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Development of Educational Games Based on Design Thinking to Improve Mathematical Thinking Skills

Muhtarom [1], Sugiyanti [2], Muhammad Saifuddin Zuhri [3], Nur Latifah Dwi Mutiara [4], Hendrisa Adrillian [5], Milagros Baldemor [6]

[1] Universitas PGRI Semarang, Indonesia; muhtarom@upgris.ac.id
[2] Universitas PGRI Semarang, Indonesia; sugiyanti@upgris.ac.id
[3] Universitas PGRI Semarang, Indonesia; zuhriupgris@gmail.com
[4] Universitas PGRI Semarang, Indonesia; nurlatifah@upgris.ac.id
[5] Universitas PGRI Semarang, Indonesia; adrillian92@gmail.com
[6] Don Mariano Marcos Memorial State University, Philippines; mbaldemor@dmmmsu.edu.ph

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Abstract

The development of technology has a significant impact on the world of education. One of them is the use of games as a learning medium. This study aims to develop an educational game integrated with a live worksheet. The development research was conducted using a design thinking approach. The design thinking stages are carried out through five steps: empathize, define, ideate, prototype, and test. The feasibility of educational games is reviewed based on expert assessments, the practicality of educational games is reviewed based on student response questionnaires, and the effectiveness of educational games is reviewed based on the results of field trials. A total of thirty students of SMP Muhammadiyah 5 Semarang became research respondents. The study results showed that educational games are feasible for mathematics learning, with an Aiken V value of 0.93. The practicality test results showed that students responded to 88.67%, with a very good category. The effectiveness test of using educational games with SPSS using the Wilcoxon Signed Test obtained a Sig. 2-tailed value of 0.000 <0.05. This shows that educational games can improve students' mathematical thinking skills in data presentation materials. This study suggests improvements in creating educational games that need to pay attention to interesting storylines and the placement of practice questions to increase students' motivation in learning mathematics.

Keywords Al Educational Games; Mathematics; Mathematical Thinking; Liveworksheet

Corresponding Author
Muhtarom
Universitas PGRI Semarang, Indonesia; muhtarom@upgris.ac.id

1. INTRODUCTION

Mathematics is used in various aspects of daily life (Szabo et al., 2020; Zhang & Zhang, 2023). However, learning in Indonesia focuses on students' cognitive abilities and does not foster students' mathematical thinking (Jatisunda et al., 2020). The research concluded that students experienced difficulties in mathematics because they could not make connections between materials and had difficulty applying concepts to complex questions. Mathematical thinking skills help students form ideas (Ahdhianto et al., 2020; Yayuk & As'ari, 2020). Students who can think mathematically can

interpret problems from another point of view.

The data presentation material taught to grade VII students is one of the important materials in mathematics learning because it can train students' mathematical thinking skills, especially in data analysis and representation. This material allows students to understand processing and presenting information more systematically and easily. Data presentation includes various forms of representation, such as tables, bar charts, line charts, and pie charts. By mastering this material, students are expected to be able to transform raw data into informative and easily analysed visual displays, both by themselves and others. This ability is important because it trains logic, accuracy, and data interpretation skills, which are very much needed in everyday life and for advanced learning (Hudiburgh & Garbinsky, 2020). However, even though this material has many benefits, a few grade VII students have difficulty teaching it. Many students are not used to processing data and do not understand the right steps to present data in diagrams or tables. Common mistakes that often occur include mistakes in determining the scale, choosing the right type of diagram, or interpreting the meaning of the data that has been presented. These difficulties indicate that a more interactive and contextual learning approach is needed so that students can better understand the concept of data presentation (Latifah & Afriansyah, 2021). Therefore, teachers need to provide learning media that can help students develop skills in presenting and analysing data in a fun and meaningful way.

There are still many one-way learning methods, where the teacher is the centre of information and students play a passive role as recipients of the material. This approach often makes students feel bored, less motivated, and have difficulty understanding abstract concepts. Monotonous learning is the cause of students' difficulties in learning mathematics (Ahdhianto et al., 2020; Jatisunda et al., 2020; Yayuk & As'ari, 2020). Students also quickly feel bored during mathematics learning because learning is monotonous (Muhtarom et al., 2023). In conditions like this, the effectiveness of the learning process becomes less than optimal, especially in building deep conceptual understanding and emotional involvement of students in the material being taught. Media applications can help improve students' mathematical thinking abilities (Amri & Setyaningrum, 2022). Using technology in learning media in games can create students' curiosity to complete games (Amri & Setyaningrum, 2022; Foriansyah & Taurusta, 2022). Games that contain educational content and are applied in the learning process can be said to be educational games. Educational games are a medium used in learning to increase users' knowledge through unique and exciting media (Cheung & Ng, 2021; Lamrani & Abdelwahed, 2020). Educational games can present learning material or content created in the form of games to attract students' attention to learning, so that students do not get bored quickly and can understand the material provided (Amri & Setyaningrum, 2022; Korkmaz, 2021).

