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Development of Problem-Solving-Based Digital Learning Media for Flat-Sided 3D Geometry in Junior High School

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ABSTRACT

Mastery of concepts is necessary for students in learning geometry, particularly in the topic of flat-sided 3D spatial structures. A strong grasp of concepts is achieved through non-routine problem-solving exercises, which are an integral part of problem-solving-based learning. According to the OECD (Organisation for Economic Co-operation and Development) of Education and Skills 2030, problem-solving-based learning is considered an important component in the curriculum of 60% of countries worldwide. The use of digital media is an innovative approach in education that can transform abstract geometric forms into real-world situations. The focus of this research is to develop digital media to enhance conceptual understanding among eighth-grade students at Yosowinangun Junior High School. The outcome of this study is a valid, practical, and effective digital learning medium for improving conceptual understanding. The research adopts the ADDIE model as the methodological framework. The research sample consists of twenty eighth-grade students. Data collection instruments include validation sheets, practicality questionnaires, interviews, and tests. The research findings indicate that the learning media is valid based on the analyzed validation sheets. Furthermore, the learning media is considered practical based on student response questionnaires, with an average score of 83.3%. The learning media also has a potential effect on conceptual understanding, as evidenced by the overall test results falling into the good category with an average score of 74.75%. Therefore, problem-solving-based digital learning media becomes an effective tool to assist students in developing their conceptual understanding in the process of learning flat-sided 3D spatial structures in geometry.

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A. INTRODUCTION

Geometry is one of the mathematical topics taught in schools. With students' mastery in the field of geometry, it will support them in learning other mathematical subjects such as algebra (Ziatdinov & Valles, 2022) and calculus (Martínez-Planell & Trigueros, 2021). With the understanding of students in geometry, it will affect their ability to learn other topics in mathematics. In line with that, geometry content is a major component in the PISA test questions (Firmansyah et al., 2020; Siahaan et al., 2021). One of the geometry topics taught in schools is flat-sided 3D spatial structures. Conceptual understanding is the main point in learning about flat-sided 3D spatial structures Rohmah & Indriati (2021), with the concepts of surface area being referred to (Bukauskas et al., 2019; Yuliana et al., 2022) and volume (Gropp et al., 2020).

Students acquire a strong conceptual understanding through non-routine problem-solving exercises Ergen (2020), which demand critical thinking skills Wakhata et al. (2023) and problem-solving abilities (Ergen, 2020). In line with that, the analysis conducted by the Organisation for Economic Co-operation and Development (OECD) of Education and Skills 2030 has revealed that critical thinking and problem-solving skills have become part of the curriculum in 60% of countries worldwide (OECD, 2021). Based on this, the implementation of problem-solving-based learning has become an interesting topic on an international scale (Fitri & Sari, 2020). However, field observations indicate that problem-solving approaches are still rarely applied in the context of flat-sided 3D geometry learning (Aziiza & Juandi, 2021).

Another factor that can support conceptual mastery, particularly in the topic of flat-sided 3D spatial structures, is the use of instructional media (Derebaşi, 2019; Nurjanah et al., 2020), specifically digital learning media (Andrés et al., 2023; Nurjanah et al., 2020; Saptono et al., 2023). The use of learning media, particularly digital media, is necessary for learning flat-sided 3D geometry, as digital media not only provides good visual effects but also creates an engaging learning environment that influences the understanding of the material being learned (Fansury et al., 2020). The suitable software to use is *Adobe Animate 2020*. *Adobe Animate 2020* itself is a software that allows users to create interactive animations and web content Anwyl et al. (2020); Vlasenko et al. (2020), supporting various export formats such as HTML5, video, GIF, SVG, and other animation formats that can be used on both smartphones and PCs (Bakri, 2019). Additionally, users can design their own media according to the material and students' knowledge level (Mulders et al., 2020). Additionally, digital learning media can bridge the gap between abstract concepts and more concrete examples (Matthews, 2021; Ulang et al., 2022). Aligned with that, the use of digital media as a means for students to develop their reading skills in a digital environment has been a subject of focus in the reading framework of PISA 2018 (OECD, 2021).

