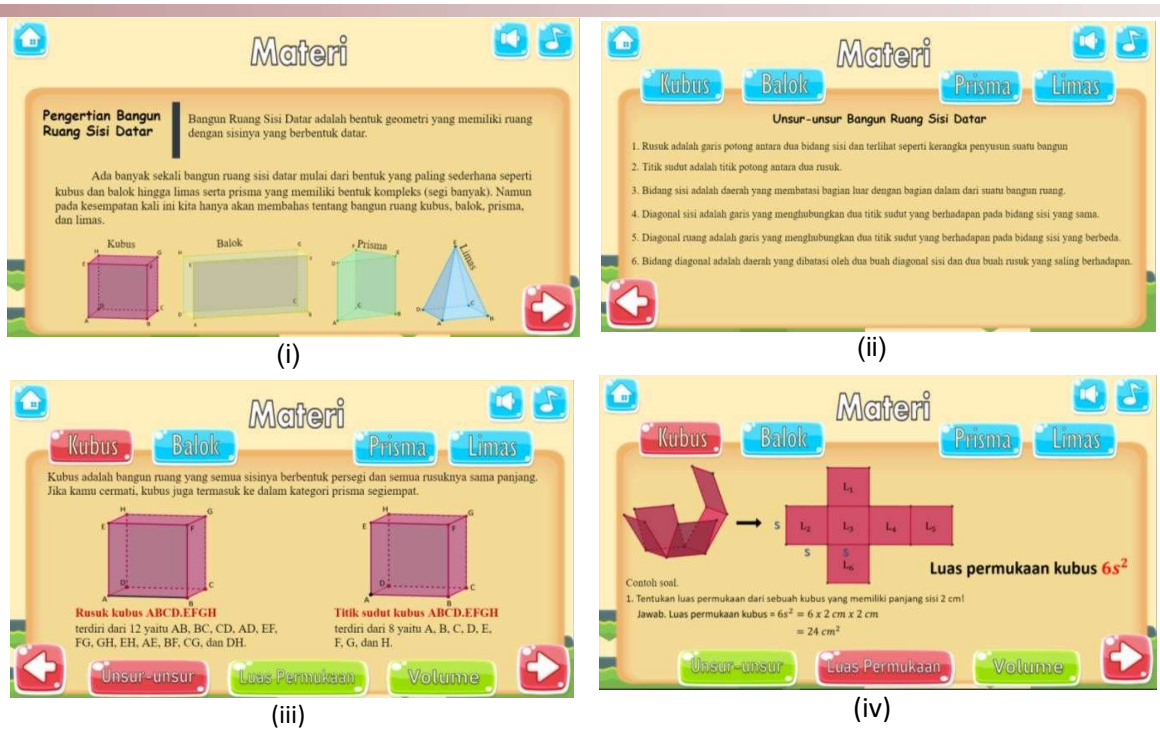


Figure 2. User interface of the material presentation

With respect to interactivity aspect, this game enhances with moving illustrations for example Figure 2 (iii) and (iv). In Figure 2(iii), when the game explains the side of cube, the side reffered will appear in different colour. The net of the cube is moving open and close to illustrate that the nets when folded will form a cube (Figure 2(iv)). Moreover, the game gives the opportunity to the users to choose the material to be studied and they can go back or forward, so that the users can learn in their own phase. Interactivity is an important aspect in instructional media because it allows users to explore and active participate in learning (Jewwit, Moss & Cardini, 2007).

The presentation of the images made with the help of the GeoGebra application is designed in such a way as well as giving different colors with the aim that students can understand well each flat side shape. The use of color to distinguish other parts can help students learn (Fister & McCarthy, 2007). The layout and the sentences used in explaining material are arranged properly and appropriately to the junior high school students so that the information can be read and understood by students easily. The explanation of the concepts and procedures related to solid geometry are then followed by two questions for each object, this design aimed to confirm students understanding of the concepts and procedures learnt previously.

In the game menu, there are eighteen levels, and the users have to complete the previous level in order to open the next level. Each solid geometrical object has four levels in which the first two levels dealing with surface area and the next two dealing with volume.

