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Development of android-based edutainment game to improve mathematics problem-solving ability

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ABSTRACT

The development of technology has presented several choices of unique, creative, and innovative learning media that can be used in the learning process. Besides being a challenge, involving innovative and creative learning media also provides opportunities for students to improve their mathematical problem-solving skills. This research will focus on research on the development of edutainment game media that can be used on smartphones (Android). Media development is carried out by adapting the ADDIE model which contains five (5) stages, namely analysis, design, development, implementation, and evaluation. Furthermore, descriptive quantitative analysis was conducted to review the feasibility of the media. The results of the analysis show that edutainment games are feasible as learning media to improve mathematical problem-solving abilities in terms of validity, practicality, and effectiveness.

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Introduction

The quality and quantity of education are one of the problems that continue to rise along with the development of technological sophistication. The use of innovative technology becomes an important thing and needs to be considered in the implementation of education and teaching in the field of mathematics (Stošić, 2015). This is because, several studies have shown that integrating technology in teaching makes a major contribution to teaching mathematical concepts and principles (National Council of Teachers of Mathematics, n.d.). One of the steps that can be taken in integrating technology in the learning process is to use technology-based learning media (Bourgonjon et al., 2009). Technology-based learning media has a wider and diverse presentation space. For example, technology-based learning media can be designed as well as possible so that they not only present the mathematical concepts to be studied but can present mathematics learning activities that involve student participation. Lecturers have an awareness that integrating technology in teaching will have a positive effect (Allsop & Jessel, 2015). However, the technology-based learning media used is still relatively less varied and has an up-to-date nature.

The survey results show that Indonesia is the country with the highest game users from several other ASEAN countries (newzoo, 2017). On a smaller scale, it also shows that 80% of 125 students like to play games. However, games as a learning medium are still very limited, especially in high-level education and teaching. Massive games in Indonesia have the potential to be used as a medium for learning mathematics.

Well-organized game activities can be an innovative medium for learning mathematics (McLaren et al., 2017). Based on its characteristics, games have a higher chance than other learning media in binding student

interest in learning (Sudarmilah et al., 2013). Apart from the aspect of interest, game-based learning media can provide a meaningful learning process for students. Students will carry out a series of fun activities to gain an understanding of the material being studied. A good understanding, in the end, contribute to students having the ability to think mathematically at a higher level, one of which is the ability to solve mathematical problems. Students can understand the learning material, not only emphasizing how much effort the lecturer/teacher makes to explain the material. However, through meaningful self-study activities. A well-designed edutainment game media can certainly facilitate meaningful learning activities (Hsbollah & Rosli, 2022). Meaningful learning has a close relationship with improving mathematical problem-solving abilities (Jana & Fahmawati, 2020).

Method

This development research is designed to produce a valid product so that it can be implemented and utilized in the learning process. The main objective of this development research is to produce an Android-based edutainment game media product. The development model used in this study is a learning media development model adapted from the ADDIE model (Branch & Kopcha, 2014). The ADDIE model contains the following five stages of development: analysis, design, development. Implementation, and evaluation. The framework of this research can be seen in figure 1.

