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Implementation of augmented reality-assisted learning media on three-dimensional shapes

Surya Amami Pramuditya [1 *], Sri Pitriyana [1], Toto Subroto [1], Risnina Wafiqoh [2]

[1] Mathematics Education Study Program, Universitas Swadaya Gunung Jati, West Java, Indonesia

[2] Mathematics Education Study Program, Universitas Muhammadiyah Bangka Belitung, Bangka Belitung, Indonesia

[*] Correspondence: amamisurya@ugj.ac.id

Abstract

This research is motivated by the low understanding of students in studying the object of geometry study. The media that had previously been used in the form of a spatial framework made of bamboo or iron turned out to take up quite a lot of space and was not practical to carry in large quantities. Therefore, efficient and practical media are needed to help visualize concrete objects in learning. This research aims to implement Augmented Reality (AR)-assisted learning media on the material of three-dimensional shapes. This study uses an explanatory qualitative method. The participant in this study was one student from one of the junior high schools in the Cirebon Regency. Data collection techniques used are through interviews and documentation. The analysis technique consists of three stages: data reduction, data presentation, and concluding. The results showed that the AR application could make it easier for the student to understand the material and solve the problem of three-dimensional shapes. However, the student still has a little difficulty using the application and is a little confused when identifying the parts of the cube because the image of the shape raised by the application is still not clear. This research implies that AR applications can make students' spatial abilities better.

Keywords: augmented reality; geometry; instructional media; three-dimensional shape

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Introduction

The mathematics that is studied in schools has many fields of study, one of which is geometry. Geometry is one of the important branches of mathematics because most of the items seen, used, and utilized by humans consist of geometric objects (Serin, 2018). Studying geometry allows humans to understand the world by comparing shapes, objects, and relationships (Pamungkas et al., 2020). Therefore, the branch of geometry needs to be studied by students.

Geometry is a branch of mathematics that deals with space (spatial). Every visualization on earth is geometry, so the application of geometry is often found in everyday life in almost all areas of creativity and human reason (Cesaria et al., 2021; Fiantika et al., 2017). Geometric shapes can even be easily found in homes, such as houses, doors, blackboards, tiles, and others, so that geometry does not become a foreign thing for students (Pasani, 2019). From a psychological point of view, geometry represents abstractions from visual and spatial experiences, such as planes, patterns, measurements, and mapping (Abdussakir, 2009). Therefore, this branch of science is helpful for training students' spatial intuition that can be used in everyday life.

Geometry taught in schools consists of several materials, including flat shapes, spatial shapes, and geometric transformations. The level of difficulty in the flat shape material is not high enough. It is different from the spatial material, which has a high level of difficulty and abstraction because in studying it, students are required to have a high imagination to pour three-dimensional shapes into two-dimensional images (Sulistyaningsih, 2014). The level of abstraction of geometric objects, especially high spatial figures, is the cause of the lack of understanding of students in studying it, so this material is considered difficult to learn (Sutiarso & Coesamin, 2013; Wahyudi et al., 2018). In addition, the orientation of learning mathematics, which is only result-centered, also causes the level of understanding of students' geometry to be still low (Umam & Supiat, 2019).

One of the media used by previous researchers to study and understand the concept of geometrical geometry is a cube frame visual aid made of bamboo or iron. Based on research by Situmorang and Sopia (2020) and Mustaqim (2016), cube framework props or other spatial structures made of bamboo or iron can help students concretize abstract concepts in spatial geometry so that students can recognize and master the basic concepts of spatial construction such as angles, straight lines, planes, and line projections. However, the spatial framework often takes up quite a lot of space because of its large size, especially if many frames are used. In addition, students also need time to make props whose materials come from nature, such as bamboo. Therefore, we need efficient and practical media in terms of manufacture and use following the material to be delivered, one of which is by making a digital framework with the help of Augmented Reality (AR).

Augmented Reality is a technology that combines virtual objects in two-dimensional or three-dimensional forms that are projected into a real environment and then displayed in real-time (Mustaqim, 2016). With AR technology on geometric objects, objects can be visualized concretely through a virtual three-dimensional image similar to the original object, right above the flat plane image on paper (Ningtias et al., 2013). To identify objects, AR technology requires a device with a camera, such as a computer or a smartphone, to insert virtual objects into the real world; then, the output will be displayed through the monitor (Saputri & Sibarani, 2020). AR-assisted learning media is very suitable for use in learning mathematics today because AR technology is following current conditions that use Android a lot (Masyhud et al., 2021).