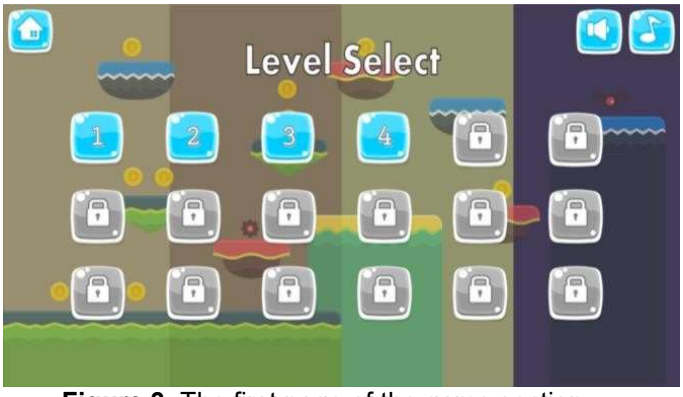


Figure 3. The first page of the game section

The design of the game refers to one of familiar non-educational game namely Super Mario Bros. This aimed to attract students to play the game, it gives the feeling that students are playing while learning. The use of familiar game design is one of the design priciples for educational games in mathematics (Chorianopoulos, Giannakos, & Chrisochoides, 2014). The users must pass through a track with a chasm that has the same width using the control buttons located at the bottom. Players can also collect coins contained in each zone; one coin will add one number to the coin symbol in the upper left corner. In addition, there are also obstacles in the form of flying and ground enemies that the player must avoid so as not to reduce the three lives for each play zone, although the player can destroy these enemies by falling on them and will get an additional two coins. There is a backsound music that can be turn on and off or adjusted volume level as preferred.

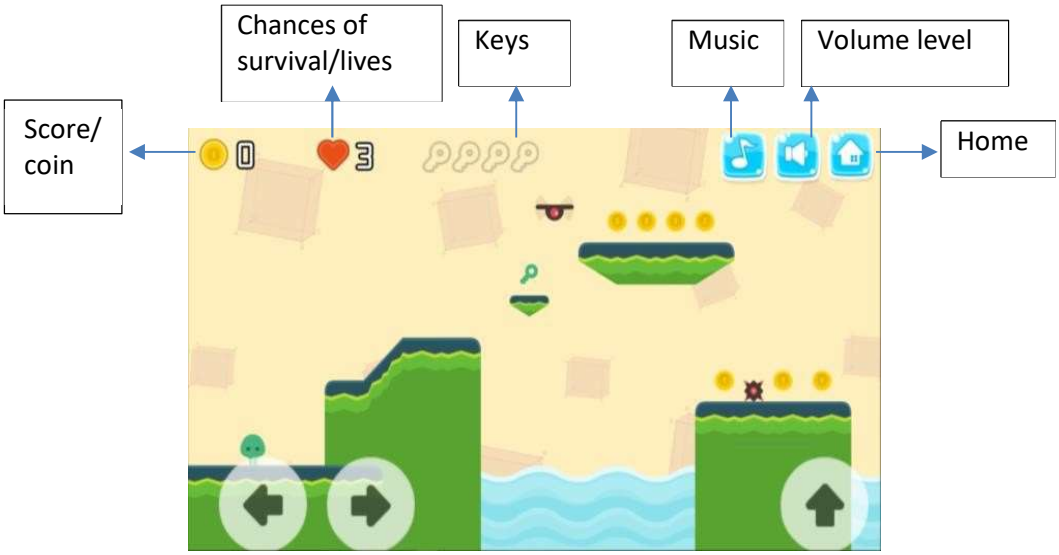
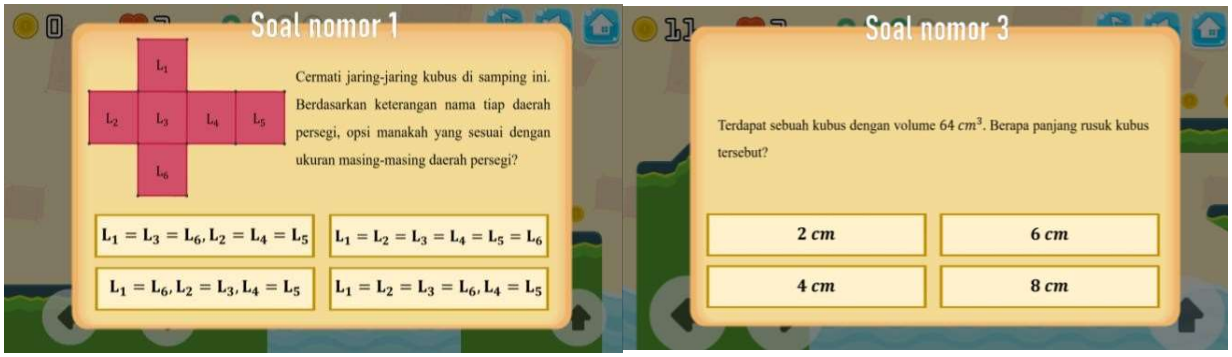


Figure 4. Example of interface game

If the player takes the first key in play zone 1, a question will appear that have to be answered with a score of 25 for the correct answer and 0 (zero) for the wrong one. Each zone consists of four questions with two categories, namely surface area and volume.



