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Android Educational Game "MATHOLIC" Based on Van Hiele's Geometric Thinking Level on Plane Figures

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Abstract

The objective of this study was to produce an educational game based on Van Hiele's geometric thinking level called "MATHOLIC" on plane figures material in fourth-grade elementary school. This research was Research and Development (R&D), which used the ADDIE model. The subjects of this study were fourth-grade students of Tlumpu Blitar State Elementary School. The data collection instruments were interview guidelines and questionnaires. The data was obtained in the form of qualitative data and quantitative data. The results of this study showed that: (1) the material experts gave the level validity of MATHOLIC 95,8%, while media experts gave the validity level of MATHOLIC 94,4%, and the classroom teacher gave the level validity of 98%, which meant that MATHOLIC was very valid; (2)student responses in small group trials obtained a percentage of the practicality was 95% and in the field trial was 97,7% which meant that MATHOLIC was very practice; (3) the average score was 87,7 in the small group trial and 96,4 in the field trial which meant that the average was already above the Minimum Completeness Criteria score. MATHOLIC was declared valid and practical to be suitably used in learning mathematics. This study showed the validity and practicality of learning media in educational games that use van Hiele's theory. The findings of this study will be a solution for teachers who have difficulty teaching the material of plane figures to make it more effective and easily understood.

INTRODUCTION

Background

The phenomenon of the covid-19 pandemic resulted in the emergence of an online learning policy at all levels of schools in Indonesia. Although learning is carried out online, teachers must continue carrying out the learning process well, according to Regulation of

the Indonesian Ministry of Education and Culture No. 22 of 2016 on Standards of Primary and Secondary Education Process (Indonesian Ministry of Education and Culture, 2016). In all areas, not least in math, teachers must ensure that pupils learn in a fun environment. Most students think mathematics is a challenging and boring subject (Yuniawatika et al., 2016). Mathematics is considered important because the material studied relates to implementation in daily activities (Amalia et al., 2020) (Chasanah et al., 2021).

Mathematics has three scopes to be studied: numbers, measurement geometry, and data analysis. Geometry is considered a difficult scope to study (Amaliyah AR & Mahmud, 2018). One of the results of research on the analysis of students' difficulties in understanding geometric materials stated that students learning outcomes in geometry materials are pretty low, namely 15,3% of students who can solve the problem of plane figures circumference correctly and 3,8% who solve plane figures area problems correctly (Fauzi & Arisetyawan, 2020). Through such research, students have difficulty understanding concepts, using principles, and solving plane figure geometry problems. Students' difficulties in learning plane figure materials need to be addressed immediately because plane figures are the basis for studying plane figure materials at the next class level.

Geometry requires a mature understanding of concepts in students to master them. Efforts to improve the quality of learning in overcoming these problems can be made through learning media such as research by Badjeber and Suciati. The study shows that using learning media in games can increase students' understanding of geometry (Badjeber & Suciati, 2021). Van Hiele's theory is one of the learning theories that must be accommodated in the learning materials in order for geometry to be studied effectively.. According to Van Hiele (Fuys, 1984), there are five levels of development of geometric thinking: level 0 (visualisation), level 1 (analysis), level 2 (abstraction or informal deduction), level 3 (deduction), and level 4 (rigor). Through the theory of learning, students can learn geometry based on the level of thinking geometry so that it is expected to master the concept of geometry well.

Elementary students tend to quickly understand the material presented in the form of concrete objects. This is in line with Piaget's theory of cognitive development which states that elementary school students are at the concrete operational stage, which means that students are easier to learn to use the concrete form of an object. Therefore, there needs to be a good manipulation of concrete objects so students can understand the concept. One way to manipulate it is by using learning media in the form of games. The use of games in mathematical learning aligns with the theory of learning initiated by Zoltan Paul Dienes. He argued that any mathematical concept presented in concrete form would be well understood (Dienes, 1971). This means that game-style objects play a vital role when properly manipulated in math lessons. The application of digital game-based learning can be a solution to the fun learning challenges during the covid-19 pandemic (Wati, 2020). Currently, students more often play games using smartphones that should be used to support the implementation of online learning. This phenomenon can be an idea to use educational game learning media that can be run through a smartphone.

