Development of Android-based Mathematics Educational Game

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Article Info

Article History

Received:
10 June 2025
Accepted:
11 November 2025

Keywords

Android
Educational game
Linear equation
Valid
Practical

Abstract

The advancement of information and communication technology (ICT) supports its integration into education, including the use of Android-based learning media such as educational games. Responding to students' needs in learning linear equations, an Android-based math game named Petualangan PGL was developed. This study aims to design and test the validity and practicality of this game as a learning medium. The research employed the van den Akker development model, consisting of preliminary analysis, design, and evaluation or revision stages. The final product is an Android game accessible online via smartphones. Expert validation involving three specialists in learning media and mathematics showed high validity, with media and learning material scores of 90% and 94%. Student response results indicated a high level of practicality at 85.32%, confirming its suitability for classroom use. The game includes three main features: account login, gameplay with three levels, and a scoring system. Hence, Petualangan PGL is recommended as an effective digital medium for mathematics learning.

Introduction

The development of information and communication technology (ICT) is beneficial in everyday life and also provides entertainment (Huda, 2020). The development of ICT also provides benefits in various fields, including education. One of the uses of ICT is the Android operating system. The Android operating system is a Linux-based operating system developed by Google for smartphones and tablets (Adminuin, 2024). Android is open source, allowing users to access and download applications from Google Play, such as games. A game is a form of entertainment with rules that players must follow (Najuah et al., 2022). Mobile games are downloaded onto mobile devices. Each game has its own unique features and appeal. According to Alwi et al (2023), people generally like action, adventure, and RPG games. The rapid development of ICT has made games not only a form of entertainment but also a tool for education, such as educational games. Educational games are a type of media used to increase the insight and knowledge of users (Najuah et al., 2022). Educational games have a significant influence on student motivation (Ren & Liu, 2024). Educational games are a unique and engaging learning medium that can be applied in various subjects, including mathematics.

Mathematics learning is an interactive learning activity that aims to improve students' problem-solving skills and concept construction (Gusteti & Neviyarni, 2022). One of the topics discussed in mathematics learning is linear equations. The learning material on linear equations is often considered difficult because students have

difficulty understanding formulas, calculations, and modeling problems into mathematical forms. Using learning media that is interesting and relevant to the material on linear equations can be an effective way to improve students' understanding and help them overcome learning difficulties (Novitasari & Fathoni, 2022). Students' mathematics learning outcomes can be improved through the use of relevant and effective learning media (Rachman et al., 2023). Students become more active and learning becomes more enjoyable if the learning media used is interesting. Game-based learning can significantly improve children's cognitive abilities, such as problem-solving, memory, and attention. It has a positive impact on children's social skills, such as cooperation, communication, and empathy. It helps children develop better emotional regulation skills and reduces negative emotions, such as anxiety and aggression. It increases children's motivation and engagement in learning. In addition, it also increases children's engagement in learning (Alotaibi, 2024).

Technology-based learning has great potential to improve education in Indonesia (Aliyah & Masyithoh, 2024). The use of digital learning interventions in mathematics teaching can help improve student performance (Quilloy, 2022). ICT can be integrated into mathematics learning media, including educational games. Mathematics educational games can be mobile games in the form of Android-based educational games. Learning media in the form of Android-based educational games can increase student motivation and interest in learning (Sarifah et al., 2022). According to Choir and Abdullah (2021), integrating Android-based interactive learning media into the learning process positively impacts student learning achievement. Digital learning media also has a positive effect on students both in their free time, inside and outside of school, due to the ease of accessing information from technology (Joshi et al., 2025). Good learning media must, of course, go through several stages before they can be used in learning. According to Chaeruman (2019), a comprehensive validation process involving experts in subject matter, learning design, learning media, and communication, as well as users, guarantees the quality of good learning media.