Furthermore, to create a more immersive learning experience for students, the researchers decided to leverage augmented reality technology. Augmented reality technology involves merging digital or virtual elements with the real world, creating an experience that combines physical and digital reality (Chen et al., 2019; Turner, 2022). The chosen application for this research is *3D Geogebra*. This research is based on the shortcomings of a study Maulana & Rafianti (2023) that identified a gap where students could only explore spatial structures provided by the researchers. Hence, if a spatial structure is not included in the media, students might encounter difficulties. One of the advantages of *3D Geogebra* is that it enables students to create and observe spatial structures in more detail due to the availability of zoom in and zoom out features (Medina Herrera et al., 2019; Walkington et al., 2023). Therefore, the researchers are interested in integrating digital learning media by utilizing augmented reality technology and a problem-solving approach using *Adobe Animate* and *3D Geogebra* applications. The objective of this research is to develop digital learning media that supports problem-solving learning for flat-sided 3D geometry material using augmented reality features.

B. METHODS

The research method used in this study is development research. This development research aims to determine the use of digital learning media to support problem-solving learning in flat-sided 3D geometry material. This research follows the ADDIE stages, which include: Analyze, Design, Development, Implementation, and Evaluation (Branch, 2010). The subjects of this research are the eighth-grade students of SMP NU Yosowinangun in the academic year 2021/2022. The ADDIE model applies a structured and flexible continuous approach. The essence of this approach is that the development process is divided into a series of stages with a logical sequence, and the results of each stage can be used as a reference or input for the next stage(Nguyen & Sanchez, 2021).

The explanation of the ADDIE stages is as follows: (1) The analyze stage involves analyzing the problems faced by students, students' basic abilities, relevant materials related to the problems, and the learning objectives to be achieved; (2) Design Phase, in this phase, the researcher begins with the preparation of the product, which includes creating a flowchart and developing assessment instruments consisting of validation sheets, student practicality questionnaires, and test questions; and (3) Development Stage: In this stage, the learning media is given to content experts and media experts for validation. Experts will review the content, design, and language. After revising it according to their suggestions, the media is then tested with three students representing high, medium, and low cognitive abilities, based on the teacher's recommendation. Furthermore, after the revision stage, the next step involved conducting a trial with a group of 6 students, consisting of 2 students with high cognitive abilities, 2 students with moderate cognitive abilities, and 2 students with low cognitive abilities. The implementation stage involved testing the media in the class under study. The evaluation stage in this research was conducted through formative evaluation with the aim of determining whether the learning objectives were achieved or not, as shown in Figure 1.