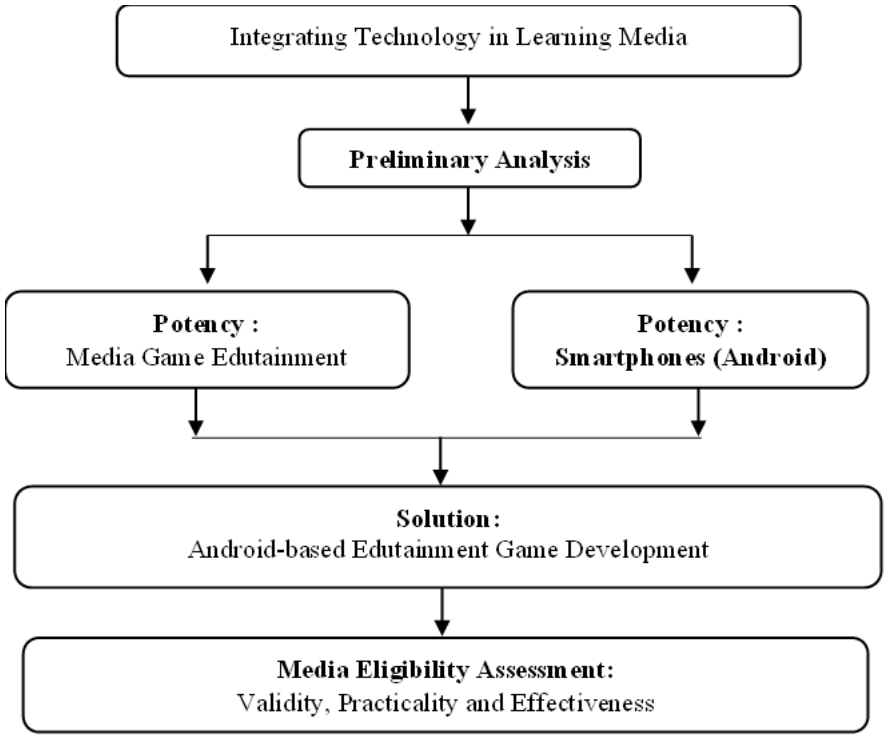

Figure 1. Research Framework

The main result of this development research is to produce an Android-based edutainment game to improve mathematical problem-solving skills for prospective Mathematics teachers which are developed through the following procedures: preliminary analysis, design, product development, implementation, and evaluation.

In this study, BM adventure was developed using Construct 3 software. Construct 3 is a game engine that is used to build games or applications that are suitable for several platforms. Games that have been created through the Construct 3 program will be distributed to platforms, especially Smartphone (Android), Windows, Mac, and Linux. The concept of developing BM adventure can be seen in Figure 2.

The design of the BM adventure game media is systematically developed to produce decent game media (meeting the criteria of validity, practicality, and effectiveness). The design starts from the game concept design stage, game design, implementation, and exporting to get the game in APK form.

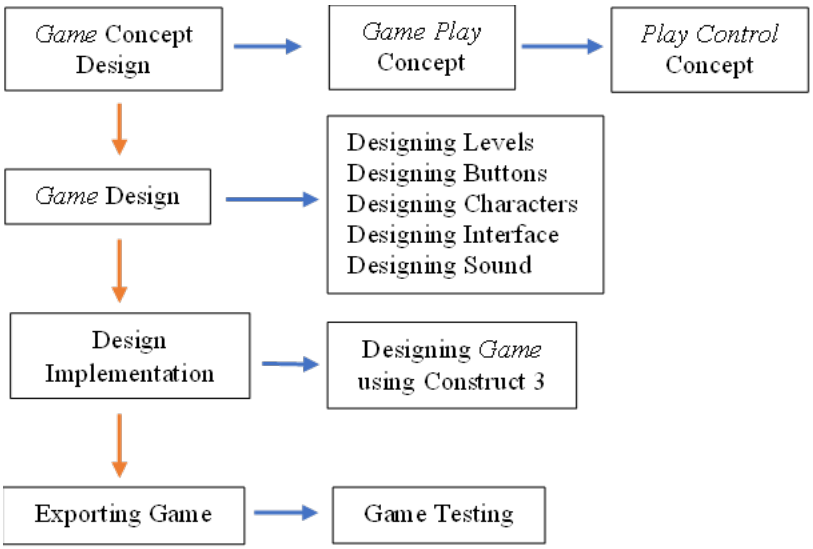

Figure 2. Game Design Flowchart

Results and Discussions

The media developed in this study was carried out through five stages of ADDIE development (Branch & Kopcha, 2014). The ADDIE stages in this study started from the preliminary analysis stage, design, development, implementation, and evaluation.