The development of Android-based educational mathematics games has been carried out by previous researchers. Research conducted by Enjelita, Oktaviana, and Ardiawan (2023) developed an Android-based educational game using Construct 2 software and two-dimensional (2D) graphics. In addition, research conducted by Yuliana, Firdaus, and Oktaviana (2022) also developed an Android-based educational game using Construct 2 software and two-dimensional (2D) graphics. However, the development of 3D-based educational games is still limited. Furthermore, the development of educational games with a First Person Perspective (FPP) is still limited, making it interesting to create such games with 3D graphics. Based on the problems and potential described, the researcher attempted to design an Android-based educational mathematics game called Petualangan PGL using Unity 3D software. Therefore, this study aimed to develop a valid and practical Android-based educational game learning medium using Unity 3D software to increase student motivation in learning mathematics, specifically linear equations.

Method

This study employed the development research method using the Akker model (Akker et al., 2013). This model has systematic procedures and is suitable for use in the development of learning media (Akker et al., 2013). The

development of learning media products involved three primary stages, namely (1) preliminary analysis stage, (2) design stage, and (3) evaluation and revision stage. In the preliminary analysis stage, the researchers determined the endpoint, starting point, and local construction theory. In the design stage, the researcher designed an educational media product in the form of an Android-based mathematics educational game using Unity 3D software and tested the functions contained in the game. In the evaluation/revision stage, the researcher tested the validity and practicality of the game in junior high schools.

The instruments used in this study were media validation sheets, learning material validation sheets, and student response questionnaires. The media and learning material validation sheets were used to obtain validity data from validators regarding educational games. This included both media aspects, such as the functions within the game, and the problems contained in the game from the learning material on straight line equations. The student response questionnaire was used to obtain practical data on the use of educational games in learning. The analysis of the validity and practicality data of educational games used the following formula.

$$P = \frac{\sum_{i=1}^{n} x_i}{\sum_{j=1}^{n} x_j} \times 100\%$$

Where: P : Product Percentage

$\sum_{i=1}^{n} x_i$: total score of expert assessment answers

$\sum_{j=1}^{n} x_j$: total highest answer score

Results

The media developed in this study is an Android-based educational mathematics game. The results of this Android-based educational game development study are based on three main stages, namely (1) the preliminary analysis stage, (2) the design stage, and (3) the evaluation and revision stage (Akker, 2013).

Preliminary Analysis Stage

At this stage, an initial identification of students' needs regarding educational games is carried out. The initial identification begins with determining the difficulties and learning needs of students regarding linear equation material. Next, a literature study is conducted to identify the difficulties students have in understanding linear equation material. The results of the literature study show that: (1) Students experience difficulties and confusion when encountering non-routine linear equation problems related to real life (Setyaningsih & Firmansyah, 2022). (2) Students are inaccurate in applying formulas, fail to apply formulas, and have difficulty calculating sequentially (Sehajun & Tambunan, 2021). (3) There is a lack of understanding of the concept of solving problems; students experience difficulties when operating with non-natural numbers and difficulty in determining the inverse operation of solving equations (Holmlund, 2025). (4) Students have difficulty reading the problems, difficulty reading graphs, and a lack of understanding in constructing data in tables (Kenney & Ntow, 2024). (5) Difficulties in understanding the formulas used in the problems, lack of ability in calculating the answers, and difficulties in modeling the problems into mathematical form (Elagha & Pellegrino, 2024).

Based on the literature review conducted, it can be concluded that students experience difficulties in learning linear equation material, such as determining formulas, reading graphs, modeling problems into mathematical form, and understanding everyday life-related problems.

To overcome and prevent students' learning difficulties in studying linear equation material, learning media are needed to assist students in their learning (Hasan et al., 2021). Digital-based learning media such as Android-based educational games can engage students, increase their motivation, and positively influence their behavior towards learning mathematics (Norshahimi et al., 2024). Android-based mathematical educational games were developed to support students' learning process. Mathematical educational games were developed to motivate students to deepen their knowledge of linear equations.

Design Stage

After identifying students' learning difficulties, an Android-based educational math game was designed for development. During the development process, software and hardware were used to develop the Android-based educational math game. The design process was carried out in several stages, namely:

Game Flowchart

A flowchart depicts all events in a system as a diagram connected by lines or arrows. Flowcharts are used to ensure a clear system flow, preventing errors in the interpretation and use of the developed application.