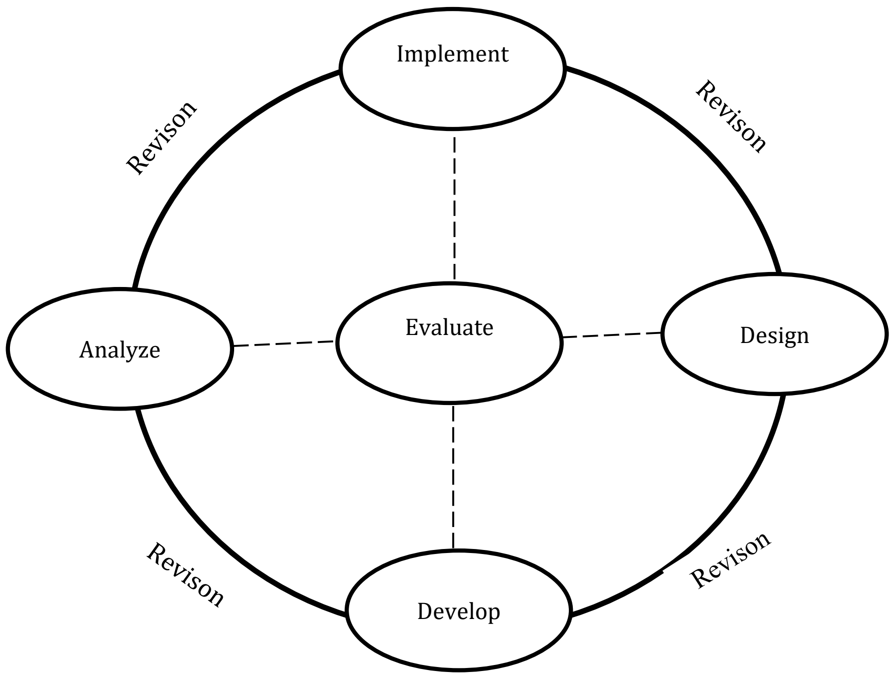


Figure 1. The Proces Flow of ADDIE

The validity of the learning media was obtained based on expert validation using a validation questionnaire, which was qualitatively analyzed based on the comments and suggestions of the experts. Three experts were involved in this research, as shown in Table 1.

Table 1. List of Experts for the Validation Process of Learning Media

No	Name	Field of Expertise
1.	WW	Learning Media Expert
2.	RT	Geometry Learning Expert
3.	SR	Learning Process Expert

The practicality of the learning media was obtained based on the practicality questionnaire results and the interview process conducted during the student and group trials. The results were qualitatively analyzed using the practicality formula, which is:

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

$P\ is$ Percentage of student responses; $f\ is$ frequency of answers; $n\ is$ number of respondents. The Practicality Criteria are as shown in Table 2.

Table 2. Practicality Criteria

Intervals	Category
$\boldsymbol{P = 0\%}$	Nobody
$\boldsymbol{0\% \leq P < 25\%}$	Few students
$\boldsymbol{25\% \leq P < 50\%}$	Almost Half
$\boldsymbol{P = 50\%}$	Half
$\boldsymbol{50\% < P < 75\%}$	Most of
$\boldsymbol{75\% \leq P < 100\%}$	Almost All
$\boldsymbol{P = 100\%}$	All

The effectiveness of the learning media is determined based on the pre-test and post-test results during the implementation stage, which is followed by a class of 20 students. The students' answers are then scored to determine their level of proficiency, which is further analyzed to identify the indicators of conceptual understanding that emerge. Furthermore, N-Gain is used to observe the improvement that occurs. The following are indicators of conceptual (Hidayat & Nuraeni, 2022; Yanala et al., 2021; Yulianah et al., 2020), namely: (1) students are able to restate a concept; (2) Students classify objects according to specific characteristics; (3) Students present concepts in various forms of mathematical representation; (4) Students explain the relationships between one concept and another; and (5) Students apply concepts in problem-solving. The students' test results are then categorized according to the level of conceptual understanding ability in Table 3.

Table 3. Assessment Criteria

Point	Criteria
$85,00 - 100,00$	Very Good
$71,00 - 84,99$	Good
$55,00 - 70,99$	Enough
$30,00 - 54,99$	Less
$< 30,00$	Very Less

Then the scores obtained by students were analyzed by adjusting the following criteria (Hake, 1999): N-Gain is high if $0.7 < g \leq 1$, N-Gain is moderate if $0.3 < g \leq 0.7$, and N-Gain is low if $0 < g \leq 0.3$.

C. RESULT AND DISCUSSION

This research focuses on the development of problem-solving-based digital learning media with a focus on geometry topics such as surface area and volume of flat-sided 3D structures, pyramids, and prisms. The final product is a valid and engaging digital learning media that has a potential effect on students' conceptual understanding, as explained based on the ADDIE stages.

1. Analyze

At this stage, the researcher analyzed the eighth-grade students of SMP NU Yosowinangun. It was found that during classroom learning, the students were unable to grasp the concepts effectively using the available learning resources such as books and teaching modules. Furthermore, the researcher also analyzed the K-13 curriculum for flat-sided 3D geometry material in 8th grade. According to the competency standards (KI and KD) for flat-sided 3D geometry, two indicators were developed for the topic of flat-sided 3D geometry: (a) identifying the process of finding the surface area and volume formulas of prisms and pyramids, and (b) solving problems related to the surface area and volume of prisms and pyramids. Furthermore, the researcher analyzed the learning objectives, which are for students to understand the concepts of surface area and volume of prisms and pyramids, and for students to develop their mathematical conceptual understanding skills.