Research on educational games has been produced by several researchers, namely Amirulloh et al., on fractional number material (Amrulloh et al., 2019). Then, research by Mubharokh et al., with products in the form of games played on computers, can improve student learning outcomes, so it can be said that educational games are valid, practical, and effective for use in mathematics learning (Mubharokh et al., 2021). The research results suggest developing mathematics educational games that can be used on Android phones, so that the use of mathematics educational games is more flexible. Apart from that, existing educational games do not contain worksheets to determine students' mathematical thinking abilities when using this educational game. Therefore, it is necessary to integrate interactive worksheets in developing mathematics educational games. This interactive worksheet was created using the live worksheets application. Applying live worksheets in learning can train students' mathematical thinking skills (Nurjiah et al., 2024; Rusmiati et al., 2024; Widianti et al., 2024; Zainal et al., 2024).

The description above highlights the importance of developing educational games to improve students' mathematical thinking abilities. The educational game created is a role-playing (RPG) type with a storyline linked to data presentation material. This game also has challenges, namely "monster" characters that will be encountered and must be defeated in the storyline. The formulation of the

problem in this study is how to develop educational games that can improve students' mathematical thinking skills. A thinking design approach will be integrated into the development of educational games. This study aims to determine the validity, practicality, and effectiveness of educational games based on thinking design to improve students' mathematical thinking skills.

2. METHODS

This research is included in the development research (R&D) to develop educational games (Okpatrioka, 2023). The development model used is the Design Research model with the following stages: (1) preliminary research, (2) prototyping stage, and (3) assessment stage (Akker et al., 2006). In carrying out the research, it was guided by a design thinking approach with an innovation process and problem-solving. The design thinking approach goes through 5 phases or stages of the Stanford School of design thinking, namely: the empathize stage, the define stage, the ideate stage, the prototype stage, and the test stage (Saolina et al., 2024; Schmarzo, 2017).

The preliminary research stage is an analysis to find problems and find solutions that can overcome them using the stages in design thinking, where the empathize stage is to gain an understanding of the characteristics of students and teachers (Schmarzo, 2017), and collect information related to what needs support the development of educational games (Jayanti & Purwosetiyono, 2024; Utomo et al., 2024). The define stage is to understand and analyse the results obtained in the empathise stage (Kijima et al., 2021; Luka, 2019; Rusmann & Ejsing-Duun, 2022; Schmarzo, 2017). The ideate stage is to design solution ideas from the results of the previous stage analysis (Foriansyah & Taurusta, 2022; Luka, 2019; Utomo et al., 2024). The design of the educational game researcher has a main menu that contains several buttons, namely CP, material menu, LKPD, and game menu. Then, the material menu contains a collection of explanations related to mathematics teaching materials. Furthermore, the most important part of the game menu contains several games that can be completed by mastering the material before using it (Foriansyah & Taurusta, 2022; Korkmaz, 2021; Novia et al., 2020). The games are related to the material in the material menu. Therefore, students are expected to study the material before playing the game.

The prototyping stage is a product development phase that is an important part of design thinking. Educational games are designed to be student-centred because prototypes allow designers to test ideas and improve them. There are three stages of development, namely the stage of developing educational games, validating them with validators, and making revisions according to suggestions from validators (Amri & Setyaningrum, 2022). The assessment stage is the stage of testing the feasibility or readability of educational game products that have been developed (Luka, 2019). At this stage, educational games were implemented on SMP Muhammadiyah 5 Semarang grade VII students. The respondents in this study were 30 students.