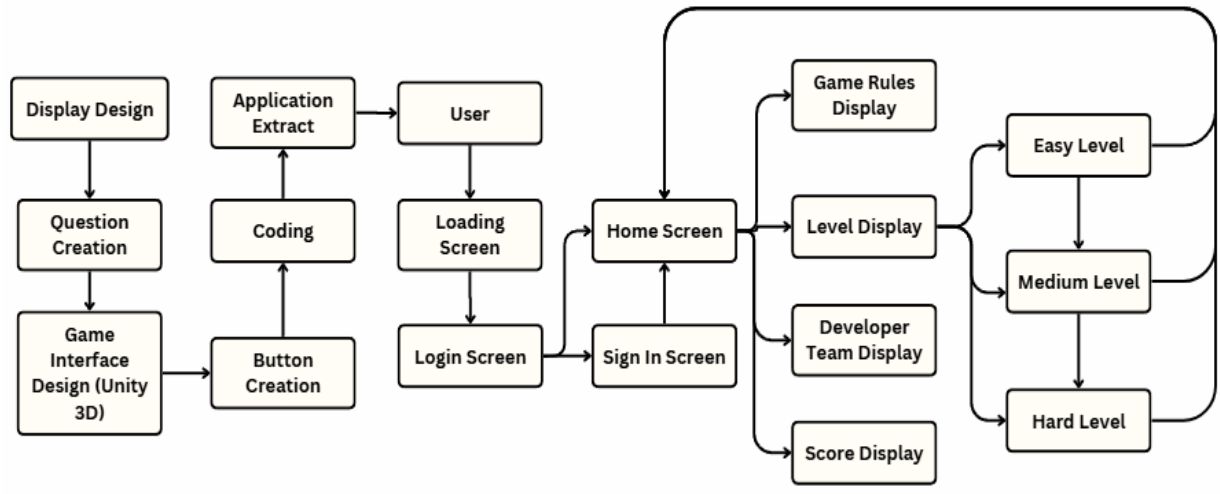


Figure 1. Flowchart of Petualangan PGL

Use Case Diagram

This diagram provides users with an overview of the things that can be done in a system. Use case diagrams are often used to describe the processes that occur in a system, emphasizing what users can do.

