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Developing mathematics virtual reality based on understanding mathematical concepts

Putri Mutiara Anisa, Saenih, Anisa Oktaviani, Surya Amami Pramuditya *, Mohammad Dadan Sundawan

Mathematics Education, Universitas Swadaya Gunung Jati, West Java, Indonesia

* Correspondence: amamisurya@ugj.ac.id

Abstract

This research was motivated by students' difficulties understanding the basic concepts of abstract flat-side spatial shapes. So, learning media is needed to help students understand the material that is made interesting by utilising technology in the form of virtual reality. The research aims to determine the development of virtual reality media towards students' conceptual understanding, which has been tested validly and practically, so that it can be used as an active and exciting learning media. The method used in this research is a qualitative approach using the Research and Development method and the ADDIE model using the Millealab application. Participants were eighth-grade students at junior high schools. The outcomes of the research show that virtual reality is an innovative learning media that utilises technological developments in learning media and provides a quick, engaging, and fun understanding so that students can more easily understand mathematical concepts in flat-sided material. Virtual reality learning media has been extensively tested to be valid, practical, and suitable for use in learning. Suggestions for this research can provide an innovative development of virtual learning media, which still has many shortcomings, so that it is much better and produces like learning.

Keywords: geometry; learning; virtual reality

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Introduction

Increasingly advanced technological developments impact educational progress so that they can help improve the quality of human resources (Hafni, 2021). Therefore, the use of technology must be maximized, especially learning today. According to Moreira, learning media are instruments that show facts, concepts, principles, and procedures to make them more accurate or concrete (Batubara, 2020). Learning media is generally still conventional, influencing students' interest in mathematics lessons. To make the teaching and learning process more participatory, this needs to be changed through technology learning resources. (Firdaus, 2017). Technology-based learning media are being produced instead of traditional learning media. Virtual reality technology was employed in this study using the Millealab platform. With the use of virtual reality technology, users can view visual displays that have been designed to resemble real-world scenarios. With virtual reality technology, everything can seem real, and many people have used it abroad and domestically (Fardani, 2020). Virtual Reality is a media that displays image projections from a smartphone screen to make them more straightforward and more realistic (Asikin et al., 2019). VR presents a visual experience (Pramuditya et al., 2022). Virtual Reality can display three-dimensional objects to make them look authentic and make depictions of learning media more real. This learning media also aims to provide a pleasant learning sensation so students can understand the material presented through Virtual Reality.

Basic understanding is referred to as understanding concepts. When students can categorize or classify objects or link a name to a specific set of objects, they develop an idea. Concepts include abstract ideas to classify an object and explain what is an example and what is not an example. What is needed is the ability to understand the concepts of mathematics (Raihanah et al., 2020). It can be easier to answer mathematical difficulties if one has a solid understanding of mathematics (Yunita et al., 2020). All of the content in mathematics classes is related to one another. (Runtuhkahu et al, 2014) Assert that mathematics is an organized discipline requiring foundational knowledge as a precondition for advanced skills. Geometric shapes with flat sides are one of the maths components included in the 2013 Curriculum. To anticipate the increasingly rapid development of science and technology, reform is needed, especially in mathematics learning (Umar, 2012). Indicators of students' mathematical understanding are divided into five categories, namely: 1) Applying formulas in simple calculations and carrying out calculations using instrumental understanding, 2) Improving one concept or principle with relational concepts or understanding, 3) Linking one concept or principle with other concepts or principles, 4) Applying formulas in simple calculations and, 5) Carrying out calculations with an instrumental understanding (Dewi et al., 2018).

Several things cause students to lack understanding of mathematical concepts, especially in understanding the concept of flat-sided geometric shapes. Students are more likely to learn mathematics by memorizing formulas but not understanding the basic concepts, imitating the teacher's way of doing example problems, and lacking an understanding of concepts in learning (Sutopo et al., 2022). Apart from that (Fahlevi et al, 2020) stated that the difficulties experienced by students were because students did not master the concept of flat-

sided geometric figures. Material concepts that are not mastered are the cause of difficulties experienced by students, so learning goals are challenging to achieve (Rahmiati et al., 2017).

