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Conceptual Knowledge through Instruction Interactive Teaching Materials Integrated Augmented Reality

Sudirman[1], Irena Puji Luritawaty[2*], Ebenezer Bonyah[3]

Master of Mathematics Education, Graduate School, Universitas Terbuka
Jalan Cabe Raya, Pamulang, Tangerang Selatan, Indonesia
[1]sudirman.official@ecampus.ut.ac.id

Department of Mathematics Education, Institut Pendidikan Indonesia
Jalan Terusan Pahlawan No. 32, Garut, Jawa Barat, Indonesia
[2*]irenapuji@institutpendidikan.ac.id

Department of Mathematics Education, AAMUSTED
Kumasi, Ghana
[3]ebbonya@gmail.com

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Abstrak

Konsep luas permukaan dan volume 3D merupakan salah satu konsep penting untuk membangun pengetahuan matematis lainnya yang lebih aplikatif. Namun, siswa kesulitan dalam memahami konsep tersebut. Perlu adanya teknologi yang dapat membantu siswa, misalnya Augmented Reality (AR). Penelitian ini bertujuan mengungkap peningkatan pemahaman konsep luas permukaan dan volume prisma melalui Instruction Interactive teaching materials integrated Augmented reality (I-ITMIAR). Desain penelitian yaitu exploratory case study terhadap 32 siswa dan satu guru matematika di salah satu sekolah menengah pertama di Kabupaten Indramayu. Data penelitian diperoleh dari wawancara, observasi, dan tes. Data dianalisis secara kualtiatif menggunakan analisis konten dan statistik deskriptif. Hasil penelitian menunjukkan penggunaan AR memberikan peningkatan signifikan dalam pemahaman siswa terhadap konsep-konsep geometri, khususnya luas permukaan dan volume prisma. Melalui visualisasi tiga dimensi yang dihasilkan, siswa dapat melihat dan berinteraksi dengan model prisma secara real-time. Penggunaan AR dapat menjadi alat bantu efektif umeningkatkan pemahaman konsep.
Kata Kunci: Augmented reality; Instruction Interactive Teaching Materials; Luas Permukaan; Pengetahuan Konsep; Prisma, Volume.

Abstract

The concept of 3D surface area and volume is one of the important concepts for building other more applicable mathematical knowledge. However, students have difficulty in understanding the concept. There needs to be technology that can help students, such as Augmented Reality (AR). This study aims to reveal the increase in understanding of the concept of surface area and volume of prisms through Instruction Interactive teaching materials integrated Augmented reality (I-ITMIAR). The research design is an exploratory case study of 32 students and one mathematics teacher at a junior high school in Indramayu Regency. Research data were obtained from interviews, observations, and tests. Data were analyzed qualitatively using content analysis and descriptive statistics. The results showed that the use of AR provided a significant increase in students' understanding of geometric concepts, especially the surface area and volume of prisms. Through the resulting three-dimensional visualization, students can see and interact with the prism model in real-time. The use of AR can be an effective tool to improve conceptual understanding.
Keywords: Augmented Reality; Instruction Interactive Teaching Materials; Surface Area; Conceptual Knowledge; Prism; Volume.

I. INTRODUCTION

Understanding the concepts of surface area and volume of prisms is a crucial aspect in learning three-dimensional geometry (Chiphambo & Mtsi, 2021; Huang & Wu, 2019). These concepts not only underlie mathematical theory but also have significant practical implications in various disciplines such as architecture, engineering, and product design. Surface area refers to the total area of all the outer surfaces of an object, while volume measures how much space the object can fill (Martin, 2009; Battista, 2012). Both of these concepts are important in various applications, from calculating construction materials to designing products, where an accurate understanding of capacity and area is needed. Therefore, mastering the concepts of surface area and volume of 3D geometry is key to building solid and applicable mathematical knowledge (Park et al., 2018).

In the context of mathematics learning, traditional approaches often face challenges in effectively delivering these mathematical concepts, especially 3D geometry. Physical models and two-dimensional graphical representations are often inadequate to describe the spatial relationships and complex structures of 3D objects (Krüger et al., 2022). These limitations create an urgent need for more innovative teaching methods that can overcome these shortcomings and enable students to gain a deeper understanding of abstract geometric concepts. This is where the role of modern technology, especially Augmented Reality (AR), becomes very relevant (Yaniawati et al., 2022; Fatihah et al, 2023; Sudirman et al., 2023; Sudiman & Susandi, 2024).