2. Design

Based on the analyze stage, the researcher designed a digital learning media consisting of basic competencies, materials, quizzes, and the researcher's profile depicted through a flowchart (Figure 2). Furthermore, the researcher developed assessment instruments consisting of a media validation sheet, a practicality questionnaire sheet, and test questions. The validation sheet consists of 12 statements for media experts, 10 statements for subject matter experts, and 10 statements for teachers. The practicality questionnaire consists of 15 statements. Meanwhile, the test questions consist of 4 essay questions that are included in the learning media, as shown in Figure 2.

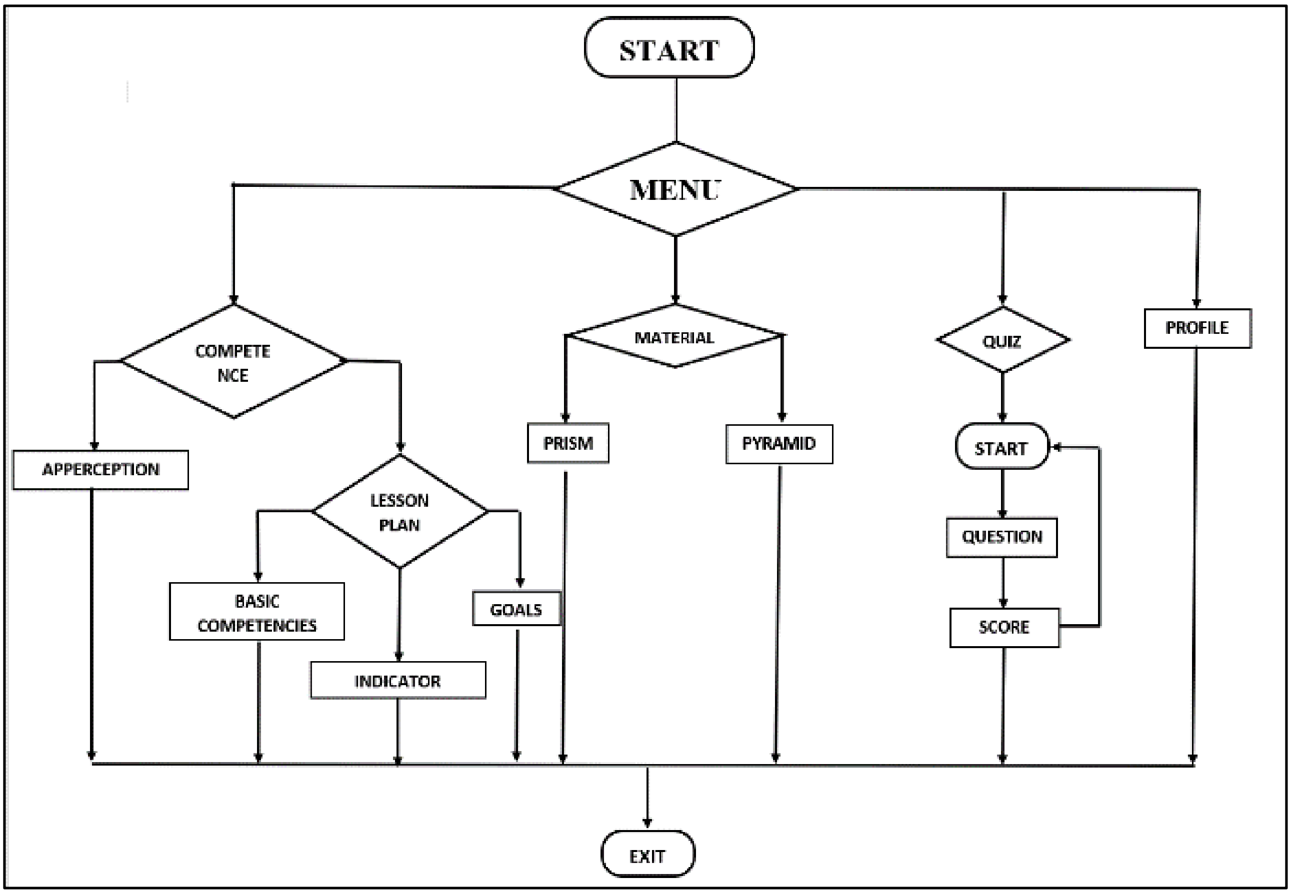


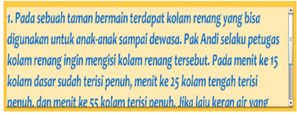
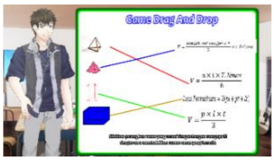
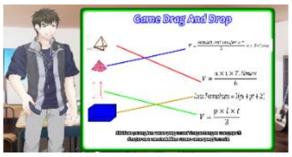
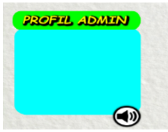
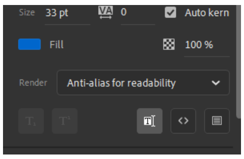
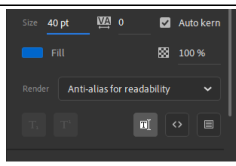
Figure 2. Flowchart of Digital Learning Media for Flat-Sided 3D Geometry Material

3. Design

At this stage, it begins by providing the learning media to three experts or specialists simultaneously, and then the researcher provides a validation sheet. The sheet contains statements regarding whether the created learning media is deemed appropriate. After revising the learning media based on the experts' comments and suggestions, the media can be considered valid. A media can be deemed valid if it aligns with the (Kim et al., 2019; Marwick & Partin, 2022). Several revisions based on the experts' comments and suggestions are presented in Table 4.

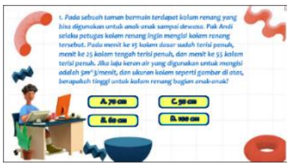
Table 4. The Revision Decision Based on Expert Advice and Comments

Before Revision	Advice and Comments	Revision
	Provide illustrations in the questions to enhance students' imagination	 Provide simple illustrations to stimulate students' imagination

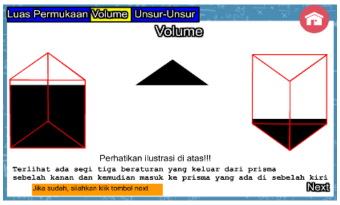