Based on facts that researchers found from several research journals, some students still have difficulty understanding flat-sided geometric material, one of which was mentioned in research (Mutia et al., 2017). Students experience difficulty understanding the concept of blocks and cubes, detecting the surface area formula, and using the surface area formula for blocks and cubes. The difficulties experienced by students in studying the material on flat-sided geometric shapes are (1) difficulty understanding the concept of definitions on flat-sided geometric shapes, (2) difficulty understanding and using the principles of writing corner points, side planes, side diagonals, space diagonals, and diagonal planes. In flat-sided geometric shapes, (3) difficulty understanding and using the principles of drawing flat-sided geometric shapes and their nets, (4) difficulty understanding and using the principles of naming flat-sided geometric shapes, (5) difficulty understanding and using concepts in determining parts -parts of flat-sided geometric shapes, (6) difficulty understanding and using the concept of comparison between volume and surface area in flat-sided geometric shapes, (7) difficulty understanding the concept of material prerequisites for flat-sided geometric shapes (Yunitasari et al., 2019). In the research update, students experienced difficulties understanding the material on flat-sided geometric shapes. Currently, the learning carried out by teachers uses the independent curriculum learning method, which focuses on students' creativity, talents, and interests. The creativity possessed by students is undoubtedly different from that of others, which makes teachers have to innovate, be interactive, and be efficient. In mathematics, learning media through virtual reality is currently being developed to make it easier for students to improve their ability to understand the material on the sides of flat shapes.

Based on these outcomes, researchers are interested in developing mathematics learning media by following technological developments in the current era and using virtual reality technology. So, in this research, it is hoped that virtual reality learning media based on understanding this concept can be tested as valid and practical and suitable for use as a mathematics learning media, especially in flat-sided geometric material. With the above background, the following problem formulation is: How can the development of virtual reality media based on understanding mathematical concepts in flat-sided geometric material be tested validly and practically?

Methods

This research uses the R&D (Research and Development) method. The product development in this research is Virtual Reality in the form of the Millealab application. MilleaLab is a virtual reality simulation development application that creates virtual reality-based educational content. The research design uses the ADDIE model. Analysis, design, development, implementation, and evaluation are the five research phases referred to by the ADDIE model (Arosi et al., 2021).

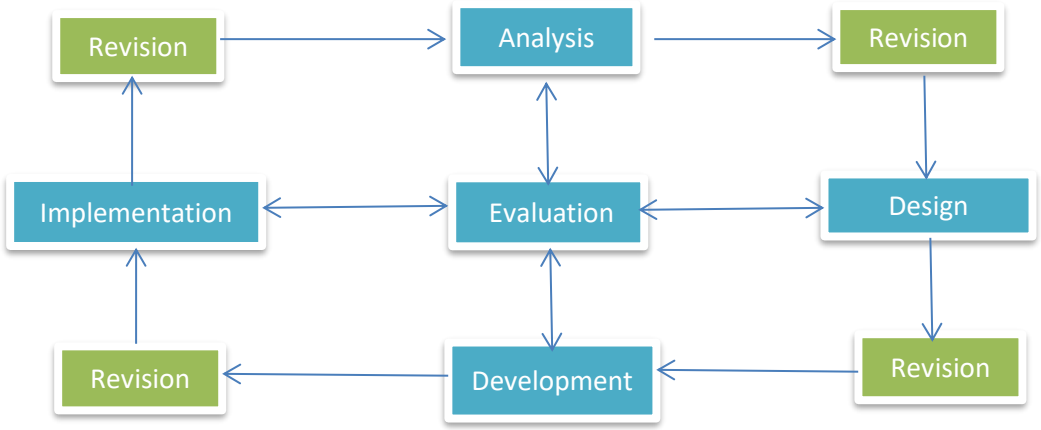


Figure 1. ADDIE stages

Figure 1 explains the ADDIE model, which refers to five research stages, namely: 1) Analysis, 2) Design, 3) Development, 4)Implementation, and 5) Evaluation. The following is the model ADDIE research:

Analysis

Analysis activities were carried out through interviews, which were carried out to find out information about students' learning needs in the material building of flat-sided rooms. Apart from that, data analysis was also obtained from supporting research articles.