AR technology offers a new way to visualize and explore mathematical concepts that are difficult to access through conventional methods (Cai et al., 2023; Martín-Gutiérrez et al., 2017; Wu et al., 213). With AR, students can see and interact with 3D objects as if they were actually in the physical environment (Hung et al., 2017; Saputro et al., 2024). In addition, AR technology allows students to manipulate geometric objects, observe changes in real time, and receive immediate feedback that strengthens students' understanding (Sarkar et al., 2023; Sudirman et al., 2020). These interactive features not only make the learning material more interesting but also help students overcome difficulties in understanding spatial relationships and complex structures. In addition. The ability to present dynamic and interactive visualizations makes AR a very potential tool in overcoming the challenges of understanding 3D geometry and increasing student engagement in the learning process (Abdinejad et al., 2021).

However, despite the potential of AR technology, students often struggle to understand 3D geometry, especially in terms of surface area and volume (Seah & Horne, 2020; Ng et al., 2020). 3D geometry concepts feel abstract because students cannot easily visualize them in three-dimensional space (İbili et al., 2019). This makes it difficult for students to calculate the surface area of a prism, which requires an understanding of how each side of the prism contributes to the total area, while calculating volume requires an

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understanding of how the space inside the prism is measured. Without adequate visual aids, students struggle to visualize and understand the spatial relationships needed to complete these calculations.

Several studies have shown that AR can be an effective solution to this problem. As Gargrish et al. (2020) explained that AR provides interactive visualizations that allow students to see and interact with geometric objects in a virtual environment. In addition, previous studies have also indicated that AR can improve students' understanding of mathematical concepts in a more intuitive way (Schutera et al., 2023). For example, students can manipulate the shape of a prism, change its size, and see how these changes affect the surface area and volume directly. This helps students develop a better understanding of the relationships between variables and the calculations performed.

However, there is a significant research gap regarding the specific application of AR in teaching the concepts of surface area and volume of prisms. Many existing studies focus more on the application of AR in general or on other mathematical concepts, while research that specifically explores the application of AR to prisms is still limited. This study aims to fill this gap by introducing and evaluating the use of Instruction Interactive Teaching Materials Integrated Augmented Reality (I-ITMIAR) in the context of learning the concepts of surface area and volume of prisms.

This study offers an integrated solution by developing and implementing I-ITMIAR as a tool in 3D geometry learning. By integrating AR technology into interactive teaching materials, this study aims to improve students' understanding of the concept of surface area and volume of prisms in a more effective and interesting way. I-ITMIAR is designed to provide a more immersive learning experience, allowing students to explore prism objects in 3D, perform calculations with immediate feedback, and understand how various variables affect the calculation results. It is hoped that this approach will improve learning outcomes and provide new insights into how technology can be optimized in mathematics education, thereby improving the quality of education and preparing students for future challenges.

II. METHOD

This study adopted an exploratory case study design to understand how the use of Instruction Interactive Teaching Materials Integrated Augmented Reality (I-ITMIAR) can affect students' understanding of the concepts of surface area and volume of prisms. An exploratory case study was chosen because it allows researchers to investigate this phenomenon in depth in a real educational context, namely grade VIII. This study was conducted in several key stages: (a) The first stage involved the development of I-ITMIAR teaching materials specifically designed to teach the concepts of surface area and volume of prisms. These materials include interactive elements that utilize AR technology to create a more immersive and visual learning experience. Prior to implementation, the researcher ensured that all materials had been approved by the school and parents of students, and met research ethics standards. The second stage was the implementation of I-ITMIAR teaching materials in grade VIII D during the research period. The mathematics teacher facilitated the use of AR technology during the learning session, where students were directly involved with the teaching materials and interacted with geometric objects in a virtual environment. During this process, the researcher collected data through observations, interviews, and tests to assess the effectiveness of AR in improving students' understanding.

This study involved two eighth grade mathematics teachers and 32 students from class VIII D. The mathematics teachers were responsible for implementing AR-based teaching materials and providing guidance during the learning sessions. They were also involved in the evaluation process and provided insights into their experiences using this technology in teaching. The students involved consisted of 12 males and 20 females. Students' participation in this study involved direct interaction with I-ITMIAR during the learning activities. They would be the main focus of observations and interviews to evaluate how AR impacted their understanding of the concepts of surface area and volume of prisms.