Problem of Study

Implementing online learning at the elementary school level is a new thing experienced by teachers and students. During online learning, students find it increasingly difficult to learn math material. So far, mathematics is considered a difficult subject (Yuniawatika et al., 2016). Mathematical materials, especially geometry, are often challenging to learn (AR & Mahmud, 2018). This is in line with the results of interviews with teachers of grade IV Tlumpu Blitar State Elementary School and questionnaire results that showed 81.5% of students had difficulty in math materials, especially plane figures materials. These difficulties must be overcome immediately because mathematics is an

important science in the practice of daily life (Amalia et al., 2020). A medium is needed to make mathematical objects dynamic and manipulatable (Sholikhah & Pradana, 2018). Learning media in educational games can increase students' enthusiasm for learning mathematics (Amanda, 2019). In math learning, teachers have used learning media in games that are crossword puzzles made using TTS Maker. However, the game is still simple and only for introducing the term. For students to benefit from online learning, teachers must provide interactive tools, help students understand the material, and allow for presenting real objects. Given that students today prefer playing mobile games on smartphones, the development of educational games as learning materials seems reasonable.

State of the Art

Various studies have been conducted on developing educational games in geometry learning. At first, Fauzi & Arisetyawan (2020) examined the issues that 4th graders in elementary schools were having with the mill material and the area of plane figures, as shown by the low number of students who were able to answer problems. In line with that, the analysis conducted by Simbolon & Sapri (2022) also showed that students have difficulty understanding the concept of plane figures. In comparison, Juanti et al. (2021) describe students' difficulty learning geometry, including errors in receiving information and difficulty using concepts. Secondly, related to geometry learning theory, Arifin et al. (2014) apply Van Hiele's theory-based learning to improve students' understanding of geometric materials. Huzaifah (2011) reported that understanding geometric concepts in 38 students increased each cycle when using Van Hiele's learning theory.

Meanwhile, Sutriani et al (2018), who implemented Van Hiele's learning theory on learning, improved students' understanding of the properties of plane figures from the initially low category to reach the high category. Third, Anugrahini (2017) developed educational games related to learning media in educational games to increase students' motivation to learn mathematics. An android-based plane figures application created by Pramadana et al. (2018) should be utilised to help students study plane figures materials because it was tested on the general public and produced high-quality results with good categories. Amanda (2019) also developed an android educational game for 4th-grade plane figures material that effectively increases the average student's grade. In addition, Karim & Savitri (2020) developed a mathematical learning medium in the 4th grade of elementary school that contains some material with average validation results showing good categories. One of the results of previous studies showed that students had difficulty understanding the geometry of plane figures. Other research shows that android educational games are considered feasible, practical, and effective as learning media. In addition, Van Hiele's theory can also help improve students' understanding of geometry. In order to help students who struggled with studying plane figures material in the fourth grade, the researcher created a product in the shape of an educational android game based on Van Hiele's level of geometric thinking. This project was undertaken since, up to this point, no research had produced an Android educational game based on Van Hiele's level of geometric thinking.