Design

Virtual reality design will be used as a learning medium. First, a product will be designed and used in virtual reality via the Millealab platform. Then, material, questions, and answers will be created, compiled, and presented in virtual reality.

Development

At this stage, the researcher ensures that all the instruments needed for the research have been prepared. Experts will save and validate the virtual reality design created on the Millealab platform. After passing the validation, it will be tested for practicality so that the virtual reality learning media can be used and tested valid.

Implementation

After the previous stage's validation steps and outcomes, a limited trial was carried out on eighth-grade students. Aims to obtain information and get suggestions and input on virtual reality learning media. The limited trial involves students and also requires a student response questionnaire using virtual reality learning media; then, the outcomes of this response questionnaire will be processed and analyzed by researchers.

Evaluation

The evaluation stage will be carried out to improve the product's shortcomings and weaknesses to make it better. The evaluation process is carried out at each stage of ADDIE to obtain the development of virtual reality learning media that is proven practical and valid so that it can be developed
used.

In this study, the research subjects consisted of validation test subjects, lecturers, and teachers. In contrast, practical test subjects in this research consisted of 25 students from one of the state junior high schools in Indramayu with a limited scale of eight-grade. The data used in the study was gathered through observation, interviews, and reading research-related literature. An interview guide is a tool used to gather information about the issues and requirements of the product that has to be designed. In order to conduct interviews, questions and answers were discussed in person with respondents, who were teachers and students. An interview guide sheet is used in these inquiries.

Results

We obtained research outcomes in the form of data regarding the viability of using this learning medium, specifically: 1) test outcomes validation of Virtual Reality learning media based on understanding mathematical concepts in flat-sided geometric material, and 2) practicality test outcomes of Virtual Reality learning media based on understanding mathematical concepts in flat-sided geometric material, from research conducted in one of the state schools in the Indramayu district with eight-grade research subjects. In developing this learning media, researchers used the ADDIE model; the outcomes obtained in developing learning media were as follows:

Analysis stage

At this analysis stage, the researcher analyzed the feasibility of developing learning media as a benchmark and guideline for developing this learning media. The data collection technique used was reading and studying national and international journals that discussed the development of media as a learning medium and conducting interviews with mathematics teachers. The following stages are carried out in the analysis, namely 1) curriculum analysis, 2) material analysis, and 3) media needs analysis.

Curriculum analysis

In this stage, the researcher carried out a curriculum analysis, which included Indicator Competencies and Basic Competencies in the curriculum analysis process; the researcher explained the curriculum content so that this learning media was needed. Then, the competency achievement indicators students are expected to achieve are adjusted to the existing essential competencies. Once Indicator Competencies, Basic Competencies, and competency achievement indicators have been analyzed and determined, informatics content needs to be added and integrated into basic competencies in the basic framework and structure of the 2013 curriculum at the primary and secondary education levels. This is because students are expected to participate actively in their learning, and teachers must be able to provide interactive teaching patterns during the learning process to meet student's basic needs and develop their abilities in the digital era.

Analysis of flat-sided geometric material

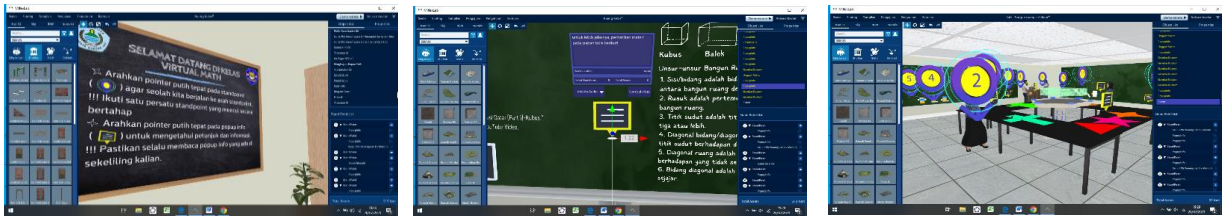
At this stage, we carry out an analysis of the flat-sided building materials that are adapted to the learning media that will be developed. The observations at Junior high schools, home to eight-grade, indicate that students' comprehension of mathematical concepts is inadequate when solving problems involving flat-sided geometric shapes. This is evident in the symptoms, which include students' inability to solve problems that differ from the examples and their memorization of the formula but lack of understanding of the solution. The meaning is that the material they have studied still cannot be applied in their lives.