Analysis

Preliminary analysis is carried out by analyzing four categories, namely; (1) situation analysis; (2) needs analysis; (3) curriculum analysis; and (4) technology analysis. The results of a survey of 125 active students of the Mathematics Department, 77.6% have used learning media in the form of books or modules, 40.5% have used worksheets, 95.2% have used slide presentations, 20.8% have used teaching aids, and 0.8% have used application- based learning media. The survey results explicitly show that the majority of learning media used in the learning process are books, modules, and presentation slides. This condition contradicts the demands of students to use innovative and creative media in the learning process. Out of 125 students, 47.2% have the perception that Android-based game media allows them to be used as innovative learning media. Meanwhile, another 24.8% chose 3D-based simulation media and 27.2% chose AR-based E-books.

Design

At this stage, the researcher carries out activities related to preparing and designing the design of the Android-based edutainment game that will be developed. There are 3 activities at this stage: introduction, design draft, and material. First, it has been determined that the type of game to be made is an adventure, because it was easier to insert material that needs to be adapted to the game's storyline. Then, determined a few things such as game characters, game storylines, create flow charts and storyboards. Last, material preparation is carried out such as logic material, images, animations, and sound effects.

Development

The product development stage is the process of making the design that has been made into a unified whole, which is called the BM adventure game. The product development phase includes production, evaluation, and revision.

Production

The edutainment game media was developed using Construct 3 and will then be distributed to students. At this stage, the Android-based edutainment game media has been completed. Media can be used on Android smartphones (minimum version 5.1 Lollipop) and can be used on PCs with Windows, Linux, and Mac systems. The media has been exported into APK form with a size of 22 MB.

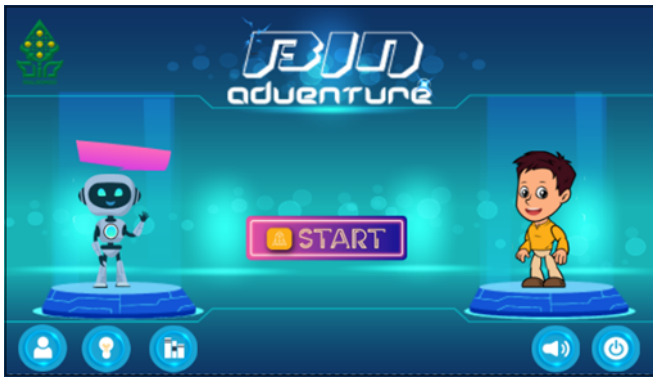

Figure 3. Main Menu Display

Evaluation

After the media is developed, the next step is formative evaluation activities. This formative evaluation was conducted to determine the level of validity of the BM adventure game media and the level of quality of the Logic material presented on the media. There are several stages in the evaluation stage:

Review by Expert

The BM adventure game is formatively evaluated by media experts. This evaluation is intended to determine the lack and level of feasibility in terms of media validity. Evaluation is carried out after the media is ready to be used and has been evaluated independently by the researcher.

Table 1. Media Validation Score

Score Interval	Category
$X > 147$	Very high
$119 < X \leq 147$	High
$91 < X \leq 119$	Moderate
$63 < X \leq 91$	Low
$X \leq 63$	Very low

Table 2. Material Validation Score

Score Interval	Category
$X > 79.8$	Very high
$64.6 < X \leq 79.8$	High
$49.4 < X \leq 64.6$	Moderate
$34.2 < X \leq 49.4$	Low
$X \leq 34.2$	Very low

Result of validation review

The media validation in the first stage is the expert validator assessing the game content. Game content assessment consists of nine aspects consisting of 35 statements. So that the maximum score that can be obtained is 175 and the minimum score is 35. The results of the validator's assessment of the media can be seen in Table 3.

Table 3. Media Validation by Validators

Assessment Aspect	Max. Score	Validator 1	Validator 2	Average
Content Quality	10	10	9	9.5
Learning Objectives	15	14	12	13
Procedures and Feedback	20	20	15	17.5
Affective	15	13	13	13
Interface Design	60	57	47	52
Interactivity	30	29	22	25.5
Accessibility	10	9	10	9.5
Usability	10	9	9	9
Standard Conformance	5	4	4	4
Total				**153**

From the table above, the assessment of media validity by experts shows that the BM adventure game media is in a very high category.