Gap Study & Objective

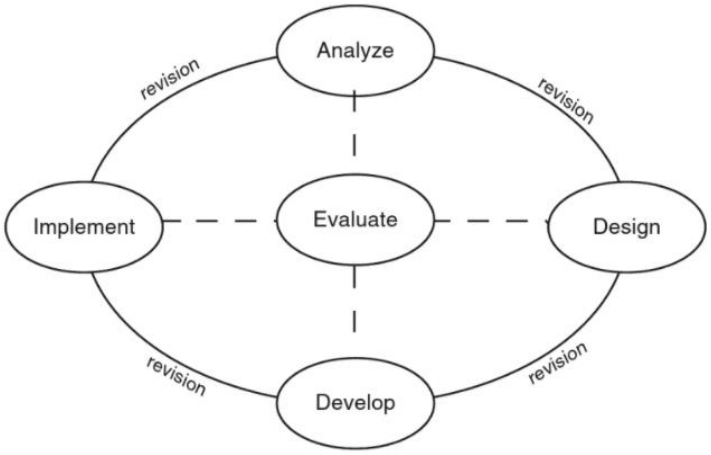
The rationale above suggests that pupils struggle to grasp geometry concepts and plane figures. Students' comprehension of geometry is considerably aided by using suitable geometry learning theory. Students commonly use their smartphones for gaming instead of completing homework on time because they believe that games are more pleasant than math classes, which they find tough and boring. To motivate students to learn and have fun while learning, researchers produced the "MATHOLIC" android educational game based on

Van Hiele's geometric thinking level on the plane figures curriculum. This game is called MATHOLIC, and it is hoped that children will enjoy and be enthusiastic about learning mathematics, which was previously seen to be a tough topic. This study attempts to create a valid MATHOLIC according to material specialists, media experts, classroom teachers, and students.

METHOD

Type and Design

This type of research is R &D (Research and Development), which means producing a product and assessing its effectiveness of the product (Saputro, 2017). The development research model used in this research is the ADDIE development model. The ADDIE model is an approach that emphasises the analysis of interactions between components that coordinate by existing phases (Rayanto et al., 2020).
The product development phase with the ADDIE model, consists of 5 stages as follows.



Picture 1. ADDIE Model

Analysis

This stage analyses students' needs through grade IV teacher interviews and provides a questionnaire to analyse student needs.

Design

The design stage contains a research design that will be carried out, including product designs.

Development

This stage realises the product design made using the constructed two applications. Products developed are reviewed by material expert validators, media experts, and classroom teachers.

Implementation

The product was tested in a small group of 7 students with high, moderate, and low ability in fourth-grade Tlumpu Blitar State Elementary School Blitar City and continued with field trials by 26 students of fourth-grade Tlumpu Blitar State Elementary School. In implementing the trial, students fill out practicality questionnaires and work on evaluation problems.

Evaluation

Evaluation is the stage where the action taken aims to know the success of a product in meeting learning needs. Evaluation is carried out at each stage.

Data and Data Sources

Both qualitative and quantitative data were collected for this investigation. Results of interviews with classroom teachers, as well as critiques and suggestions made by subject matter experts, media experts, classroom teachers, and students, are used to create qualitative data. Comparatively, the assessment score results provided by subject matter experts, media experts, classroom teachers, and students are used to obtain quantitative data. In this study, 26 kids with varied abilities from grade IV Tlumpu Blitar State Elementary School school year 2021/2022 and 27 students from grade IV Tlumpu Blitar State Elementary School school year 2020/2021 served as the subjects.

The following data sources were used in this development research: (a) the results of interviews with classroom teachers; (b) the need analysis questionnaire; (c) validation questionnaires filled out by material experts, media experts, and classroom teachers; (d) the practicality and evaluation value of small group trials, which were conducted to 6 representative learners from class IV Tlumpu Blitar State Elementary School; and (e) the practicality and evaluation value of field trial evaluation, which was conducted to all students.

Data collection technique

Interview

Interview guidelines are a collection of questions arranged in such a way as to analyse problems and needs. The source in this interview is the teacher of 4th grade Tlumpu Blitar State Elementary School. The question items in the interview are as follows:

1. How to conduct online learning in class IV Tlumpu Blitar State Elementary School?
2. Are there any obstacles during the implementatifon of online learning?
3. What contents are difficult for students to receive during online learning?
4. What materials do students find difficult?
5. What efforts have been made to overcome difficulties in learning mathematics?
6. What learning media is used in online learning?
7. Have you ever used a mathematical learning medium in the form of a game?
8. How do students respond when games are used in learning?
9. What are the disadvantages of the gaming media that you have used?
10. What do you think about the development of android-based educational games for math content on materials that students find difficult?
11. What is your opinion about the development of android based educational games for math content on material that students find difficult?
12. What kind of android education games do you expect to support math learning?
13. What curriculum is used in math learning in grade IV Tlumpu Blitar State Elementary School?