Analysis of learning media needs

Technology-based learning in implementing the 2013 curriculum is expected to create a more enjoyable learning process to foster students' interest in the learning process, help students understand, and make the learning process student-centered (Utami et al., 2021). Based on the outcomes of observations made on junior high school mathematics teachers in one city in Indonesia, students need learning media that can be studied independently when studying flat-sided geometric material. In the flat-sided geometric material, students learn to calculate and explain the definitions by directly showing the object (Rida, 2021).

Design Stage

At this stage, the researcher made a design plan related to the product to be developed, namely the MilleaLab virtual reality learning media. The researcher made a flowchart about the created learning media development media. The developed media design is based on the outcomes of the analysis carried out in the previous stage. In developing this media, researchers used a virtual reality platform, MilleaLab. MilleaLab is a virtual reality platform that creates a virtual world learning environment where creators or teachers are given freedom. In creating their world to create a learning environment (MilleaLab, 2019). Following are several examples of virtual reality learning media designs, which can be seen in Figure 2 (a), (b), (c), and (d) below.



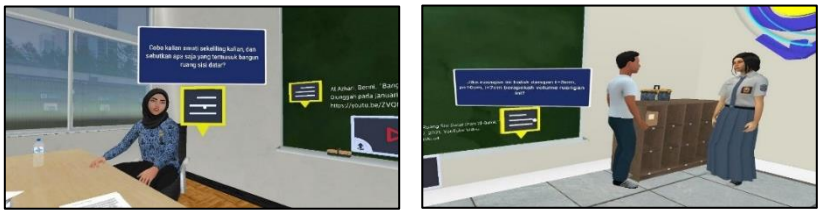
(a) (b) (c)

Figure 2. (a), (b), and (c) Virtual reality learning media design

Then, after the initial design had been completed, the researcher created a research instrument in the form of a validation sheet for virtual reality learning media, which was made based on research references that had been conducted (Akbar, 2016) and something similar in the form of research on the development of virtual reality-based learning media by (Abdussalam et al., 2018).

Development stage

At this stage, the researcher realizes the design created in the previous stage: creating learning media products using the MilleaLab platform. The media product produced is a virtual class on the MilleaLab application, which students can later access via smartphone. The learning material is presented in the form of text on a whiteboard, along with videos and animations that are appropriate to the material. The Virtual Reality display on a smartphone is presented in Figure 3 (a) and (b) below.



(a) (b)

Figure 3. (a) and (b) *Virtual Reality display on a smartphone*

Two learning media experts, each from lecturers and teachers with at least a bachelor's degree in mathematics education and certification, handled the virtual reality learning media validation procedure. Each validator is responsible for rectifying any faults in the virtual reality learning materials and determining whether they are appropriate for student assessment. The outcomes obtained are as follows:

Media validation expert

The first validation process was with the lecturer. The focus tested on media experts includes aspects of virtual reality design, material aspects, learning aspects, and ease of use. The validation process with media experts refines the virtual reality design.

Based on interviews, several recommendations needed to be considered. For example, information instructions should be provided at the start and end of the virtual class so that students can use virtual reality learning resources if they study independently at home. After rewriting a few sections that did not follow the recommendations, it was determined through interviewing students that virtual reality learning materials were legitimate and appropriate for them to use.

Material validation expert

The second validation, namely with teachers and the focus tested on media experts, includes virtual reality design, material, learning, and ease of use. *The question asked is how does the media look? and is the image, video, and sound display clear?.* Based on the interview outcomes, it was found that there are several suggestions, namely adding aesthetic background sound in the mathematics lab so that students do not get bored when exploring the mathematics lab. Then the researcher asked the question again: *Is the content of the material presented by Indicator Competencies and Basic Competencies*? and *What is the feasibility or validity of a mathematics learning medium based on conceptual understanding, especially in flat-sided geometric material?* Based on the interview outcomes, it was

concluded that the virtual reality learning media was valid and suitable for students with revision notes.