Material validation on the media has also been carried out. Validation is intended to see how appropriate the content, presentation, and visual communication are for the material presented in the game. The results of material validation on the media can be seen in Table 4.

Table 4. Material Validation by Validators

Assessment Aspect	Max. Score	Validator 1	Validator 2	Average
Content Eligibility	45	36	42	39
Presentation Eligibility	20	15	19	17
Visual Communication	30	25	28	26.5
Total				**82.5**

Based on the results of material validation on the media, an average value of 82.5 was obtained. The validated BM adventure game media was then revised by the researcher. Media revisions are made based on comments and inputs given by the validator. After the media is revised, a limited trial will be conducted.

Limited Trial

The limited trial in this study was conducted to review whether the BM adventure game media was feasible to be applied in the implementation stage or not. Through a limited trial, researchers received comments and suggestions regarding the BM adventure game media. This trial phase is carried out to minimize deficiencies and errors in the BM adventure game when used in the implementation phase.

The subjects involved in the limited trial were 4 students and 1 mathematics lecturer. BM adventure game media is given to test subjects to be used on smartphones or PCs. The test subjects were asked to run the game at least up to level 3.

Revision

Based on the results of the evaluation in the previous stage, data regarding the quality of the media, responses to the media, criticism, and suggestions from experts, lecturers and students were obtained. Several kinds of data are then analyzed to find out the weaknesses and advantages of the developed edutainment game media. Next, the researcher conducts an analysis to determine which parts need to be improved, replaced, or continued.

To get decent game media, it is necessary to revise the media based on the comments and suggestions that have been received. The revision of this BM adventure game was carried out twice and gradually. The first revision was made after getting comments and input from the validator. The second revision was carried out after the limited trial was completed.

Implementation

After the media is used in the learning process, the next activity is to carry out tests and fill out questionnaires. The test was conducted to determine the students' mathematical problem-solving ability after using the BM adventure game. While filling out the questionnaire to find out the practicality of the BM adventure game.

The assessment of mathematical problem-solving ability test results refers to the indicators of mathematical problem-solving abilities. These indicators assess how students can solve mathematical problems which are represented in four stages. First, students can understand the problem. Second, develop a settlement strategy. Third, do the completion and check the answers.

Assessment of media practicality is based on five aspects. First review how the use of media. Second, related to the ease of access, operation, and the level of difficulty of the challenges in the BM adventure game. Third, reviewing whether the media presents activities that support interactivity. Fourth, the function of media in increasing user interest. Finally, review the level of creativity that exists in the BM adventure game.

Evaluation

The evaluation stage in this study was aimed at determining the feasibility of the BM adventure game as a medium for learning mathematics in logic material. To find out whether the BM adventure game is feasible or not as a learning medium, an evaluation of three aspects is carried out. The first evaluation was carried out and see the feasibility of the BM adventure game from the aspect of its validity. Furthermore, evaluation is carried out after the media is used by students and lecturers/teachers to see the level of effectiveness and practicality.

Product Validity

The validity of the BM adventure game media was reviewed based on the results of expert validation of media content and material presented in the media. Media validation assesses nine aspects including; "(1) the quality

of media content; (2) learning objectives; (3) procedures and feedback; (4) affective; (5) interface design; (6) interactivity; (7) accessibility; (8) reusability; and (9) standard conformity". In contrast to material validation on media, material validation also has its assessment aspect. Material validation on the media reviews the feasibility of content, presentation feasibility, and visual communication.

The results of media validation by the validator are 141 and 165 respectively. Based on this assessment, obtained an average of 153. The media validation assessment concludes that the BM adventure game has a very high media validity. In addition to validating media, the validator also validates the material contained in the BM adventure game. Material validation in the media reviews three aspects including; (1) the appropriateness of the content of the material in the media; (2) the feasibility of presenting the material on the media; and (3) visual communication related to how the material is given. The results of the validation of the material on the media by experts obtained scores of 76 and 89. The conclusion of the material validation assessment in the BM adventure game has a very high material validity.