Questionnaire

Questionnaire is a data collection technique that gives respondents a set of statements (Sugiyono, 2016). Instruments in the form of questionnaires are used to analyse students' needs, assess the validity of MATHOLIC educational games that have been developed, and assess the practicality of products. The student's needs analysis questionnaire contains a question with a "yes" or "no" answer. Instruments in the form of questionnaires are also used for product validation. The following is a MATHOLIC validity assessment grid modified from Dewi (2012) and adapted to the theoretical basis of educational game development based on the theoretical basis used.

Table 1. Validation Grid

Aspects	Indicators	Media Expert	Material Expert	Teacher
Quality	Completeness of game elements	√		√
	Meet the principles of educational game development			
	Meets educational game development criteria			
Effectiveness	Meet learning needs	√		√
	Media is easy to use			
	Fun media			
Content	Material conformity with KD		√	√
	Conformity of material to indicators			
	Conformity of matter to purpose			
	Traceness of material content			
	Material completeness			
	Accuracy of material concepts			
	Accuracy of material coverage			
	The suitability of the example in the material			
	Suitability of images in clarifying material			
	Conformity to Van Hiele's level of thinking geometry			
Language	Language accuracy according to EYD		√	√
	Conformity with intellectual learners			
	Use of punctuation			
	Accuracy of sentence structure			
	Accuracy in the use of the term			

The evaluation grid for the game is based on the fourth-grade plane figures material from Van Hiele's geometry thinking level, as shown in the table below..

Table 2. Practically assessment grid

Aspects	Indicators
Practicality	Ease of use
	Attraction
	Efficiency

Data Validity

The assessment of product validity involves material experts, media experts, and classroom teachers who are experienced and have expertise according to their field. Furthermore, the assessment of product practicality is carried out in 2 stages: small group trials and field trials. From the various techniques used, data is obtained that strengthens each other.

Data analysis

Qualitative data in criticism and advice provided by material experts, media experts, classroom teachers, and students are analysed descriptively. Quantitative data in the form of student needs questionnaires is made using the Guttman scale with two answer options, namely "yes" and "no" in each statement (Sappaile, 2007). Student needs are analysed with percentage techniques. The following is the formula used for the analysis of student needs.

$$P = \frac{f}{n} \times 100\%$$

Description : P = percentage
f = frequency of each selected answer
n = the sum of all answers

Interpreting the percentage results of each answer is done using the following categories.

Table 3. Criteria for the results of the need analysis questionnaire

Percentage(in %)	Categories
0 - 1	None
2 - 25	A small part
26 - 49	Less than half of it
50	Half
51 - 75	More than half of them
76 - 99	Most
100	Entirely

Source : (Munggaran, 2012)

If the percentage of "yes" answers is more than equal to 50%, it can be concluded that the answer to the question asked is "yes" and vice versa (Andini et al., 2018).

Quantitative data in the form of validation results by experts and teachers are analysed using the Likert scale, which has a level from very positive to very negative (Sappaile, 2007) For the needs of quantitative analysis, the words in the assessment are changed in the form of scores 5 (very good), 4 (good), 3 (enough), 2 (less), and 1 (very less). The score is obtained by summing the entire score in each aspect and then converted to a percentage form using the following formula.

$$\text{Vah} = \frac{Tse}{Tsh} \text{ x } 100\%$$

Description : Vah = Expert validation
Tse = Total score achieved
Tsh = Total expected maximum score

The results of validation percentages by experts and teachers converted into percentages are interpreted according to the following table.