After the validation of the virtual reality learning media was completed, the researcher carried out several revisions to maximize the development of the media being created, then analyzed the outcomes of the validation data, then edited the comments and improvements from the validator that were acceptable to get a final product that was better than before. The final result of the improvement is adding information instructions at the beginning and a direct welcome instead of using an info pop-up and adding information instructions at the end on how to close the application. After improving or revising the media based on suggestions and input from expert validators, the researchers conducted trials on eight-grade students at junior high school, namely 25 students, and conducted practical interviews.

Implementation stage

At this stage, the first two stages are carried out: the questionnaire and interview. The questionnaire stage was carried out globally with three categories: 25 students in eight grades, five students selected to be interviewed in depth regarding student responses using Virtual Reality learning media, and 20 teachers. Data obtained from implementation outcomes in the form of questionnaires and interview outcomes were then analyzed.

Questionnaire

In the questionnaire stage, there are three aspects: 1) the convenience aspect, 2) the content aspect, the content aspect of Virtual Reality, and 3) the satisfaction aspect. Each question has the following information: (SA = Strongly Agree, A = Agree, D = Disagree, and SD = Strongly Disagree).

Convenience aspect

At this stage, the researcher will see the response regarding the convenience aspect of virtual reality learning media, including material, information, instructions, and use. This aspect has four questions, and the outcomes of these four questions will be shown in the following table:

Table 1. The convenience aspect

Question	Student				Teacher			
	SA	A	D	SD	SA	A	D	SD
Is the flat-sided geometric material presented here easy to understand?	56%	44%	0%	0%	15%	80%	5%	0%
Is the learning media easy to use?	52%	48%	0%	0%	25%	70%	5%	0%
Is the guidance information easy to understand?	56%	44%	0%	0%	20%	75%	5%	0%
Can you explore the environment easily?	60%	40%	0%	0%	85%	85%	5%	0%

Based on Table 1, the highest result for the question 1 was 56% for students and 80% for teachers, so it can be said that students and teachers can easily understand the flat-sided geometric material on the Virtual Reality learning media. Meanwhile, the lowest result for students is 0% and teachers are 5%. It can be said that there is still a little material that is not understood.

Based on question 2, the highest result was 52% for students and 70% for teachers, which suggests that Virtual Reality learning media is easy to use. The lowest result shows 0% students and 5% teachers, which suggests that some teachers still disagree. So, it is concluded that students and teachers easily understand the use of virtual reality learning media, but some still have difficulty using it.

Based on question 3, the outcomes achieved by students obtained a high score of 56%. In comparison, the teacher got 75%, so it can be said that students and teachers can understand the existing information instructions. However, the lowest score is 5%, so it can be said that there are teachers who cannot understand that information.

Based on question 4, the outcomes achieved by students and teachers who got the highest scores, namely 60% students and 85% teachers, it can be said that students and teachers in the aspect of ease get outcomes that using virtual reality can easily explore the environment. However, some teachers with a score as low as 5% are unable to understand and explore virtual reality.

Content aspect

Aspects of the convenience of learning media include audio, video, images, 3D objects, and displays. This aspect has four questions, and the outcomes of these four questions will be shown in the following table:

Table 2. The content aspect

Question	Student				Teacher			
	SA	A	D	SD	SA	A	D	SD
Are the sounds, videos and images displayed visible?	60%	40%	0%	0%	25%	70%	5%	0%
Do the 3D objects seem as realistic as in the real world?	66%	34%	0%	0%	15%	70%	15%	0%
Is the display of learning media attractive?	52%	48%	0%	0%	25%	75%	0%	0%
Is it appropriate to repeat understanding of material that is not yet understood?	80%	20%	0%	0%	35%	60%	5%	0%

Based on Table 2, the outcomes achieved by students and teachers obtained the highest scores, namely 60% by students and 70% by teachers. Thus, it can be said that the audio, video and images displayed in Virtual Reality look very clear. However, 5% of teachers have the lowest scores, so it can be said that the audio, video, and images displayed in Virtual Reality are not very clear.