Based on the validity assessment, it can be concluded that the BM adventure game meets the validity aspect with a very high category. The validity of the BM adventure game has met the validity of the media assessment based on the LORI indicator which assesses the efficiency of media use (Leacock & Nesbit, 2007). The overall media validity assessment indicators have consistent internal quality and meet media development theories (Plomp & Nieveen, 2010). Therefore, the BM adventure game media can be said to be feasible as a medium for learning mathematics, especially on logic material from the aspect of its validity.

Product Practicality

After analyzing the validity of the media, an analysis of the results of the media practicality questionnaire was also carried out. The practicality questionnaire reviewed the practicality of the BM adventure game as a learning medium.

The summary of the results of the BM adventure game practicality questionnaire can be seen in Table 5.

Table 5. Level of the Practicality of the Media

Score	Category	Percentage
$\boldsymbol{X > 92,4}$	Excellent	0.00%
$\boldsymbol{74,8 < X \leq 92,4}$	Good	81.91%
$\boldsymbol{57,2 < X \leq 74,8}$	Fair	18.09%
$\boldsymbol{39,6 < X \leq 57,2}$	Poor	0.00%
$\boldsymbol{X \leq 39,6}$	Very Poor	0.00%

The results of filling out the practicality questionnaire of students obtained that 81.91% considered the BM adventure game as a practical learning medium on good category and 18.09% considered it quite fair practical.

Lecturers can organize practical learning using technology-based games (van Rosmalen et al., 2013). The results of the observations also show that the BM adventure game is practically used in the learning process. It is shown that the lecturers do not do many learning activities such as lectures or explaining the material. Activities are more dominated by student activities trying to complete the BM adventure game.

The practicality assessment obtained is also influenced by the easy accessibility of the media. The level of ease of accessibility is an aspect that can determine the level of practicality of the media (Bourgonjon et al., 2009). The BM adventure game has a small size of 22 MB so it does not meet the capacity of Android smartphones and PCs. In addition, the easy installation process also makes the BM adventure game a practical learning medium.

Overall the practicality of the media depends on how the management and development of the media have been done (Fuqoha, 2015). The BM adventure game is designed with attention to the challenges and missions that must be completed. Pay attention to the balance between the challenge of the game and the level of difficulty of the material presented. Management and development that pays attention to these aspects also make the BM adventure game practical as a medium for learning mathematics, especially in studying logic material.

Product Effectiveness

The evaluation of the BM adventure game media after it is declared valid and practical, an assessment of its effectiveness will be carried out. The assessment of the effectiveness of the media was reviewed based on the results of the mathematical problem-solving ability test. The mathematical problem-solving ability test reviews four indicators, including: 1) the ability to understand the problems presented; 2) formulating a settlement strategy that will be carried out; 3) perform the solution with mathematical operations or analysis; and 4) re-examine the correctness of the results or answers that have been obtained.

The mathematical problem-solving ability test focuses on the material that has been taught through the BM adventure game, namely the material of mathematical logic. The results of the mathematical problem-solving ability test will be used to assess the feasibility of the media from the aspect of its effectiveness. BM adventure games are said to be effective if they meet the following two criteria; 1) more than 80% of students have mathematical problem-solving skills at least in the high category; and 2) the average student's mathematical problem-solving ability is at least in the high category.

The summary of the results of the mathematical problem-solving ability test can be seen in Table 6.

Table 6. Mathematical Problem-Solving Ability Test Results

Score	Category	Percentage
$X > 80$	Very High	12.77%
$60 < X \leq 80$	High	68.09%
$40 < X \leq 60$	Moderate	17.02%
$20 < X \leq 40$	Low	2.13%
$X \leq 20$	Very Low	0.00%

The results of the mathematical problem-solving ability test have met the first effectiveness criteria. Analysis of the test results showed that 68.09% of students' mathematical problem-solving ability scores were in the high category and 12.77% were in the very high category. Therefore, 80.85% of students have mathematical problem-solving skills in the minimally high category. In conclusion, the results of the mathematical problem-solving ability test meet the first criteria, namely more than 80% of students have mathematical problem-solving abilities at least in the high category.