Data collection methods used in this study include observation, interviews, and tests: (a) Observations were conducted to see how students interact with AR-based teaching materials. Researchers observed students as they used AR technology, recorded how they manipulated the prism model, and evaluated the level of engagement and difficulties faced by students. These observations provide insight into the dynamics of learning and the effectiveness of AR in the classroom context. (b) After the learning session, researchers conducted interviews with students to obtain their responses regarding the use of AR. This interview aimed to evaluate whether students felt that AR helped them understand the material. Some of the interview questions asked included students' experiences using AR, aspects that were helpful or confusing, and comparisons with traditional learning methods. (c) A comprehension test was used to measure how well students understood the concepts of surface area and volume of prisms after using I-ITMIAR. This test was designed to evaluate students' knowledge through various types of questions, including multiple choice, essay, and practical applications. This test aims to provide a quantitative picture of the increase in students' understanding as a result of using AR.

Qualitative data from observations and interviews were analyzed using content analysis methods. This process involved identifying key themes that emerged from the data, such as students' reactions to AR, their level of understanding, and feedback on the learning materials. The researchers categorized the data into these themes to reveal patterns and trends related to the impact of AR on learning. Next, data from the tests were analyzed using descriptive statistics. This included calculating the mean, median, and standard deviation of students' test scores to assess the effectiveness of AR in improving conceptual understanding. This analysis provided useful information regarding the extent to which the use of AR affected students' learning outcomes numerically.

III. Result and Discussion

A. Result

1. Implementation of I-ITMIAR on The Surface Area of Prisms

At the first meeting, the teacher asked students to study the teaching materials provided by the teacher. The teaching materials used by students are teaching materials that integrate AR technology. In addition, the teaching materials also contain instructions that must be carried out by students. The cover of the AR-integrated geometry textbook can be seen in Figure 1.

Figure 1. AR Integrated Teaching Material Cover

In the teaching materials, there are six instructions that must be followed by students, namely (a) The "Let's Remember" instruction aims to awaken students' initial understanding before starting to learn new material. (b) The "Let's Connect" instruction contains an explanation or statement that aims to connect students' initial knowledge with the concept of the material that will be learned by students. (c) The "Let's Explore" instruction contains instructions to explore by observing, listening, listening, and seeing 3D geometric shapes by pointing the camera of a cellphone that has the AR application installed. (d) The "Let's Communicate" instruction contains instructions to communicate in writing the results of the exploration process. (e) The "Let's Elaborate" instruction contains instructions to solve different problems, which aims to ensure that the new knowledge obtained by students can be internalized properly. (f) The "Let's Practice" instruction contains instructions to complete exercises that are done independently or in groups. This aims to ensure that students can understand the material well.

In the "let's remember" phase, students are asked to recall the material from the previous meeting, namely the cube net. Students are asked to mention the number of plane shapes found in the cube net and write the name of the plane shape and the formula for determining the area of the plane shape in the table provided in the AR integrated 3D geometry teaching material (See Figure 2).

No	Bangun Datar	Rumus Luas Bangun Datar

Figure 2. Instruction Table "Let's Remember".

After filling in Table 2, students are asked to connect the surface area of a cube shaped like a gift box. Gift boxes generally resemble cubes. Gift boxes can be made of cardboard and the outside is covered with paper with various motifs. Next, students are asked to pay attention to the picture of the dimensions of the gift box as below (See 3). After that, students are asked to write down the shape and formula of the plane that makes up the gift box.

Figure 3. Gift Box Dimensions in “Let’s Connect” Instructions

After writing down the geometric shapes and their formulas, students are asked to interpret the relationship between the area of paper used to cover the gift box and the surface area of a cube.

Next, the researcher asked the students to point the cellphone camera at the marker image (See Figure 4). After that, the students were asked to pay attention to the surface of the 3D shape that appeared on the cellphone camera. The 3D animation of the gift box can be seen in Figure 4.