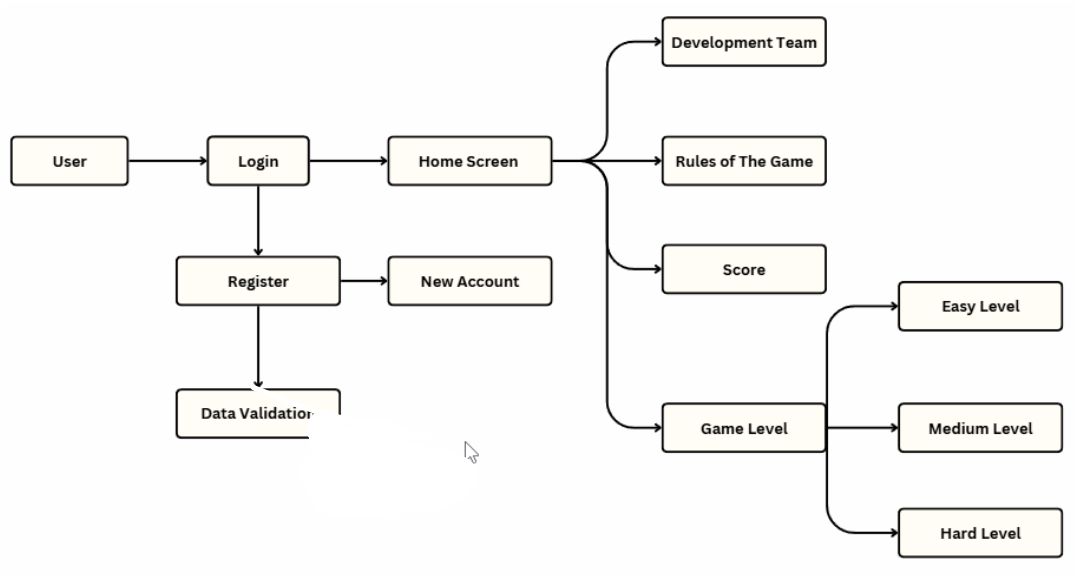


Figure 2. Petualangan PGL Use Case Diagram

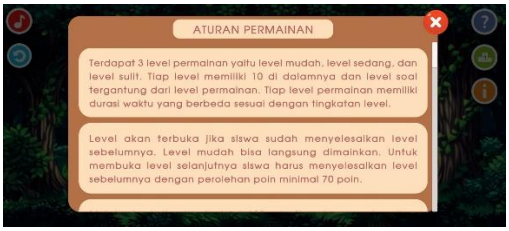
User Interface

The User Interface (UI) aims to provide an overview of the appearance of a developed system, thereby reducing misinterpretation and ensuring that it meets user expectations. UI design includes the initial appearance of an application and the limited interactions available to users.

a

b

c



d

e

f

g

h

Figure 3. a. Login UI, b. Account Registration UI, c. Homescreen UI, d. Game Rules UI, e. Development Team UI, f. Level Scoring UI, g. Game Level UI, h. In-Game UI

Code

The programming or coding stage aims to transfer the game design results into a predetermined programming language. All designed parts are converted into code, which is then exported into an application.

Evaluation/revision Stage

The evaluation/revision stage was conducted to test the developed Android-based mathematics educational game through validity and practicality tests. The media validity test was conducted by validators, while the practicality test involved Year 8 students. The validators were lecturers specializing in learning media and junior high school mathematics teachers.

Media Validation

Media validation was conducted to gather suggestions and input for improving the Android-based mathematics education game that had been developed (Sugiyono, 2013). Media validation assessment was conducted on five assessment indicators, namely ease of use, text, display, sound, and integration. The results of media validation are presented in Table 1.

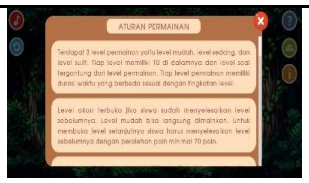
Table 1. Media Validation Results

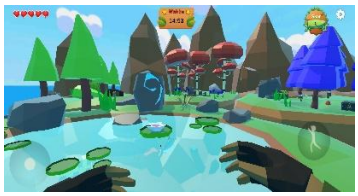
Validator	Percentage of Validity (%)					Average
	Ease Of Use	Writing	Appearance	Sound	Integration	
VPS	80%	80%	100%	100%	100%	92%
TZ	87%	95%	100%	80%	80%	88%
AT	73%	80%	90%	100%	100%	89%
Average	80%	85%	97%	93%	93%	90%
Validity Level	Valid	Highly Valid	Highly Valid	Highly Valid	Highly Valid	Highly Valid

Table 1 shows that the validation of the Android-based mathematics education game is highly valid. Ease of use received a score of 80%, writing received a score of 85%, appearance received a score of 97%, sound received a

score of 93%, and integration received a score of 93%. The average validity assessment score is 90% overall, which is classified as highly valid. The validators provided several suggestions for improvement to enhance the quality of the Android-based math education game, thereby producing a better product.

Table 2. Validator Suggestions and Improvements Made

No	Fitur	Before Revision	After Revision
1.	Before starting, there should be game instructions.	Nothing	 The game instructions are displayed on the initial screen and can be viewed by pressing the game instructions button.
2.	There should be a display for the development team.	Nothing	 The developer team display is on the wall display and can be viewed by pressing the developer team button.
3.	Adjust the time for each level according to the students' abilities. Then change the color of the time and score to black.		 The time for each level is adjusted according to the students' abilities. The easy level has a time limit of 15 minutes, the medium level has 20 minutes, and the advanced level has 30 minutes.
4.	The chest detector is smaller.		 The chest detector has been reduced in size, so characters must be very close to open it..