In addition, two-dimensional or three-dimensional image media can improve student understanding and learning outcomes because pictures can explain material through visual communication symbols (Damayanti et al., 2018; Wardani et al., 2013). It can help teachers in carrying out learning in the classroom. Learning applications that use AR technology can simplify the teacher's task in presenting material, shorten the time required, and create a more interactive learning atmosphere (Suharso, 2012). However, in its application, students also need to make adjustments first if students are familiar with this technology for the first time. Because there are two types of students, there are types of students who adapt quickly, but there are also students who take a long time to adjust (Saputra & Muharammah, 2020).

Previous research related to AR technology was carried out by Rusnandi et al. (2015), which shows that AR as a learning medium can be used as a visual aid for modeling geometric shapes displayed in three dimensions. Because the data processing is fast and real-time, the appearance is easy to understand by the user and is also interactive with a three-dimensional model. Next, research by Nugroho and Ramadhani (2015) concluded that AR applications make it easier for students to see and understand three-dimensional shapes, not only in the form of two-dimensional images. In line with research, Estheriani and Muhid (2020) and Sungkur et al. (2016) state that AR can help students understand difficult material such as geometry to help students understand complex mathematical concepts. In addition, research conducted by Hanan et al. (2018) also shows that AR has the potential to renew mathematics teaching materials, especially in learning to construct flat planes using three-dimensional objects, so that learning becomes more interesting.

The media in the form of a spatial framework made of bamboo or iron takes up quite a lot of space and is less practical to carry in large quantities. Therefore, the novelty in this research is the use of learning media in the form of a spatial framework in digital form assisted by AR technology. This research is a follow-up study from research that has been carried out by Hanan et al. (2018). In previous research, Hanan et al. (2018) have developed learning media assisted by AR applications. Based on the background described, the researchers are interested in implementing Augmented Reality-assisted learning media on the material for three-dimensional shapes, namely a cube, to help students learn independently and with teacher guidance.

Methods

This study uses a qualitative approach with an explanatory method that aims to explore a phenomenon in participants based on the research focus. The search is in the form of personal experiences while studying, aiming to build students' thinking activities in terms of knowledge, especially on AR-assisted flat plane material. This in-depth search was carried out on one participant, namely a student studying the material for constructing a flat plane from one of the junior high schools in Cirebon Regency for four months. The number of participants is limited to one student because the study was conducted during the COVID-19 pandemic.

This participant search was in the form of participants' backgrounds who: (1) liked mathematics subjects, including the material for building flat spaces; (2) had a history of good grades; (3) the volunteerism of the students to become participants. The research instrument used in this study was AR-assisted teaching materials and interview guidelines whose validity was continuously built during the study. According to Hayashi Jr et al. (2019), validity in qualitative research is continually built up throughout research and is not an isolated outcome of tests, metrics, or precautions. The interview technique used is an unstructured interview.

The data was obtained through interviews and artifacts (participant documentation), both text and images. The data collected was analyzed based on the stages of data reduction, data presentation, and concluding (Ridder et al., 2014). In the data reduction stage, all the data taken are selected and sorted based on the research focus for coding. After the data is coded based on the relationship with this research, it is presented in the form of a schematic and visualization. Based on the presentation of the data, conclusions can be drawn from the findings of this study.

Results

Implementation stage

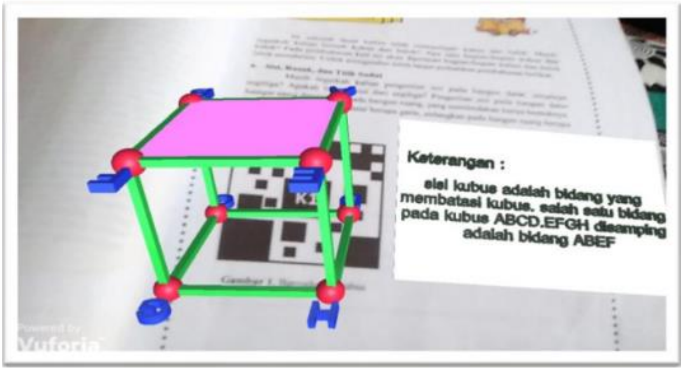
At the implementation stage, the researcher explained AR-assisted teaching materials on the flat plane space building material that would be given to students. The study was conducted on one junior high school student from Cirebon Regency to obtain an in-depth description of the condition of the participants when studying the material for building flat planes with the help of Augmented Reality. The researcher only accompanies the subject when learning AR-assisted flat plane shape in this study. The goal is to find out the use of AR in flat-plane space construction material. Then the student is asked to scan the barcode contained in the teaching materials and identify the parts of the cube with the help of a cube-shaped digital framework. The results are as follows.