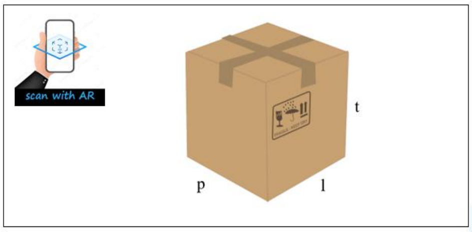
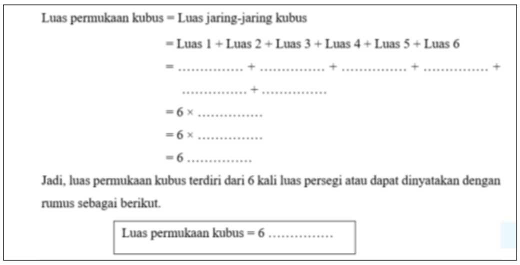


Figure 4. Gift Box Marker on “Let’s Explore” Instructions

After students observe the 3D animation form of the surface of the gift box, students are asked to communicate in writing such as being asked to draw the shape of the gift box and mark each edge. Furthermore, students are asked to make a net, complete and continue the process to determine the surface area of the cube from the shape of the gift box. After exploring understanding through the AR application, students are asked to follow the instructions "Let's Communicate". The results of the communication can be written as in Figure 5.



Luas permukaan kubus = Luas jaring-jaring kubus

= Luas 1 + Luas 2 + Luas 3 + Luas 4 + Luas 5 + Luas 6

= .... + ... + ... + ... + ... + ...

= 6 × ....

= 6 × ....

= 6 ....

Jadi, luas permukaan kubus terdiri dari 6 kali luas persegi atau dapat dinyatakan dengan rumus sebagai berikut.

Luas permukaan kubus = 6 ....

Figure 5. Construction Determines the Surface Area of a Cube in the Instructions “Let's Communicate”

When students were asked to complete and continue the filling as in Figure 5, most students asked how to determine area 1, area 2 and so on. Then the researcher answered by sending a voice regarding how to complete the filling.

After that, students were asked to elaborate on their understanding of the surface area of a cube by solving problems given by the researcher. The researcher asked students to solve problems in the “let’s elaborate” phase. There were two problems that students had to solve, the first problem was to determine the area of wrapping paper needed to wrap a gift with a side length of 25 cm and the second problem was to determine the surface area of two bathtubs without a lid. After students finished working on the problem, students were asked to confirm their answers by pointing the camera at the QR Code image (See Figure 6). After that, students were asked to understand the explanation of the video.

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Figure. 6. QR Code elaboration phase

In the "evaluation" instruction, students are asked to point the cellphone camera at the marker image (See Figure 7).

Figure 7. Evaluation Phase Marker

Students are asked to pay attention to the surface of the 3D shape that appears on the cellphone camera.

2. Implementation of I-ITMIAR on prism volume material

This study began with the teacher asking students to open the AR-integrated 3D geometry teaching materials in Chapter 7. After that, students were asked to fill in each instruction in the AR-integrated 3D geometry teaching materials related to the volume of the prism. The researcher asked students to understand each instruction and phase in the AR-integrated 3D geometry teaching materials. In the "Let's Connect" phase, students were asked to recall the surface area formula of a cuboid. Next, the researcher gave the students a question, "do you still remember the surface area formula of a cuboid?", after that, the students answered "Remember". The researcher continued by giving the question "do students know whether there is a relationship and difference between the surface area of a cuboid and the volume of a cuboid?" After that, students were asked to fill in the instructions in the "let's remember" phase. After the "let's remember" phase, the researcher tried to connect the knowledge that students already had with the material to be studied. The researcher gave a problem in the form of a bathtub. The researcher asked students to pay attention to the shape of the bathtub as in Figure 8.

Figure 8. Bathtub Dimensions

The researcher explained that a bathtub is a piece of equipment that is used to store water for bathing. Furthermore, the researcher explained that most bathtubs are made in the form of blocks without a lid and the water capacity in the bathtub is very dependent on the size of the bathtub such as length, width and height. The researcher also asked the students that "if in your house, the bathtub is in the form of a block with a length of 1.25 meters, a width of 1 meter and a height of 1 meter, what is the volume of the bathtub?". Most of the students looked silent. In this phase, students were asked to discuss with their group members to find out the answers to the questions given by the researcher. Students showed a good response by discussing and asking questions to each other with their group members. After that, the researcher explained that the knowledge that students already have is very useful in understanding the concept of the volume of a block. Furthermore, to be able to find out the formula for the volume of a block, students were asked to follow the instructions in the "let's explore" phase.