The research data were collected using expert validation sheets, student response questionnaires on the practicality of educational games, and students' mathematical thinking ability tests. Expert validation data was used to determine the validity of the educational game developed by the researchers. The validation data analysis used the Aiken V formula. To determine the validity of the Petualang Statistika educational game, the results of Aiken's V coefficient that had been obtained were compared with the Aiken's V table value seen through the Aiken's table index (Ulfah et al., 2020). Student response questionnaire data on the practicality of educational games were obtained during the trial of the final product research of educational games (Amri & Setyaningrum, 2022). Data from student responses in using educational games were analysed using the following formula:

$$\text{PNRS} = \frac{\sum_{i=1}^{n} \text{NRS}}{\text{NRS}_{\text{max}}} \text{ x } 100\%$$

Information:

PNRS = percentage of student response scores

NRS = total value of student responses to each statement item

NRS_{max} = maximum student response value

n = number of respondents

The next step is to determine the student response category by comparing the percentage of PNRS with Table 1 (Andriani et al., 2021).

Table 1. Student Response Questionnaire

Results of Calculation	Interpretation
PNRS ≥ 85%	Very Good
70% ≤ PNRS < 85%	Good
50% ≤ PNRS < 70%	Fair
PNRS < 50%	Poor

Meanwhile, the effectiveness of the developed educational game can be analysed through pretest and posttest data. Analysis of pretest and post-test results was compared using the Wilcoxon signed test, which is used to measure differences between two groups of paired data with an ordinal or interval scale, but does not have a normal distribution (Windi et al., 2021)The results of this evaluation will determine the validity, practicality, and effectiveness of the educational game being developed.

3. FINDINGS AND DISCUSSIONS

Preliminary Research Stage

In this phase, the researcher created a questionnaire containing several questions that would be used to collect initial data from seventh-grade students and mathematics teachers who taught seventh grade in the Merdeka curriculum. Then, the questionnaire was distributed to students and teachers. Analytical information to determine problems experienced by students and teachers. The results of a questionnaire for 62 students showed that students liked statistics material because of the logical thinking and calculation skills taught in statistics. Most students have difficulty learning mathematics, especially statistics material, because the material is difficult to understand, and the teacher's way of teaching is still using lectures. Figure 1 shows the results of a questionnaire on the causes of students' difficulties. Most students also expressed that they hope teachers teaching statistics material in class can make learning more enjoyable by applying interesting methods and providing more challenging math games. However, the majority of teachers experience difficulties in creating educational games that are interesting for students.

Researchers used the empathic principle, where the problems and needs of students and teachers were stated specifically in formulations using the Point of View and How Might We techniques (Febriansari et al., 2023; Luka, 2019).

a. Defining the Problem with Point of View

Point of view is a way of obtaining user information to obtain solution design ideas. Point of view functions to obtain problem statements described by students and teachers as information for creating

solution design ideas. Researchers defined the problem of 62 respondents from seventh-grade students in the independent curriculum, namely that students considered mathematics lessons less interesting and boring.

b. How Might We

How Might We is a method for exploring as many ideas as possible to solve a problem or challenge by changing a statement into a question. Researchers compile the information needed for each problem solution and how to solve the problem that will be addressed.

In the ideation stage, researchers began to design a game and determine the material used in seventh grade, namely statistics and data presentation sub-material. They also collected practice questions that could train students' mathematical thinking skills. In the initial stage, the researcher conceptualised the content flow of the Statistical Adventure educational game, which can be seen in Figure 1.