	the questions used need to be that long, use the scroll text feature	 The questions are created using the scroll feature to prevent them from appearing too long
	In a drag and drop game with geometric formulas, if possible, both the formula and the geometric shape should be draggable, not just one of them.	 Students are free to place the geometric shapes and their formulas, they just need to adjust them to the lines
Nothing	Provide a button to turn off the music as not all students enjoy studying with music.	 The researchers added a button to turn off the music
	For the font, since this will be based on Android, it is recommended to make the font size larger.	

After revising, the researcher presents the learning media again to confirm the quality of the media that has been created. Subsequently, the researcher asks experts to provide statements regarding whether the media is suitable for use or requires further revision. Continued by providing learning media to 3 students with different levels of ability, namely high, medium, and low. After the students tried the provided media, the researcher administered a practicality questionnaire to assess the practicality of the media and requested feedback as considerations for media revisions. The comments, suggestions, and revisions from the student trials are presented in Table 5.

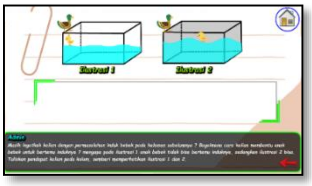
Table 5. The Revision Decision Based on One-to-One Advice and Comments

No	Advice and Comments	Revision
1.	 Before the revision, the questions appeared too lengthy, which made the students uninterested in reading them	 The questions are created with a scrolling system to save space, and illustrations are provided to give an initial visual representation of the questions. The background is also modified to a simpler design

2



In delivering the material, there are still more writings than animations



In delivering the material, a small game was included as an introduction to the problem, along with the addition of illustrative videos.