Table 4. Validation results criteria

Percentage Score (%)	Category	Test Decision
0 - 50	Invalid	Cannot be used
50.01 - 70	Less valid	It is recommended not to be used due to significant revisions
70.01 - 85	Valid enough	Can be used with minor revisions
85.01 - 100	Very valid	Can be used without revision

Source : (Akbar, 2015)

Furthermore, the results of filling out the practicality questionnaire filled by students were analysed using the following formula.

$$\text{P} = \frac{\sum x}{N} \text{ x } 100\%$$

Description : P = percentage
$\sum x$ = number of scores obtained
N = maximum number of scores

Table 5. Practicality results criteria

Percentage Score (%)	Category	Test Decision
0 – 25.00	Impractical	Cannot be used

25.01 – 50.00	Less practical	It is recommended not to be used due to major revisions
50.01 – 75.00	Practical	Can be used with minor revisions
75.01 - 100	Very practical	Can be used without revision

Source: (Kumalasani, 2018)

RESULT

Analysis

Based on the results of interviews with fourth grade teachers at Tlumpu Blitar State Elementary School, the results obtained are (1) students collect assignments are not on time because they tend to use smartphones to play games; (2) students have difficulty on mathematical content especially plane figures material; (3) The teacher has offered to video call if the student is having difficulties, but the student still does not understand the material; (4) teachers have used learning media in the form of crossword puzzle games but the game is still simple and can only be for the introduction of terms; (5) students are enthusiastic when using games in the implementation of learning; (6) teachers need learning media that are able to present concrete forms of objects; (7) teachers need learning media in the form of educational games that are in accordance with the curriculum, presenting fun material, and contains evaluation questions; (8) the curriculum used as the basis for the implementation of mathematics learning in Tlumpu Blitar State Elementary School is the 2013 curriculum with basic competencies referring to Permendikbud No.37 of 2018. Furthermore, from the interview results, a detailed analysis of the curriculum for basic competencies in geometry material for grade 4 plane figures was carried out, namely KD 3.9 and KD 4.9, regarding the circumference and area of square, rectangular, and triangular plane figures.

Furthermore, a needs analysis was carried out through a questionnaire to strengthen the teachers' opinions in the interviews. The results of the needs analysis questionnaire show that each question gets a "Yes" response of more than 50%, so each question has a "Yes" answer conclusion (Munggaran, 2012). The results of the student needs analysis questionnaire are as follows.

Table 6. Results of student need analysis

Questions	Percentage of Answer	Conclusion of Answer
Does online learning feel boring?	81.5%	Yes
	18.5%	
Do you find it difficult to understand math materials during online learning?	81.5%	Yes
	18.5%	
Do you have trouble learning plane figures material?	81.5%	Yes
	18.5%	
Do you need additional math learning media on plane figures material other than books from school?	77.8%	Yes
	22.2%	
Do you like to play mobile games using a smartphone?	51.9%	Yes
	48.1%	
	88.9%	Yes

Do you agree if a developed game about plane figures that can be operated using an android smartphone to help learn the material in a fun way?	11.1%

Design

Home Page

The MATHOLIC main page contains usage instructions, developer profiles, and menus.

Picture 2: Home Page

Menu

In the menu section contains Competence, Cari Pasanganku, Tangram Bangun Datar, Puzzle Tetris, and Ayo ke Sekolah.

a. Competence contains basic competencies following the material in MATHOLIC. The fundamental competencies used are KD 3.9 and 4.9 for grade IV elementary mathematics, according to Permendikbud No.37 of 2018.

Picture 3: Competence

b. Find My Partner is a subgame designed according to level 0 (visualisation) of Van Hiele's geometric thinking level. In this game, the user is asked to pair the illustration with the appropriate plane figures

Picture 4: Find My Partner

c. Tangram Plane Figures is a subgame designed according to level 1 (analysis) and level 2 (abstraction/ informal deduction) at the level of thinking of Van Hiele geometry. Level 1 relates to the user being asked to arrange a tangram and then directed to find the properties of the plane figures. In comparison, level 2, in the form of commands, compiles a chart of relationships between plane figures after knowing the nature of each quadrangular plane figure.