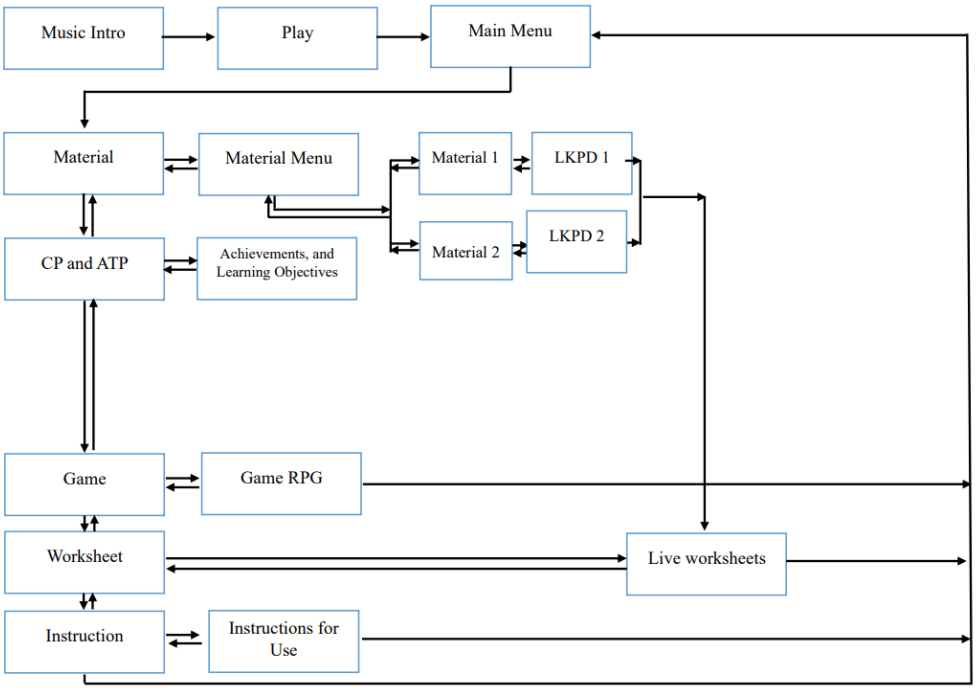


Figure 1. Game Application Flowchart

Prototype Stage

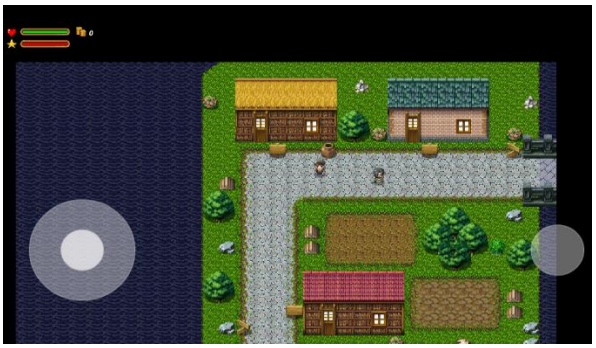
The initial stage was to design the main menu of the educational game and select the introductory music. The main menu consists of several buttons: learning achievements (CP) and flow of learning objectives (ATP) buttons to display learning achievements and learning objectives in the statistics adventure application, a material button that contains a summary of data presentation material related to LKPD and games, an LKPD button to display LKPD assisted by a live worksheet, a game button to start the adventure game, and a button for instructions on using the statistics adventure application. Figure 2 shows the main menu display of the Adventure Statistics educational game application.

Figure 2. Main Menu Display

In the next stage, researchers began to design the characters used in the game using the RPG Maker MV application, which can be seen in Figure 3. The characters developed consist of main characters (students and teachers), supporting characters (shop sellers), and enemy characters (characters who must be defeated when playing the game so that students can continue the material).

Figure 3. Game Character Design with the RPG Maker MV Application

Researchers developed a map students had to go through while studying Statistics material in a game. The folders consist of the main map, school map, home map, canteen map, equipment folder, and forest map. Maps are used to develop the storyline and place practice questions according to the storyline (Amri & Setyaningrum, 2022). The characters and questions have been collected. The researchers created the game in stages and obtained the display shown in Figure 4.



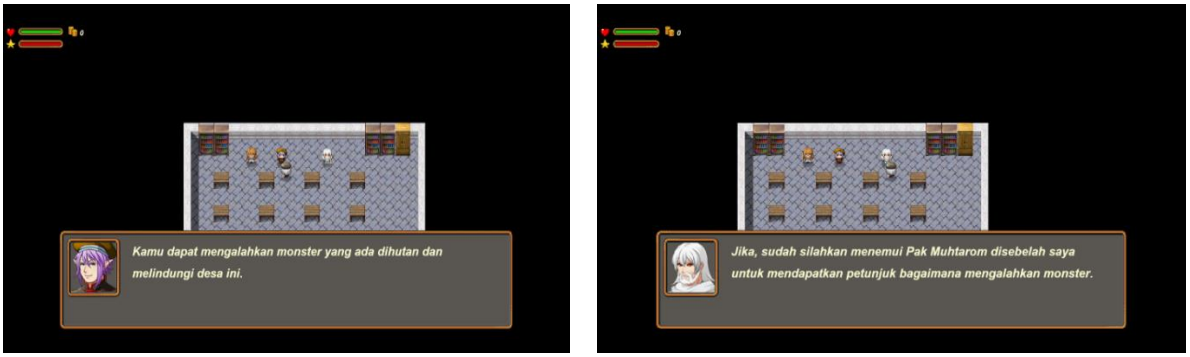


Figure 4. Designing a Game Map

Educational games can be used on students' cell phones, so they can use them without being at school. Researchers followed the LKPD with the help of live worksheets, which can be seen in Figure 5.