In the “let’s explore” phase, students are asked to understand the derivation of the cuboid volume formula by pointing the cellphone camera at Figure 9. Students are asked to observe the arrangement of unit cubes from the 3D shape that appears on the camera. Furthermore, students are asked to write down the number of unit cubes, the unit size, and its volume. To help students write down the results of their observations, an example is given in the first shape.

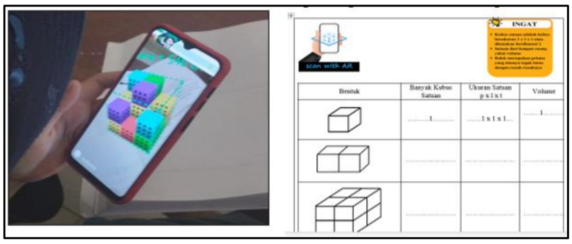

Figure 9. AR Markers and Animations in the “Let’s Explore” Instructions

The 3D animation that appears can be seen in Figure 9. In the animation, students will see a stack of unit cubes. After seeing the 3D animation that appears, students are asked to fill in the table for the second, third and fourth shapes. The results of the answers show that there are students who ask about unit cubes. The researcher explains unit cubes and how to fill in the table. Furthermore, to discuss with their friends to communicate the meaning of their findings, students are asked to conclude and complete the contents in the "let's communicate" phase in the teaching material. The results of the students' answers show that students are able to write down their findings and can derive the cuboid volume formula well.

Next, to confirm the answer to the problem, students are asked to point the camera at the QR Code Figure in the “Let’s Elaborate” instruction. After that, students are asked to understand the explanation of the video. Next, in the “Let’s Practice” instruction, students are asked to point the cellphone camera at the Figure marker below (see Figure 10).

Figure 10. “Let’s Practice” Markers and Animations

As for the 3D animation that appears, such as Figure 10, next, students are asked to pay attention to the arrangement of tofu that is put into the box that appears on the cellphone camera.

3. Test Results and Analysis of Student Answers

After four learning sessions (two sessions on the topic of determining the surface area of a prism and two sessions on the topic of the volume of a prism), the researcher conducted a final test and obtained descriptive data presented in Table 1. The data include the average scores of the pre-test and post-test.

Table 1.
3D Geometry Surface Area and Volume Test Results

	Pretest	Posttest
N	32	32
Minimum Score	34	44
Maximum Score	66	84

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Average	48	68

The pre-test results showed that out of 32 students who took the exam, the lowest score achieved was 34, while the highest score was 66, with an overall average score of 48. This indicates that before the implementation of the interactive instructional module integrated with augmented reality, students' understanding of the concept of surface area and volume of prisms was at a moderate to low level. In addition, the post-test results showed a significant increase. The lowest score achieved increased to 44, while the highest score reached 84, with an overall average score of 68. This average increase of 20 points indicates that the use of augmented reality in learning has a positive impact on students' understanding of the concept of surface area and volume of prisms. In addition, the increase in the minimum score also shows that students with low abilities have made significant progress, thereby reducing the gap in understanding among students in the class. These results indicate that interactive instructional modules based on augmented reality can be an effective tool to improve student learning outcomes in geometry subjects.

Table 2.
Proportion of Correct Answers in Pre-test and Post-test

Indicator	Proportion of Correct Answers Pre-test		Proportion of Correct Answers Post-test	
Determining the Surface Area of a Combined Rectangular Prism and Triangular Prism	20	62.5	28	87.5
Determining the Surface Area of a Combined Cube and Triangular Prism	12	37.5	22	68.75
The volume of Combined Triangular Prism and Rectangular Prism	10	31.25	16	50
Comparing the Volume of a Cube, Rectangular Prism, and Triangular Prism Based on Their Properties	14	43.75	20	62.5
Average		43.75		67.19

The results of the pre-test and post-test showed a significant increase in the proportion of students' correct answers on various indicators of understanding the concept of surface area and combined volume of triangular prisms with cuboids or cubes. On the indicator "Determining the combined surface area of cuboids and triangular prisms," the proportion of correct answers increased from 62.5% in the pre-test to 87.5% in the post-test. Likewise, on the indicator "Determining the combined surface area of cubes and triangular prisms," there was an increase from 37.5% to 68.75%. This increase indicates that students experienced a significant increase in understanding after implementing the interactive instructional module based on augmented reality.