Picture 5: Tangram Plane Figures

d. The Tetris Puzzle is a yang subgame developed according to level 2 (abstraction/ informal deduction) at the level of thinking of Van Hiele geometry. This part is the core of the MATHOLIC game. This section focuses on materials according to KD 3.9 and 4.9.

Picture 6: The Tetris Puzzle

e. Let's go to School is the section that contains an evaluation problem to assess the extent of students' understanding of the roving and spacious material of plane figures. Evaluation questions are grouped into three types based on studied plane figures. Each plane figure has five questions with a correct score of 20 and a wrong score of 0. The evaluation problem does not immediately appear but is designed as a hill climb game where players are asked to run a school bus, and problems will appear when they arrive at the stop.

Picture 7: Let's go to School

Development

MATHOLIC educational game development is done with the help of the construction of two applications followed by a validation process. The following is quantitative data in the form of validation results.

Table 7. Material expert validation results

Aspect	Percentage	Value of Validation	Criteria of Validation
Content Language	91.67% 100%	95.835%	Very valid

Based on the score given from expert validation of material, the MATHOLIC games obtained results of 95.835%. This can be interpreted according to the validation criteria in table 4; MATHOLIC educational games entered at the achievement rate of percentage score intervals of 85.01% - 100%; that is a very valid criterion that means MATHOLIC can be used without revision (Akbar, 2015).

Material specialists advise including illustrations of the content from items created to help students better comprehend the content in MATHOLIC educational games. In drawings of plane figures, it is advised to use both images and line confirmations since the material needs to be prepared with modest adjustments in accordance with the advice provided before the trial, even though experts proclaim the findings of the validation values to be quite valid. In order to evaluate MATHOLIC's efforts, media validation by media professionals is required. Media professionals evaluate items based on their effectiveness and overall quality. The following quantitative information was verified by media professionals.

Table 8. Media Expert Validation Results

Aspect	Percentage	Validation Value	Validation Criteria
Quality	95.5%	94.4%	Very valid
Effectiveness	93.3%		

The games received a percentage of 94.4 percent based on the evaluation of the quality and effectiveness of MATHOLIC provided by media specialists. Therefore, according to the validation results criteria shown in Table 4, MATHOLIC educational games met the validation criteria to a very high degree, with an achievement rate of percentage score intervals of 85.01 percent to 100 percent. This means that MATHOLIC can be used directly. (Akbar, 2015). Further comment or advice from media specialists was not provided. According to the experts, MATHOLIC educational games are worthy of trial without adjustment. Validation by class IV teacher Tlumpu Blitar State Elementary School assesses MATHOLIC educational games based on quality, effectiveness, content, and language. The following is quantitative data validated by the class teacher.

Table 9. Classroom teacher validation results

Aspect	Percentage	Validation Value	Validation Criteria
Quality	97%	98%	Very valid
Effectiveness	100%		
Content	95%		
Language	100%		

The validation data on table 9 yielded a percentage result of 98 percent. Therefore, according to the validation results criteria shown in Table 4, MATHOLIC met the validation criteria to a very high degree, with an achievement rate of percentage score intervals of 85.01 percent to 100 percent. This means MATHOLIC can be utilised without adjustments. Furthermore. The teacher provides comments and ideas for writing errors as well as extra navigation to aid in the operation of MATHOLIC educational games.

Implementation

Small-Group Trials

The small group trial involved 6 grade IV students of Tlumpu Elementary School with high, moderate, and low abilities. The following are the results of the work on evaluation by students in small group trials.