Furthermore, the results of the mathematical problem-solving ability test also meet the second effectiveness criteria. In summary, the average mathematical problem-solving ability test of students can be seen in Figure 4. The results of the analysis show that the average mathematical problem-solving ability test is 68.34. If the average is converted to the effectiveness category, then the high category is obtained.

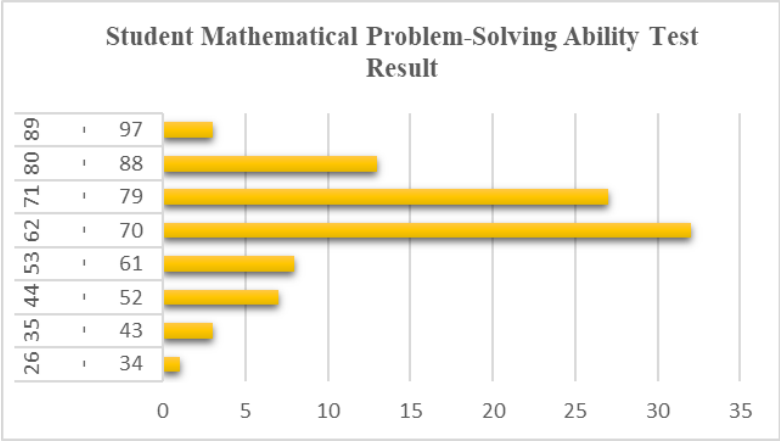

Figure 4. Diagram of Mathematical Problem Solving Ability Test Results

Based on the analysis of the mathematical problem-solving ability test, it can be concluded that the BM adventure game meets the effectiveness criteria. The analysis that has been done also shows that the effectiveness criteria obtained are in a good category. Therefore, the BM adventure game can be said to be feasible as a medium for learning mathematics from the aspect of its effectiveness.

The results of this study illustrate that a well-organized game can be an effective medium for learning mathematics. Through a series of activities that have been passed, the BM adventure game media can become an effective medium. The results of the student's mathematical problem-solving ability test after using the BM adventure game were in the high category. Research results (Alkan & Ada, 2023) also show the same thing that through game-based learning media, students' mathematical abilities can improve much better.

If analyzed more deeply, the effectiveness of game-based media starts from its function which can attract students' interest. The results of Ardani's research (2018) also show that game-based media can significantly increase interest in learning. This is because learning media in the form of games that present challenges and contain competition have great opportunities in increasing student interest in learning (Cagiltay et al., 2015). Furthermore, high interest in students will certainly encourage students to make more efforts. Self-interest can

encourage a person to acquire knowledge and skills using various methods (Demise, 2006). In the end, high interest can influence understanding and the ability to solve mathematical problems (Sirait, 2016).

The BM adventure game has presented several challenges and competitions that can attract students' interest in learning. In addition to the content of the BM adventure game that attracts students' interest, the delivery of material designed in the game also influences students' mathematical problem-solving abilities. The material presented in the game is not described directly, but students need to analyze and complete challenges to find out the concepts and principles being studied. The process of discovering the concepts and principles being studied, emphasizes deep understanding. This is because the learning process that involves direct activities makes information more secure in entering long-term memory (Bailey, 2017).

Conclusion

The development research that has been carried out has produced a product, namely an Android-based edutainment game to improve the mathematical problem-solving ability of prospective mathematics teachers, which is named the BM adventure game. The BM adventure game development process is carried out using the ADDIE development stage. After the BM adventure game was developed, an assessment was carried out to review the feasibility of the media. The results of the assessment show that the BM adventure game meets the following criteria: 1) The results of the expert's assessment show that the BM adventure game meets the aspects of validity both in terms of media content and the material presented. There is a category of validity obtained from the very high expert judgment; 2) The results of practicality assessments by both lecturers and students show that the BM adventure game meets the practicality criteria, 81.91% of students considered that the media met the good category; 3) The results of the mathematical problem-solving ability test show that the BM adventure game meets the effectiveness criteria, namely: a) 80.85% of students have mathematical problem-solving skills at least in the high category; and b) the average mathematical problem-solving ability of students is 68.34 which is included in the high category.

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