Based on question 2, the outcomes achieved by students and teachers obtained the highest scores of 66% students and 70% teachers; it can be said that 3D objects seem as

realistic as in the real world. However, 15% of teachers have the lowest scores, so it can be concluded that 3D objects in virtual reality are not as realistic as the real world.

Based on the outcomes obtained by students in question 3, with the highest score of 52%, while the teacher obtained the highest score of 75%, it can be concluded from these two factors in the content aspect that the result is that the appearance of virtual reality learning media is very interesting.

Based on the question 4, the outcomes were achieved by teachers and students with the highest score, namely 80% by students and 60% by teachers, it can be concluded that the physical aspects of learning media through virtual reality can be used to repeat understanding of material that is not yet understood by students, while a small percentage from the outcomes of the lowest score with 5% of teachers not understanding about virtual reality learning which can help students repeat previous material.

Aspect of satisfaction

In the satisfaction aspect, we will see how students and teachers respond regarding satisfaction with virtual reality learning media. This satisfaction aspect has three questions, and the outcomes of these three questions will be shown in the following Table 3 below.

Table 3. The satisfaction aspect

Question	Student				Teacher			
	SA	A	D	SD	SA	A	D	SD
Do you enjoy learning mathematics using learning media?	52%	48%	0%	0%	20%	80%	0%	0%
Does learning media make learning easy?	72%	28%	0%	0%	30%	65%	5%	0%
Can learning media be used for independent learning?	20%	80%	0%	0%	25%	75%	0%	0%

Based on Table 3, the outcomes for question 1 that achieved by teachers and students by getting the highest score of 52% by students while 80% by teachers, it can be concluded that the satisfaction aspect of getting mathematics learning outcomes, especially the flat-sided building material using learning media, is very enjoyable in using media virtual reality learning.

Based on question 2, the outcomes achieved by students and teachers obtained the highest score of 72% by students and 65% by teachers; it can be concluded that in this aspect, the outcomes show that learning media makes it easier for students to use flat-sided space material in using virtual reality learning media, but there are several teachers with scores as low as 5% who do not understand the material on building flat-sided spaces using virtual reality media well.

Based on question 3, the outcomes achieved by students and teachers with the highest scores, namely 80% by students and 75% by teachers, it can be concluded from this aspect that the outcomes obtained that learning media can be used as independent learning for students in flat-sided building materials using virtual reality learning media. Meanwhile, some

teachers with the lowest score of 5% do not agree with using virtual reality learning media as an independent learning media applied by students.

Interview

At the interview stage, the researcher selected 5 students using purposive sampling, where the researcher selected respondents based on specific characteristics that were the purpose of the interview. The first student is a female student who does not know about virtual reality and does not like mathematics, the second student is a male student who does not know about virtual reality and does not like mathematics, and the third student is a female student who already knows about virtual reality and does not like mathematics. Likes mathematics, and the fourth student is a female student who already knows about virtual reality and likes mathematics. Meanwhile, the last student, student 5, is a male student who already knows about virtual reality and does not like mathematics.

Table 4. Interview results

Subject	Interview
The first subject is a female student who does not know *virtual reality* and does not like mathematics.	*Virtual reality* is seen as a very interesting learning medium and can make it easier for students to understand flat-sided geometric material.
The second subject is a male student who does not know virtual reality and does not like mathematics.	*Virtual reality* is seen as a learning medium that is very easy to use. While learning to use virtual reality, students feel happy, entertained and not bored.
The third subject is a female student who already knows virtual reality and does not like mathematics.	*Virtual reality* learning media is seen as improving understanding of concepts.
The fourth subject is a female student who already knows *virtual reality* and likes mathematics.	*Virtual reality* is a learning medium that is easy to understand with complete explanations of the material.
The fourth subject is a male student who already knows *virtual reality* and does not like mathematics.	*Virtual reality* is seen as a learning medium that can eliminate boredom in learning mathematics, which is very difficult to understand. Its appearance is beautiful and makes students feel enthusiastic about learning mathematics.