Table 10. Student evaluation grade results on small group trials

Criteria	Value
Minimum completeness criteria Mathematics	75

Highest Score	100
Lowest Value	73.3
Average Value	87.7

Based on the value of the evaluation results, it is known that the average value obtained by students for the overall material circumference and plane figures area is 87.7, which means it is already above the Minimum completeness criteria. Furthermore, students are asked to fill out the student response questionnaire related to the practicality of MATHOLIC educational games with the following results.

Table 11. Student response results on small group trials

Statement	Percentage
Interesting game look	100%
The language you use is easy to understand	100%
Font size and type are easy to read	83.3%
Images help to understand the material well	100%
Easy-to-understand instructions	83.3%
The menu can be selected easily	100%
The game can be run easily.	83.3%
Educational games help understand the material	100%
Media can be used anywhere and anytime	100%
The use of educational games makes learning fun	100%
Percentage	95%

The results of the student response questionnaire on the small group trial showed a percentage of 95%, which if interpreted with table 5 shows a range of grades of 75.01% – 100%, which means that the product is declared very practical and can be used without revision.

Field Trials

Field trials were conducted with the subjects of all students of grade IV Tlumpu Blitar State Elementary School for school year 2021/2022. The results of evaluation grades were obtained from 26 students through field trials according to table 12 below.

Table 12. Results of student evaluation grades on field trials

Criteria	Value
Minimum completeness criteria Mathematics	75
Highest Score	100
Lowest Value	73.3
Average Value	87.7

Based on the evaluation results in table 12, the average score obtained by students is 96.4. Which means it is already on top of minimum completeness criteria. At the end of the field trial, students are required to fill out a student response questionnaire related to MATHOLIC practicality with the following results.

Table 13. Student response results in field trials

Statement	Percentage
Interesting game look	96.15%
The language you use is easy to understand	100%
Font size and type are easy to read	100%
Images help to understand the material well.	96.15%
Easy-to-understand instructions	96.15%
The menu can be selected easily	100%

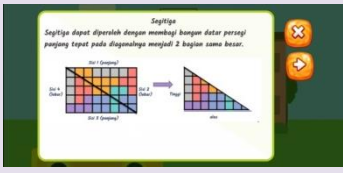
The game can be run easily	96.15%
Educational games help understand the material	96.15%
Media can be used anywhere and anytime	100%
The use of educational games makes learning fun	96.15%
Percentage	97.7%

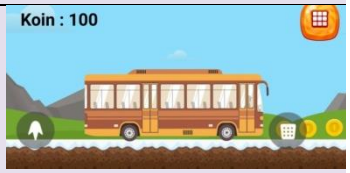
Student response results on field trials showed a percentage of 97.7%. If interpreted, table 5 shows a range of 75.01% – 100%, which means that MATHOLIC educational games are declared practical and can be used without revision.

Evaluation

At this stage, actions are carried out to determine the success of a product in meeting learning needs to review every stage that has been passed. The following is a product revision based on suggestions from validators and students.

Table 14. Revision of MATHOLIC

Before Revision	Suggestions/Inputs	After Revision
	Change the animated image to the actual image.	
	The line on the Tetris block is reinforced.	
		
		
	There is a command error in the triangle type section that should be based on the angle.	

	It is necessary to add back and exit icons to complete the navigation.	
	There is a piece of writing that's too small.	
	The distance between the climbs is too close, so the bus is difficult to climb.	

DISCUSSION

Students find it difficult to receive geometric content, particularly on plane figures, during the analysis stage, based on interviews with teachers and needs analysis questionnaires. This is supported by Fauzi dan Arisetyawan (2020), who reports on students' difficulty with the notion of geometry. Furthermore, the design and development stages take a long time since plane figures resources must be packaged according to basic competency and van Hiele geometry thinking level based on student needs..