3.

There is no calculator feature to assist students in solving problems in the media.

Added calculator feature

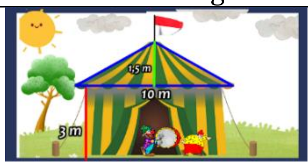
Furthermore, the revised media was provided to a group of students to assess the practicality of the learning media based on a practicality questionnaire. The practicality percentage result of 83.3% indicates that the learning media is highly practical. The percentage for each indicator can be seen in Table 6.

Table 6. The Results of the Practicality Test for Small Groups

No Statment	Result
1	83,3%
2	66,7%
3	83,3%
4	50%
5	83,3%
6	66,7%
7	100%
8	100%
9	66,7%
10	100%
11	100%
12	100%

The practicality indicates that the flat-sided 3D geometry learning media is easy to use for students, captures their interest in using it, and is efficient. The ease of use of the learning media can be assessed based on the preparation in planning it. Properly preparing the learning materials in the media is a necessity in facilitating learning (Tafakur et al., 2020). After obtaining the results from the group trial, the learning media was revised based on the suggestions and comments from the students, making it considered practical. Table 7 presents the revision decisions made during the small group.

Table 7. The Revision Decision Based on Small Group Advice and Comments

No	Before Revision	After Revision
1.	 There is only a play button	 Play and stop buttons are made to make it easier for students to listen to information in the media.
2.	 There is no hint of which part to click on to continue the media	 In the email section there is an enlarged notification as a guide to continue the media
3.	 The size is not written on the illustration image	 Instructions are given in the pictures to make it easier for students to imagine

4. Implementation

At this stage, the learning media was provided to 20 eighth-grade students at NU Yosowinangun Junior High School. It started with the researcher administering a pre-test to assess the students' initial abilities, the researcher provided 4 problems related to flat-sided 3D geometry problem-solving. After completion, the researcher asked the students to submit their pre-test answers. Next, the researcher installed the learning media on each student's device. Then, the students were asked to use the learning media until completion, which included completing the test provided in the learning media. At the same time, the researcher and colleagues conducted observations to measure the students' conceptual understanding abilities. After the students have completed, the researcher provided two questionnaires, namely the media practicality questionnaire and the conceptual understanding ability questionnaire. The conceptual understanding was also assessed based on the students' answers during the exercises in the learning media, as shown in Table 8.

Table 8. The Frequency of Students' Conceptual Understanding Abilities in Pre Test

Score	Category	Frequency	Percentage
$\mathbf{85,00 - 100,00}$	Very Good	3	15%
$\mathbf{71,00 - 84,99}$	Good	3	15%
$\mathbf{55,00 - 70,99}$	Enough	7	35%
$\mathbf{30,00 - 54,99}$	Less	2	10%
$\mathbf{< 30,00}$	Very Less	5	25%
Average	Enough	56,45	

Table 9. The Frequency of Students' Conceptual Understanding Abilities in Post Test

Score	Category	Frequency	Percentage
$\mathbf{85,00 - 100,00}$	Very Good	5	25%
$\mathbf{71,00 - 84,99}$	Good	7	35%
$\mathbf{55,00 - 70,99}$	Enough	4	20%
$\mathbf{30,00 - 54,99}$	Less	4	20%
$\mathbf{< 30,00}$	Very Less	0	0%
Average	Good	74,75	

The average pre-test score obtained by students is 56,45 while the average post-test score obtained by students is 74.75. The N-Gain value is 0.53 so that if viewed from the conceptual understanding skills the increase that occurs is included in the medium category. An example of a student's answer with a very good conceptual understanding can be seen in Figure 4.