Figure 5. LKPD Design with Live Worksheet

In the statistical adventure game section, students must be able to defeat the "monster" character by answering questions correctly. The monster's lifespan will be reduced if students correctly answer the questions within the specified period. Vice versa, if a student answers the question incorrectly, the student's age will be reduced. If students defeat the monster, the statistics adventure can be continued at the next stage. An overview of the Statistics Adventurer is presented in Figure 6.

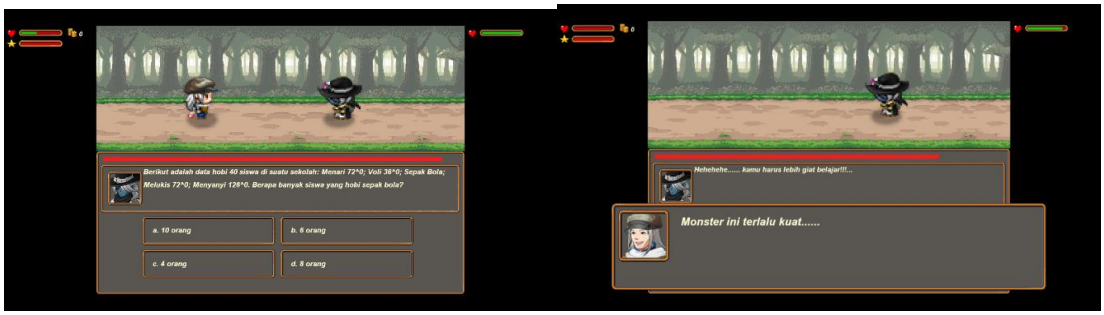
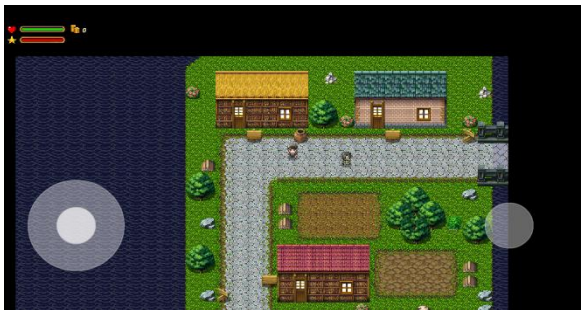


Figure 6. Statistical Adventure

After the Statistical Adventure educational game was developed, the next stage was expert validation. The results of expert validation provide input for improvements. Table 2 shows the revision

results according to the validator's suggestions. After improving the Petualang Statistika educational game, five validators were revalidated. The validation results were analyzed using Aiken's V. To determine the validity of the Petualang Statiska educational game, the Aiken's V coefficient results were compared with the Aiken's V table values seen through the Aiken's table index. As a result, Aiken's V coefficient = 0.93 > 0.87, so the Petualang Statistika educational game meets the valid criteria.

Table 2. Revised Educational Game

Before Revision	After Revision
LKPD is included in educational games for students	LKPD has been included in educational games so that students can learn
	
Error writing steps in live worksheets	Improvements to existing steps in live worksheets
	
Provides a cursor to direct the character to the right, left, up, and down, and a button to start a conversation, so that it can be used on Android	A cursor has been provided to direct the character to the right, left, up, and down, and a button to start a conversation, so that it can be used on Android
	

Assessment Stage

The final stage carried out is the assessment stage. Researchers began testing the Petualang Statistika educational game, developed for seventh-grade students at SMP Muhammadiyah 5 Semarang. This stage aims to determine the effectiveness and practicality of the educational game developed for students' mathematical thinking abilities in data presentation. Figure 7 presents documentation of research implementation.

Figure 7. Research Implementation

Research data from pretest and post-test data were then analysed using statistical tests to determine whether there were differences in students' mathematical thinking abilities at the beginning and end of using the educational game. The calculation results showed that the average pretest score was 31, and the posttest score was 81.57. Calculations using SPSS and the Wilcoxon Signed Test obtained a Sig value. 2-tailed 0.000 < 0.05 (see Table 3), then it can be concluded that H_0 is rejected, so there is a difference in the average pretest score before and posttest score for seventh-grade students SMP Muhammadiyah 5 Semarang after using the developed Statistics Adventure game.

Table 3. Wilcoxon Signed Test

Results of Calculation	Postest - Pretest
Z	-5.170[a]
Asymp. Sig. (2-tailed)	.000

The results of the practicality questionnaire show that students get very good responses to games when learning statistics. Table 4 shows student responses with a percentage of 88.67% in the very good category. Thus, it is concluded that games are practically used in mathematics learning.