(i) (ii)

Figure 5. Example of challenge in the game

A level is completed if the users reach 100 score, in other words, the users have to answer the four questions correctly. When the users complete on eleven, a pop up appreciation appears along with victory music (Figure 6). The word of appreciation is "Congratulations" to celebrate users' achievements that could increase student enthusiasm to complete the next level (Barana, Marchisio, & Sacchet, 2021).

Figure 6. Example of good achievements' appreciations

Meanwhile, a game over pop up will appear if the player falls into a ravine while crossing the track or the player's life runs out due to being hit by an enemy or the accumulated score is ≤ 75 when they reach the door at the end of the track. When the game over pop up appears, the users will hear defeat music accompanied by the words of encouragement "Try again" (Figiure 7) as a form of support so students don't just give up on completing the level and next level (Tseng & Tsai, 2006). With respect to feedback in digital game, there are conflicting results from previous research that feedback has a positive but also negative effect (Azevedo & Bernard, 1995). During the implementation phase in this study, the results of observations show that giving feedback has a positive impact on students.

Figure 7. Example of fedback and motivation

Implementation Phase

Game effectiveness analysis is carried out through the acquisition of pre-test post-test learning results. To find out the effectiveness of using media based on learning achievement tests, researchers used the N-Gain formula which was changed in percentage form. The results of the recapitulation of the average pretest, posttest, and N-Gain are presented in Table 2.

Table 2. Percentage N-gain Pre and Post-test

Data	#Students	Average Score	Standard Deviation
Pre-test	32	68.75	21.213
Post-test	32	93.13	13.060

N-gain (%)	32	79.57	42.587

It is known that the average pre-test score before using learning media is 68.75 with a standard deviation of 21.213 (Table 2). Meanwhile, the average post-test after the use of instructional media is 93.13 with a standard deviation of 13.060. In addition, an average N-gain score is 79.57% which is considered to be "effective" based on Table 1.The N-gain score implies that the game is effective for learning solid geometry particularly surface area and volume of cube, cuboid, prism and pyramid.

The next analysis is statistical analysis to determine significant effectiveness. A normality test was carried out in both classes using SPSS 25 and the results for both pre and post test data were not normal therefore the next data analysis used the Kolmogorov-Smirnov to determine the significant effectiveness of the game toward students' achievement. The result shows that the Asymp. Sig. (2-tailed) that is 0.000. Based on the decision-making basis of the Wilcoxon test, H_o is rejected so that H_1 is accepted. This implies that there is a significant difference in learning achievement with the average acquisition after using interactive learning media is greater than before learning with a game.

Table 3. Wilcoxon test of Pre and Post

Data	Sig*	Meaning
Pre & Post-test Score	0.000	H_o rejected

The N-gain score and the result of statistical analysis suggested that the game is effective for learning solid geometry. This implies that game that designed as discussed previously could help students learn mathematics and increase students understanding of the learning material. In addition, previous research studies show that educational game with good quality and good design can assist mastering concepts (Huang, Tsai, Diez, & Lou, 2014) as well as direct students' interest and attention (Kishore, 2003; Hekkert 2006). During the implementation of the game, there noticeable point that the teacher plays an important role in game-based learning because if the teachers do not understand the game it will be difficult for them to help students who have difficulties in playing game. Unfamiliarity with the games can cause ineffectiveness (De Freitas, 2006) therefore, teachers have to be familiar with the content of the games as well as the lesson plan to obtain learning effectiveness. Teachers who know the game could direct students so that the students can capture the material being studied.

CONCLUSION

The design of the educational game has a very big role in enhancing learning effectiveness. Educational games could provide a high learning interest environment and offering repeated practice. Immediate feedback allows the students to modify their errors and see their progress as well as encourage them to learn more. It offers a flexible learning situation so that students can learn in their own phase and give opportunity to actively engage and integrate various types of previously knowledge when solving the problem in the game. An interactive platform, interesting illustration, animation and challenging yet simple designs of the game encourage students to accomplish their learning objectives. However, without appropriate strategies, educational games will simply be entertainment (Yang, Lin, Wang, & Huang, 2011) therefore there is a need to make a good lesson plan so that can be used to guide the use of the educational game so that it is more effective for learning (Sun, 2011). What kind of lesson plan that is suitable for game-based learning can be explored in the future research.

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