In this case, it can be concluded that many students stated that this media was a practical medium to use and showed that virtual reality learning media on flat-sided geometric material had good practical value and could be applied and developed in the future in mathematics learning.

Evaluation stage

This evaluation stage is the process of analysing the learning media created. The following are the evaluation outcomes obtained starting from the Analysis, Design, Development, and Implementation stages.

Analysis stage

At this analysis stage, the researcher conducted a literature review from previous research journals by the media development topic being carried out. The study was carried out using around ten journals related to media development, especially those using virtual reality technology and problems related to those analyzed. There are 3 points of analysis carried out, namely curriculum analysis, material analysis, and learning media needs analysis.

Design stage

In the design or drafting stage, the researcher creates a content design and evaluates the storyboard and flowchart. The evaluation carried out at this stage is revising the flow of the storyboard and flowchart and revising the initial design on the Milllealab platform.

Development stage

The creation and development of previously designed media is carried out at this stage. Researchers use the MilleaLab platform. The evaluation carried out at this stage involves improving the design of the classroom and math lab along with the functions therein, namely the content section, and revising the classroom learning videos.

Implementation stage

The implementation stage is where virtual reality learning media is tested on students. In this limited trial, there were not too many significant obstacles; some students already understood the function and workings of the Virtual Reality tool, and perhaps only a few students needed to be instructed gradually and slowly to be able to test this media.

Based on the outcomes of the ADDIE model stage, which was carried out at the initial analysis stage, the research process regarding students' understanding of mathematical concepts in understanding the flat-sided geometric material is not very good, so learning media is needed that can explain the material well and is easy for students to understand. So, researchers are making design plans for innovative learning products that will be developed through the MilleaLab virtual reality learning media.

With the existence of technological learning media that uses the MilleaLab platform in virtual reality, efforts are being made to create learning innovations that are interesting and can be liked by students. So, the researchers carried out a validation test to conclude that virtual reality learning was declared valid and feasible based on the outcomes of the validation test. The researcher implemented it in two ways, namely through questionnaires and interviews. The researcher concluded that various aspects of interviews and questionnaires, such as virtual reality learning media, can be liked by students so that learning material about flat-sided spatial shapes is easily understood.

Researchers have created a brief tutorial or instructions for using Virtual Reality learning media, which can be accessed at the following link: https://bit.ly/TutorialMengbesarVR . Students can obtain the MilleaLab application on Android smartphones via the Play Store application. Learning media is ideal if clear, simple instructions accompany it and can be used easily by students (Surata et al., 2020).

Discussion

Virtual reality is an effective technology in solving today's real-world problems. For educational purposes in general, virtual reality has been widely proposed as a significant technological breakthrough that could have great potential for facilitating teaching and learning activities. The learning media is virtual reality media, which can help educators explain flat-sided spatial material during learning activities. Virtual reality refers to the use of interactive simulations with the opportunity to be involved in an environment that may look and feel similar to existing objects. Surroundings that create a feeling of being present in cyberspace.

Virtual reality learning has the potential to produce a significant positive impact on the educational process. The following are some impacts of usivirtual reality learning media: 1) Deepening understanding and experience. Virtual reality can take learning material to a deeper level. 2) Facilitating Experience-Based Learning: Virtual Reality can help students experience what is being taught directly in lessons that require an u ng nderstanding of abstract concepts. 3)Encourage Engagement and Motivation: Virtual Reality can create exciting and immersive learning experiences, which encourage student engagement. 4) Expanding Access to Education: The use of Virtual Reality media in education can help expand access to education for people who are in remote areas or have physical limitations because they no longer require long travel or access to certain physical facilities; 5) Supports Independent Learning, the use of Virtual Reality can also help students in independent learning. 6) It helps assess progress, and virtual reality can also be used as an assessment tool. 7)Being a Creative and Collaborative Tool in art or music learning, Virtual Reality can be a creative tool and allows more efficient collaboration between students, especially in different locations.