Table 4. Results of the Student Response Questionnaire

Description	Value
Total value	665
Maximum value	750
PNRS	88,67%
Assessment category	Very Good

Monotonous mathematics learning is one of the main factors that causes students difficulty understanding the subject matter. Conventional learning approaches that focus more on lectures and the use of textbooks are often not effective enough to arouse students' interest and motivation to learn (Ahdhianto et al., 2020; Jatisunda et al., 2020; Yayuk & As'ari, 2020). This leads to low student involvement in the learning process and difficulty understanding abstract mathematical concepts. Therefore, innovation is needed in mathematics learning methods that do not only rely on traditional methods but can also increase student involvement and understanding. Mathematics learning needs to motivate students to learn by presenting material that can be accessed via gadgets. It can be discussed, problem-solving, and practised so that mathematics learning is easy to understand and not boring. A solution for students' problems is provided by providing interactive LKPD through the live worksheet application (Rusmiati et al., 2024; Zainal et al., 2024). With this application, students can be freer to discuss, solve problems, and practice mathematical concepts directly, making the learning process more fun and less boring. In addition, this application provides an opportunity for students to learn independently and at a pace that suits their abilities, which is certainly very different from face-to-face

learning, which is very limited. The LKPD developed by researchers has helped build students' conceptual understanding when learning using educational games integrated with live worksheets. This interactive LKPD is a learning tool and a medium that strengthens the understanding of concepts learned. This allows students to remember and apply mathematical concepts in everyday life easily (Nurjiah et al., 2024; Zainal et al., 2024).

Then, the problem regarding teachers' teaching methods is solved by developing interactive media containing complete content in the form of material coverage, practice questions, evaluations, and games that students can access. This aligns with the opinion that using interactive media that is attractively designed makes students more enthusiastic to participate in the teaching and learning process, and can involve students actively (Amri & Setyaningrum, 2022; Cheung & Ng, 2021). This solution is realised as an educational game containing descriptions of teaching materials, interactive LKPD, and educational games to evaluate student understanding. The study results showed that the educational game improved students' mathematical thinking skills in the material on statistical data presentation. This is in line with previous research, namely that educational games can improve students' thinking skills (Abdullah & Yunianta, 2018). Learning using educational games influences student activity, and serious attention must be paid to the teacher's explanations (Foriansyah & Taurusta, 2022; Muhtarom et al., 2023). This research strengthens the view that educational games are one of the functions of media to clarify the delivery of messages and information in mathematics learning materials (Novia et al., 2020).

Games have guides on how to use them, which makes things easier for teachers and students. Educational games equipped with detailed instructions make students more independent in learning and more active (Abdullah & Yunianta, 2018; Foriansyah & Taurusta, 2022; Mubharokh et al., 2021). Practicality in using educational games only takes 20-25 minutes. This aligns with the principle that learning media delivers learning material that requires a short time (Cheung & Ng, 2021; Lamrani & Abdelwahed, 2020; Mubharokh et al., 2021). This can be done well because the game has a guide on how to use it, making it easier for teachers and students. Educational games equipped with detailed instructions make students more independent and active in learning (Amri & Setyaningrum, 2022). The teacher's role in managing learning activities to guide and monitor students when playing games also determines the effectiveness of using educational games in learning mathematics.

4. CONCLUSION

This research shows that developing an educational game integrated with a live worksheet-based LKPD has high feasibility, practicality, and effectiveness in supporting mathematics learning. Based on expert assessment results, the developed educational game was declared feasible with an Aiken value of 0.93. The practicality test also showed a very positive student response, with a percentage of 88.67%. In addition, the effectiveness test using the Wilcoxon Signed Test showed a significance value of 0.000 (<0.05), which means that this educational game can significantly improve students' mathematical thinking skills, especially in data presentation materials. These findings reinforce the importance of integrating interactive media and innovative design approaches in learning. This study recommends that further development of aspects of an interesting storyline and a more interactive visual display is very important to maintain students' attention and build emotional involvement while playing and learning. This research confirms that technology integration through the development of interactive educational games combined with live worksheet-based LKPD can be an alternative solution in overcoming mathematics learning that tends to be monotonous. With the design thinking approach, the developed product successfully meets the criteria of feasibility and practicality and has been proven effective in improving students' mathematical thinking skills. These results indicate that innovative and fun learning media are very much needed in facing the challenges of learning in the digital era.

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