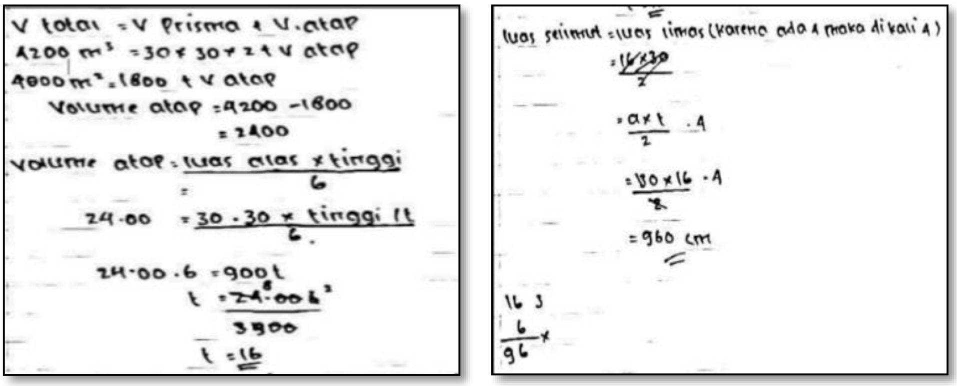


Figure 3. an Example of Student Answers

In the given response, it is evident that the WR subject fulfills the first indicator of conceptual understanding, which is restating the concepts related to the volume of a prism, volume of a pyramid, and surface area of a pyramid. After identifying the available data to determine the volume of the prism and pyramid, the WR subject meets the second indicator of conceptual understanding, which is classifying objects based on specific properties. The WR subject constructs the problem-solving approach by grouping the information needed to find the height of the roof based on the known volume. This aligns with the opinion of Al-Mutawah et al. (2019) that the ability to classify relevant information in problem-solving tasks requires a strong conceptual understanding (Sinha, 2022).

Then, subject WR fulfills the fourth indicator of conceptual understanding, which is explaining the interrelation between concepts, as evidenced by subject WR using the concept of the volume of a pyramid to determine the height of the pyramid, which will later be used to calculate the lateral surface area of the pyramid. In line with this opinion, (İbili et al., 2020) state that explaining the interrelation between volume and surface area of a geometric solid requires a high level of understanding. After obtaining the height of the pyramid, subject WR proceeds with solving the problem according to the concept of the surface area of the pyramid to find the amount of fabric needed to cover the circus tent roof. This proves that WR fulfills the fifth indicator of conceptual understanding, which is using concepts in problem-solving. However, there was a slight error in the calculation made by WR, specifically in the concept of the volume of a pyramid, where WR should have divided the product of the base area and height by three, but instead divided it by six, resulting in an incorrect calculation. This demonstrates that WR has a good understanding of conceptual knowledge.

D. CONCLUSION AND SUGGESTIONS

In Based on the research findings, it can be concluded that: (1) The developed flat-sided 3D geometry learning media is considered valid. The validity of the flat-sided 3D geometry learning media was obtained through validation by subject matter experts and media experts in the development phase of validation, as evidenced by the validation questionnaire results. The validity of the problem-solving-based flat-sided 3D geometry learning media covers content validity, design validity, and technical quality; (2) The developed flat-sided 3D geometry learning media is considered practical. The practicality of the problem-solving-based learning media was assessed through practicality questionnaires and interviews during the student group trials and implementation phase. Students expressed that the flat-sided 3D geometry learning media is easy to use and helps them understand the concepts of volume and surface area of flat-sided 3D geometry; and (3) The flat-sided 3D geometry learning media has the potential to improve students' conceptual understanding, as indicated by the post-test results in the good category at 74.75, with an N-Gain value of 0.53 based on pre-test and post-test scores.

Based on the conclusions drawn, the researchers intend to provide some suggestions for future researchers who will further explore the development of digital problem-solving-based learning media for conceptual understanding abilities. They can enhance the learning media with more advanced features such as web-based platforms, eliminating the need to install the media on each student's device. For teachers, do not hesitate to utilize ICT as a means of learning media, as this aligns with the demands of new literacies, including digital literacy.

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