5.	The run button should be removed.		 The run button was removed because it wasn't beneficial for the character.
6.	It is best to give the character a location to revive, not far from where the character fell into the ravine.		 All islands at each level have one place for characters to revive if they fall into a ravine.
7.	The run and jump buttons have been enlarged to make them easier to press.		 The run and jump buttons have been enlarged to make it easier for students to press them.

Learning Material Validation

Learning material validation was conducted by asking validators to assess the developed problems. The problems consisted of three levels, namely ten easy problems, ten medium problems, and ten difficult problems. The assessment was carried out based on three indicators: learning material, problems, and language. The results of learning material validation are presented in Table 3.

Table 3. Learning Material Validation Results

Validator	Percentage of Validity			Average
	Learning material	Problem	Language	
VPS	100%	94%	95%	96%
TZ	90%	89%	90%	90%
AT	100%	91%	95%	95%
Average	97%	91%	93%	94%
Validity Level	Highly Valid	Highly Valid	Highly Valid	Highly Valid

Table 3 shows that the validation of the learning material in the form of problems related to linear equations is categorized as highly valid. The learning material received a validity score of 97%, the problems received a validity score of 91%, and the language received a validity score of 93%. The average validity assessment result achieved an overall validity score of 94%, placing it in the highly valid category. The validators also provided suggestions for improvements to the problem learning material in the Petualangan PGL game.

Table 4. Suggestions from Validators Regarding Test Learning Materials

No.	Validator Name	Suggestions and Comments
1.	VPS	- The learning material presented in the educational game is excellent and challenging at the difficult level.
2.	TZ	- One of the problems at the easy level has been adjusted again. - One of the problems at the difficult level is unclear and needs to be corrected first. - The proportion of difficult problems has been varied again.
3.	AT	- There are several difficult-level problems with the same concept; choose one and replace the others. - The equation form of one of the problems at the easy level has been changed to $\boldsymbol{y = mx + c}$

Student Response Questionnaire

Practicality data was obtained using a TAM questionnaire by giving response questionnaires to students. Student response questionnaire data is the students' assessment of the Android-based math education game. Student response questionnaire data were used to measure whether the Android-based math education game was practical and if the application functioned properly. Before the questionnaire was distributed, Year 8 students were first introduced to the Petualangan PGL educational game. An explanation was given about the game, including its features and content. After the students were introduced to the Petualangan PGL game, they then filled out the questionnaire based on their assessment of it. The results of the student responses based on the questionnaire are presented in Table 4.

From the explanation of the TAM instrument in Table 4, it can be understood that students' views are based on factors such as perceived usefulness (PU), perceived ease of use (PEU), attitude toward using (ATU), and intention to use (ITU). In this study, the usefulness variable (PU) was measured using three statement indicators. The average PU score was 4.24, with an 84.73% agreement percentage, indicating that, on average, students agreed with the statements presented. The opinions given by students indicate that the Android-based mathematical education game Petualangan PGL provides benefits when used in learning, both in and outside the classroom. Overall, the average practicality score of the Android-based mathematical education game Petualangan PGL was 85.32%, which is considered very practical. This aligns with previous research findings,

which state that Android-based mathematical education games can improve students' understanding of mathematical concepts (Enjelilta et al., 2023). Android-based learning media, such as Android-based mathematical education games, can increase student learning motivation (Andriani & Suratman, 2021).

Table 4 Student Response Questionnaire Results

Variable	nI	$\sum x_i$	$\sum x_j$	Average	Percentage	Criteria
Perceived Usefulness (PU)	3	394	465	4.24	84.73%	Very Practical
Perceived Ease of Use (PEU)	3	373	465	4.01	80.22%	Very Practical
Attitude Toward Using (ATU)	3	418	465	4.49	89.89%	Very Practical
Intention to Use (ITU)	3	402	465	4.32	86.45%	Very Practical
Total	12	1587	1860	17.06	85.32%	Very Practical

Discussion

The development of digital learning media has become a significant innovation in enhancing students' understanding of mathematical concepts. This study developed an Android-based mathematical education game entitled Petualangan PGL using a Research and Development (R&D) approach based on the Akker (2013) model, which includes three main stages: initial analysis, design, and evaluation and revision. This game was designed using Unity software and features a login menu, game rules, a developer team, scores, and three difficulty levels (easy, medium, and difficult). Each level contains problems with varying degrees of difficulty. Development was carried out in stages to produce a valid and practical product as a mathematics learning medium (Sugiyono, 2013; Hasan et al., 2021).