In line with the opinion of Supriadi et al. (2019), virtual reality learning media based on understanding mathematical concepts in flat space material has advantages and disadvantages, including the advantages namely 1) the learning process becomes more interesting because of the appearance and the content of virtual reality learning media contains mathematical images and animations that are clear and not monotonous; 2) this learning media can be used by students anytime and anywhere via smartphone; 3) there is a learning video that explains the basic concept of flat-sided shapes which makes students understand the concept of flat-sided shapes better; 4) questions are presented in conversational form so that students are willing to answer the questions and can test students' ability to understand mathematical concepts. Although there are many potential benefits from learning using VR, there are also several challenges that need to be faced, including the level of technological development that is still evolving, expensive hardware, and the need for curriculum adjustments to integrate VR into learning.

This opinion aligns with research (Kaminska, et al., 2019) There are many proven benefits of using VR technology in education. Firstly, VR provides extraordinary visualization, which cannot be obtained in a traditional classroom. This reflects a world where the younger generation feels comfortable. Both Worlds are inclusive, allowing everyone,

everywhere, regardless of status, financial situation, and disability, to participate in the educational process. It provides unlimited access to information, books, or articles. Modern technology used in the classroom increases engagement and stimulates cooperation and engagement. It is used for a highly efficient mix of learning, encouraging independent learning and the individual pursuit of knowledge.

In developing this learning media, namely the final product, virtual reality learning media based on understanding mathematical concepts in flat-sided geometric material, it also has shortcomings that are expected to be corrected and developed even better. These shortcomings include: 1) this learning media has sufficient space for movement. Limited, users cannot freely explore the virtual world that has been created; 2) the layout of the function keys cannot be adjusted, sometimes making the function keys have a bad and inappropriate layout; 3) interaction in virtual reality learning media is limited, so students cannot have direct conversations with other students.

Thus, regarding the shortcomings mentioned above, researchers hope that in the future, there will be research that can improve these shortcomings even more. According to the opinion of (Taranilla et al., 2022) The use of VR may be a new active learning space, breaking down traditional space-time barriers where the learning process has not yet been innovated, of course, supporting the use of this technology in efforts to improve education in terms of quality and attitude because it makes it possible to know what content, how, and at what stage the use of VR is more productive in student learning.

Based on the outcomes obtained in the development of learning media, namely the final product of virtual reality learning media based on understanding mathematical concepts in flat-sided geometric material, this is an innovation in mathematical education by using virtual reality learning media to make flat-sided geometric material easier. This is easy to understand, and the material can be understood by students and can eliminate boredom in learning mathematics, which is very difficult to understand.

Conclusion

Based on the outcomes of data analysis obtained in the process of developing virtual reality-based learning media using the ADDIE model, it was validated by two validators who stated that this learning media is suitable for use as a new learning innovation in the world of education. In this description, the researcher concluded that the development of virtual reality media based on a mathematical understanding of flat-sided geometric material is an innovation in the world of education so that it can make it easier for flat-sided geometric material to be understood and comprehended by students and can eliminate feelings of boredom and saturation in learning mathematics. The paradigm is very difficult to understand.

In this case, the development of learning media through virtual reality based on understanding mathematical concepts in flat-sided geometric material still has many shortcomings and is far from perfect. The first deficiency, in this case is that the equipment facilities that support virtual reality learning are not proportional to the number of students in the classroom, both users cannot freely explore the virtual world created, thirdly the layout of

the function keys cannot be adjusted, so that the last student cannot have direct conversations with other students. Of course, suggestions are needed to provide a development innovation that is much better and can be used in creative and fun learning that students like.

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Conflicts of Interest

The authors state that there is no conflict of interest in publishing this work. Furthermore, the writers have addressed ethical concerns such as redundancy, plagiarism, misconduct, data falsification, and/or multiple publishing and/or submission.

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Author Contributions

Putri Mutiara Anisa: Editing, review, and visualization; **Saenih:** Writing—review and editing, formal analysis, and methodology; **Anisa Oktaviani:** Validation and supervision; **Surya Amami Pramuditya:** Correspondence author; **Mohammad Dadan:** Revision and supervision.

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