Cube side barcode

The following is a barcode sample, to run it you can first download the application via this link https://bit.ly/AR-SAP. In application settings allow camera and storage.

Figure 1. Barcode sample

At this stage, the student is asked to observe the sides of the cube through a cube-shaped digital framework displayed after the student scans the barcode on the teaching materials. Here is the cube framework that appears.



Caption on the figure:
the side of the cube is the plane that limits the cube, one of the planes on the cube ABCD.EFGH on the side is the plane ABEF

Figure 2. Cube side barcode scan results

Based on Figure 2, with the appearance of a cube with one side marked with a pink color, the student still looks confused and hesitant when asked to name the side of the cube. At this stage, the student cannot name the sides of the cube correctly.

Cube edge barcode

At this stage, the student is asked to observe the edge of the cube through a cube-shaped digital frame displayed after the student scans the barcode on the teaching materials. Here is the cube framework that appears.

Caption on the figure:
the edge of the cube is the intersection line between the two sides of the cube and looks like the skeleton of the cube, on the side of the cube ABCD.EFGH you can see the side EF.

Figure 3. Cube edge barcode scan results

Based on Figure 3, with the appearance of a cube, one of the edges is marked with a pink color. The student can recognize and mention the edges of the cube. Not all edges are mentioned because the student is still a little confused about naming all edges using the AR application.

Cube corner point barcode

At this stage, the student is asked to observe the corner points of the cube through a cube-shaped digital framework; that is displayed after the student scan the barcode on the teaching materials. Here is the cube framework that appears.

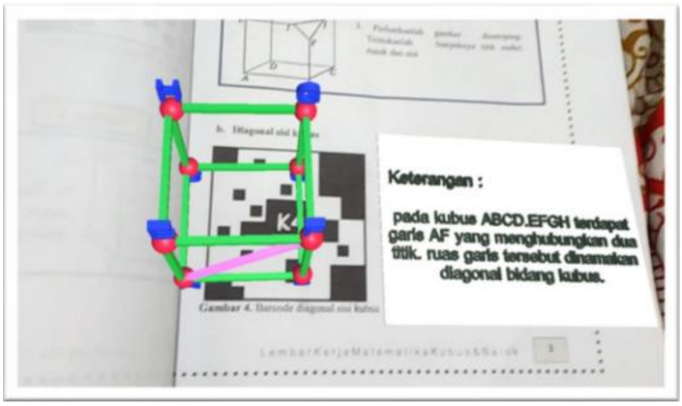
Caption on the figure:
the corner point is the point of intersection between the two edges, on the cube ABCD.EFGH on the side there are 8 corner points, namely points A, B, C, D, E, F, G, and H.

Figure 4. Cube corner point barcode scan results

Based on Figure 4, with the appearance of the cube space, the student is able to recognize and mention the corner points of the cube correctly. The student name all the corner points based on their observations on the cube frame that appears.

Side diagonal barcode

At this stage, the student is asked to observe the diagonal part of the side of the cube through a cube-shaped digital frame that is displayed after the student scan the barcode on the teaching materials. Here is the cube skeleton that appears.