Furthermore, on the indicator "Combined volume of triangular prism and cuboid," the proportion of correct answers increased from 31.25% in the pre-test to 50% in the post-test. In addition, on the indicator "Comparing the volume of cubes, cuboids, and triangular prisms based on their properties," the proportion of correct answers increased from 43.75% to 62.5%. The overall average proportion of correct answers also increased from 43.75% in the pre-test to 67.1875% in the post-test. This increase indicates that the use of augmented reality in learning helps students understand and apply complex geometric concepts better. This shows the effectiveness of interactive instructional modules in improving student learning outcomes.

4. Student and Teacher Responses

a. Student Response

To better understand the effectiveness of using I-ITMIAR in geometry learning, especially in the concept of surface area and volume, we conducted interviews with several students who have participated in learning using this technology. This interview aims to get direct views from students about how AR helps them understand the material, as well as how it affects students' motivation and confidence in learning. The following is an excerpt from the interview transcript.

First Student

Researcher	:	What do you think about the use of augmented reality (AR) in geometry learning, especially in understanding the concepts of surface area and volume?
Student 1	:	I find AR very helpful. Usually, I have difficulty visualizing 3D shapes just from Figures in books. With AR, I can see objects from different angles and understand how to calculate their surface area and volume more easily.
Researcher	:	Do you feel more motivated to learn with AR?
Student 1	:	Learning with AR is very fun and not boring. I am more enthusiastic to learn and try new things in geometry material
Researcher	:	Is there any difference in the way you understand geometry concepts using AR compared to traditional methods?"
Student 1	:	With AR, I can see firsthand how shape changes affect surface area and volume. This helps me grasp concepts faster than just reading theory.
Researcher	:	How about your ability to remember geometry formulas after studying with AR?
Student 1	:	Usually, I have a hard time remembering geometry formulas. But with AR, I can see the real application of the formulas and it is easier to remember them when working on problems.

Based on interviews with the first students, it was revealed that the use of augmented reality (AR) in geometry learning has proven to be very helpful for students in understanding the concept of surface area and volume. Students find it difficult to imagine 3D shapes only from Figures in books, but with AR, they can see objects from various angles, which makes it easier to calculate surface area and volume. AR also increases students' learning motivation, making learning fun and not boring, so they are more enthusiastic about learning and exploring new materials. Compared to traditional methods, AR allows students to directly see how changes in shape affect surface area and volume, which accelerates conceptual

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understanding. In addition, students' ability to remember geometry formulas increases because they can see real applications of the formulas, making them easier to remember when working on problems. Overall, AR has great potential to improve students' understanding, motivation, and memory in geometry learning.

Second Student

Researcher	:	What do you think about the use of augmented reality (AR) in geometry learning, especially in understanding the concepts of surface area and volume?
Student 2	:	I think the use of AR is quite interesting, but I feel that sometimes it makes me confused. I am more used to Figures in books and explanations from teachers.
Researcher	:	Do you feel more motivated to learn with AR?
Student 2	:	Actually, I don't feel a big difference in motivation. AR does provide variety, but I prefer learning the way I'm used to.
Researcher	:	Is there any difference in the way you understand geometry concepts using AR compared to traditional methods?
Student 2	:	It may be a little different, but I find it easier to understand concepts when explained directly by a teacher or through a textbook. AR sometimes makes me focus too much on the visuals, so I forget the basic concepts.
Researcher	:	How about your ability to remember geometry formulas after studying with AR?
Student 2	:	I don't think my memorization skills have changed much. AR does help with seeing real applications, but I'm still more comfortable memorizing formulas through practice and written explanations.

From this interview excerpt, it is clear that students have a less positive view of the use of augmented reality (AR) in geometry learning. Although they admit that AR is quite interesting, these students feel more confused than helped by this technology. They are more comfortable with traditional methods such as Figures in books and direct explanations from teachers. This shows that while AR offers more interactive visualizations, not all students find this approach suitable. Some students may feel burdened by the change in learning methods that they have not fully understood or mastered, so their preference remains with conventional methods that have proven effective for them.