The product validation assessment results of material specialists are 95.835 percent valid, which suggests that the product comprises very valid criteria and may be utilised without alteration (Akbar, 2015). However, there are comments from professionals who use the reference material to revise the product. Expert media validators offer suggestions for replacing animated graphics with actual photographs. This is also consistent with Dienes' viewpoint (1971). He claimed that in order for an idea or principle in mathematics to be easily comprehended by the learner, it must be able to describe concrete or tangible objects surrounding the student. Furthermore, using actual visuals helps students achieve Van Hiele's level of thinking geometry level 0 (visualisation) (Crowley, 1987).

Furthermore, it needs improvement in the form of marking on the surface of the intended object. This needs to be done to avoid confusion in students in completing challenges related to the form of plane figures on the surface of objects, especially in images with various types of plane figures. It is also following one of the elements and principles of educational games, according to Dillon (2005) , namely plot and objects. Where in the plot shows information about the commands to complete a game to be completed and the elements and principles that objects have the intent for the instructions that the player needs to have to solve in the game. So that the availability of elements and principles in the complete educational game will help players complete missions in the game easily and ideally. In addition, it is necessary to thicken the line between square units on a unit square. This improvement needs to be done to make it easier for students to calculate the square tire of the unit.

Media expert validators rate MATHOLIC educational games based on the nine game elements in-game preparation (Dillon, 2005). In addition, the preparation of games also

needs to pay attention to the eight principles of educational games (Maharani, 2018). Likewise, the fulfilment of 11 criteria for the development of educational games must also be considered so that the resulting games are quality (Silveira & Villalba-Condori, 2018). Validation results by media expert validators show 94.4%, which means the product includes very valid criteria and can be used without revision (Akbar, 2015). Media experts do not provide comments and suggestions, so qualitative data is not obtained.

The class teacher validates the product at 98 percent, indicating that it contains very valid criteria and may be utilised without alteration (Akbar, 2015). The teacher made comments and suggestions about MATHOLIC. One of them is a comment about a writing error on the product that has to be corrected because the accuracy of the content on educational games is critical (Silveira & Villalba-Condori, 2018). There are also proposals for enhancing the games' navigation. This improvement is also shared by Pramadana et al (2018) in their research which also improves the description on the menu icon, making it easier for users to utilise the application.. Research conducted by Amanda (2019) also received suggestions for improvements related to the completeness of navigation. This shows that clarity of navigation is indispensable in product development. These enhancements are required because they are related to instructional game elements, specifically user interface elements or features that communicate with games. (Dillon, 2005).

The results of small group trials and field trials were 95% and 97.7%, respectively, indicating that MATHOLIC is very practical and may be utilised without revision (Kumalasani, 2018). The average evaluation ratings in the small group and field trials were 87.7 and 96.4, respectively, placing them over the minimum completeness criteria. According to Arifin et al. (2014), learning based on Van Hiele's theory leads to an increase in students' knowledge of the idea of plane figures. Students appeared excited about the use of gaming media in math learning during the trial. This is consistent with Dienes' (1971) thinking, which holds that concepts and principles in mathematics presented in physical forms are easier to understand (Dienes, 1971).

CONCLUSION

No previous research has developed an educational game about plane figures based on van Hiele's theory. In comparison, the use of games in learning increases student enthusiasm. In addition, the use of the correct theory makes it easier for students to understand the material well. This study shows the validity and practicality of learning media in educational games that use van Hiele's theory. The findings of this study will be a solution for teachers who have difficulty teaching the material of flat shapes to students to make it more effective and easily understood by students.

The MATHOLIC educational game has a limitation in that the mathematics curriculum it contains is exclusively about plane figures. Furthermore, MATHOLIC can only be run on smartphones running Android version 8 or higher. This is a problem for customers who still use devices with Android systems older than version 8. Another disadvantage is that, while the evaluation questions on MATHOLIC are already contextually oriented, the number of questions is relatively limited, at 15 in total. The validators recommend that MATHOLIC be disseminated in other schools so that students from other schools can experience it. The products must also include other geometry resources, multiply the problems offered, and make system upgrades so that MATHOLIC can work on all Android versions.

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