Preliminary analysis shows that students still have difficulty understanding linear equation material, especially in determining formulas, reading graphs, and modeling contextual problems into mathematical forms (Yuliani et al., 2023). These difficulties also reduce student motivation and engagement during the learning process. To overcome this problem, interactive learning media are needed to improve students' conceptual understanding. According to Hasan et al. (2021) and Yuniarti et al. (2023), the use of digital learning media such as Android-based educational games can foster interest and motivation to learn through attractive visual displays and challenging game systems. In addition, Ramadhan et al. (2022) added that educational games can also improve students' problem-solving skills.

The validation results show that the Petualangan PGL learning media obtained a media validity level of 90% and a learning material validity of 94%, both classified as "highly valid." The assessment tool includes 30 linear equation problems arranged based on three levels of difficulty. These findings are in line with previous studies

stating that Android-based mathematics educational games are effective in improving students' understanding and motivation (Enjelilta et al., 2023; Andriani & Suratman, 2021). This is also in line with the findings of Qohar et al. (2021), which indicate that learning media in the form of Android-based educational games makes students excited to learn. Students who initially considered mathematics a scary subject changed their perception after using these games. After revising the design and adding features, the practicality test results showed an average score of 85.32% in the "very practical" category. However, the lowest score was in the aspect of perceived ease of use, as some students still experienced difficulties during the installation process and adapting to game controls, especially those less familiar with Android-based smartphones.

Overall, the implementation of Petualangan PGL demonstrates a high level of student learning activity, with students actively discussing and competing to solve problems. This game has several advantages, such as an attractive interface, a motivating scoring system, and a FPP game mode that provides an interactive learning experience (Rohani, 2020; Yuliana et al., 2022). In addition, this game can be accessed independently outside of class, thus supporting flexible learning. However, this game still has several limitations, such as not being available on the Play Store, being compatible only with the Android operating system, and requiring teachers to direct and supervise its use to prevent misuse for non-learning activities. Therefore, Petualangan PGL is considered a suitable innovative learning medium to enhance student motivation and understanding of linear equation material, with potential for further development in accessibility and cross-platform integration.

Conclusions

Based on the results of the research and discussion presented, it can generally be concluded that the development of Android-based educational mathematics games using Unity 3D software on student motivation in Year 8 linear equation using the Akker development model, which consists of three stages, namely (1) the preliminary analysis stage, (2) the design stage, and (3) the evaluation/revision stage, is in line with the initial research objectives, making the developed Android-based educational math game valid and practical. The Petualangan PGL game has three main features, namely (1) an account login/registration feature, (2) a play feature with three levels, namely easy, medium, and difficult, with interesting games, and (3) a score display feature that displays the highest scores of students from each level that students have played. The Petualangan PGL game application uses 3D graphics and the adventure genre with a First Person Perspective (FPP) game type. The learning material in the Petualangan PGL game has been adapted from the junior high school mathematics textbook for the independent curriculum.

The results of media and learning material validation conducted by validators show that the Android-based mathematics educational game obtained an average media validity of 90% and a learning material validity of 94%, both in the highly valid category. The Petualangan PGL game meets the criteria for high validity. The Petualangan PGL game is suitable for helping students overcome difficulties and increase their motivation to learn material related to Linear Equations (PGL).

The results of a student response survey showed that Android-based math education games received a rating of

85.32% in the "very practical" category. The Android-based math education game Petualangan PGL meets the criteria for being very practical. The Android-based math education game Petualangan PGL is easy to use, helps students learn, and aids in understanding the learning material.

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