In addition, students' learning motivation did not increase significantly with the use of AR. Although AR provides variation in learning, these students still prefer traditional learning methods. In terms of understanding geometry concepts, students find it easier to understand when explained by teachers or through textbooks than using AR, which sometimes makes them focus too much on visuals and forget basic concepts. In terms of remembering geometry formulas, these students feel there is no significant difference, and are more comfortable memorizing formulas through exercises and written explanations. This shows that although AR has the potential to improve learning, its implementation must be adjusted to students' individual needs and preferences to achieve optimal results.

b. Teacher Response

In an effort to understand the effectiveness of Instruction Interactive Teaching Materials Integrated Augmented Reality (I-ITMIAR) in geometry learning, especially the concept of surface area and volume of prisms, we interviewed one of the teachers who has implemented this technology in her class. This interview aims to explore the experiences, views, and challenges faced by teachers in using I-ITMIAR as a learning aid.

Researcher	:	What do you think about the use of Instruction Interactive Teaching Materials Integrated Augmented Reality (I-ITMIAR) in geometry learning, especially in understanding the concept of surface area and volume of prisms?
Teacher	:	I strongly support the use of I-ITMIAR in geometry learning. This technology provides a new dimension in the teaching and learning process that greatly helps students in visualizing the shape of a prism from various angles. With AR, students can more easily understand how to calculate the surface area and volume of a prism because they can see and interact directly with the 3D object.
Researcher	:	Do you see any changes in students' learning motivation after using I-ITMIAR?
Teacher	:	Yes, I see positive changes. Students become more enthusiastic and interested in learning geometry with I-ITMIAR. They seem more excited in exploring the material and more active in participating in class discussions. Learning becomes more interesting and interactive, so that students' learning motivation increases.
Researcher	:	How about students' understanding of the concept of surface area and volume of prisms? Is there any improvement?
Teacher	:	Based on my observations, students' understanding of these concepts has increased significantly. By using AR, students can see firsthand how changes in shape affect surface area and volume. They not only memorize formulas, but also understand the concepts behind the calculations, which makes their understanding deeper and more meaningful.
Researcher	:	Are there any challenges you face in implementing I-ITMIAR in learning?
Teacher	:	One of the main challenges is infrastructure and technical readiness. Not all classes are equipped with adequate devices to access AR. In addition, some students initially felt awkward or confused using this technology, so it took time to adapt. However, after a few sessions, most students began to get used to and enjoy learning with AR.

Based on an interview with a teacher regarding the use of Instruction Interactive Teaching Materials Integrated Augmented Reality (I-ITMIAR) in geometry learning, it can be concluded that this technology is very effective in improving students' understanding of the concept of surface area and volume of prisms. The teacher noted a significant increase in student motivation and participation, who appeared more enthusiastic and involved in the teaching and learning process. Although there were technical challenges related to infrastructure and students' initial adaptation to new technology, overall, I-ITMIAR proved to be able to make learning more interesting and interactive. The teacher believes that with adequate support, this technology has great potential to be widely applied in other schools, thereby improving the quality of geometry education as a whole.

B. Discussion

This study aims to explore the effectiveness of using Instruction Interactive Teaching Materials Integrated with Augmented Reality (I-ITMIAR) in geometry learning, especially on the concept of surface area and volume. Based on the test results, it was found that the use of I-ITMIAR has the potential to help students understand the concept of surface area and volume of prisms. In addition, based on interviews, many students stated that the use of AR helped them understand the concept of surface area and volume better. Clear and concrete visualizations allow students to see and manipulate three-dimensional objects from various angles, which is difficult to do with only two-dimensional figures in textbooks. This is consistent with the findings of Carbonell-Carrera (2017), which states that AR can improve students' understanding of complex concepts through more realistic and interactive visualizations. In addition, according to Ovadiya et al. (2019) concluded that the use of AR technology can significantly improve elementary school students' three-dimensional spatial perception of prisms. Furthermore, this study Hwang et al. (2021) concluded that students enjoyed learning 3D Geometry concepts such as measuring volume and surface area authentically. This study is also in line, Sudirman et al. (2022) concluded that AR technology significantly improves students' understanding of surface area and volume formulas compared to traditional teaching methods. Students can visualize and manipulate three-dimensional objects, which helps them understand the relationship between the dimensions of the object and the formulas used to calculate surface area and volume (Bali & Fridhi, 2024).

Instruction in AR-integrated textbooks can help improve students' understanding of 3D geometric surface area and volume because it provides direct visualization and dynamic manipulation of geometric objects. With AR, students can view 3D objects directly in a real-world context, zoom in, zoom out, or rotate objects to understand how changes in dimension affect surface area and volume (Yaniawati et al., 2023). The ability to disassemble complex objects into their components allows students to see how each part contributes to the total surface area and volume. Additionally, immersive learning experiences with AR allow students to walk around objects and view them from multiple angles, strengthening their understanding of measuring and calculating surface area and volume in the real world (Sudirman & Susandi, 2024).

AR also provides real-time feedback as students calculate surface area and volume, helping them understand the relationship between dimensions and size (Zhang et al., 2014). More concrete visualizations of mathematical formulas with AR show how each part of the formula contributes to the total calculation, making concepts easier to understand and remember (Widada et al., 2021). Simulating real-world situations, such as calculating the volume of water in a tank or the surface area of a material to wrap an object, allows students to apply concepts in practical contexts. Additionally, AR helps students develop better spatial perception, which is essential for understanding and applying the concepts of surface area and volume, building a strong mental image of the function of these shapes (Martín-Gutiérrez et al., 2010).

Although the results of this study show many benefits of using AR in learning, there are some challenges and limitations that need to be considered. First, implementing AR requires hardware and software that may not be available in all schools. Limited access to this technology can be a barrier for some schools, especially in remote or less developed areas. Second, there is a learning curve associated with using new technology, for both teachers and students. Adequate training and support are needed to ensure that teachers can integrate AR into learning effectively and that students can use it appropriately. Third, although AR can improve conceptual understanding and motivation to learn, its effectiveness may vary depending on the design and implementation of the AR teaching materials themselves. Therefore, it is important to develop AR teaching materials that are based on strong pedagogical principles and are appropriate to the needs of students.

IV. CONCLUSION

The results of the study showed that the use of AR in geometry learning provided a significant increase in students' understanding of complex geometric concepts, especially the concepts of surface area and volume of prisms. Through three-dimensional visualizations produced by AR technology, students can see and interact with prism models in real-time. This allows them to observe and understand the spatial structure and shape of prisms from various perspectives, which is often difficult to achieve with conventional teaching methods. In addition, the responses of teachers involved in this study also reported an increase in students' interest and motivation in learning geometry. The interactivity offered by AR-based teaching materials makes learning more interesting and enjoyable for students. They are more involved in the learning process, which in turn improves their understanding of concepts and their ability to apply this knowledge in the context of everyday problems.

The results of this study have several practical implications for educators and curriculum developers. First, the use of AR in geometry learning can be used as an effective tool to improve students' conceptual understanding. Educators can integrate AR into their lesson plans to provide a more interactive and engaging learning experience. Second, curriculum developers can consider developing more AR-based teaching materials that can be used at various levels of education. With the increasing accessibility and affordability of AR technology, AR-based teaching materials can become an integral part of future curricula.

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AUTHOR'S BIOGRAPHY

Dr. Sudirman, M.Pd.

Born in Indramayu on July 01, 1987. Lecturer at Universitas Terbuka. Completed undergraduate studies in Mathematics Education at Universitas Wiralodra, graduating in 2010; completed postgraduate studies in Mathematics Education at Universitas Negeri Semarang, graduating in 2013; completed doctoral studies in Mathematics Education at Universitas Pendidikan Indonesia, graduating in 2022.

Dr. Irena Puji Luritawaty, M.Pd.

Born in Tangerang on April 30, 1988. Lecturer at Institut Pendidikan Indonesia. Completed undergraduate studies in Mathematics Education at Sekolah Tinggi Keguruan dan Ilmu Pendidikan (STKIP) Garut, graduating in 2010; completed postgraduate studies in Mathematics Education at Universitas Pendidikan Indonesia, graduating in 2014; completed doctoral studies in Mathematics Education at Universitas Pendidikan Indonesia, graduating in 2024.

Prof. Ebenezer Bonyah.

Professor in the Department of Mathematics Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Kumasi, Ghana. Completed Bachelor of Education in Mathematics at University of Education Winneba, graduating in 2023; Completed Master of Education in Educational Administration and Management at University of Education-Winneba, graduating in 2006; Completed Master of Science in Educational Administration and Management at Kwame Nkrumah University of Science and Technology, graduating in 2010; Completed Master of Science in Industrial Mathematics at Kwame Nkrumah University of Science and Technology, graduating in 2010; Completed Doctor of Philosophy in Applied Mathematics at Kwame Nkrumah University of Science and Technology, graduating in 2014; Completed Post-Doctoral Research Fellow at Vaal University of Technology, graduating in 2017.