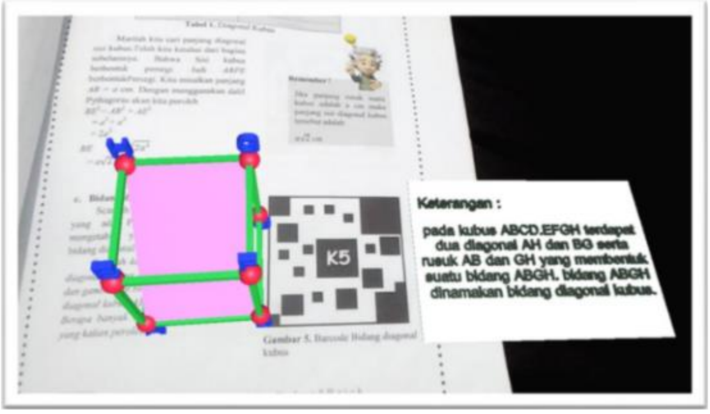
Caption on the figure:
on the cube ABCD.EFGH there is a line AF that connects two points, the line segment is called the diagonal of the cube.

Figure 5. Side diagonal barcode scan results

Based on Figure 5, with the appearance of a cube with one of the diagonals marked with a pink color, the student could recognize and name the side diagonals of the cube correctly. However, not all of the side diagonals were successfully mentioned.

Cube diagonal plane barcode

At this stage, the student is asked to observe the diagonal of the cube through a cube-shaped digital framework that is displayed after the student scan the barcode on the teaching materials. Here is the cube framework that appears.



Caption on the figure:
on the cube ABCD.EFGH there are two diagonals AH and BG as well as edges AB and GH which form a plane ABGH, the plane ABGH is called the diagonal plane of the cube.

Figure 6. Diagonal plane barcode scan results

Based on Figure 6, with the appearance of a cube with one of its diagonals marked with a pink color, the student could not identify the diagonal of the cube, so he could not correctly name the diagonal of the cube.

Barcode diagonal space cube

At this stage, the student is asked to observe the diagonal part of the cube space through a cube-shaped digital framework that is displayed after the students scan the barcode on the teaching materials. Here is the cube framework that appears.

Caption on the figure:
on the cube ABCD.EFGH there is a line BH that connects two points, the line segment is called the diagonal of the cube space.

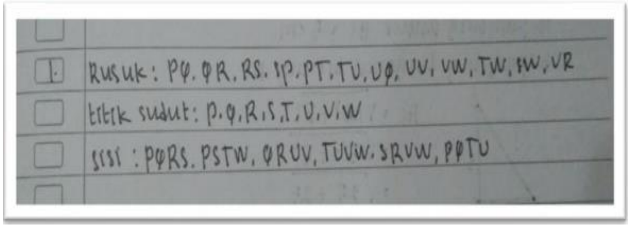
Figure 7. Space diagonal barcode scan results

Based on Figure 7, with the appearance of a cube space, one of the diagonals of the space is marked with a pink color, the student is able to identify and correctly name the diagonal of the cube space.

The stage of problem solving using the AR application

Problem 1: Identify the parts of a cube

At this stage, the student is asked to identify the edges, corner points, and sides of the cube that are known in the problem, then write his answers on the answer sheet. Following figure 8 is the answers given by the student.



Translation of the figure:
Edge: PQ, QR, RS, SP, PT, TU, UQ, UV, VW, TW, SW, VR
Corner point: P, Q, R, S, T, U, V, W
Side: PQRS, PSTW, QRUV, TUVW, SRVW, PQTU

Figure 8. Answer to question number 1

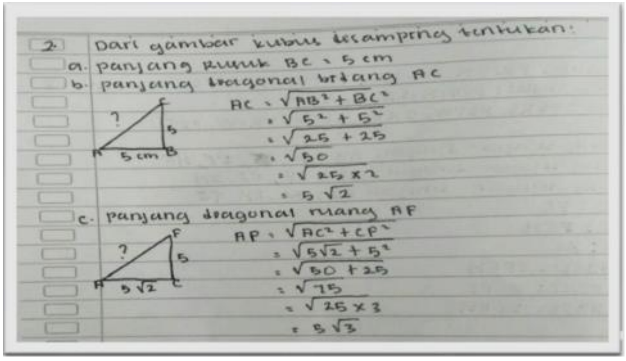
Based on Figure 8, it can be seen that the student can solve problems about the parts of the cube. The student writes down the sides, edges, and vertices of the known cube. However, this is different from the interview results. The following excerpt from the researcher's interview (R) with the student (S).

R: "Try to scan this first image using the AR application."
R : "Does it appear?"
S : "Do not apepar."
R : "It can be rotated. This is the side barcode of the cube, which side of the cube is it?"
S : "ABEF, FFGA eh… CB, GHCD, EHAD, ABCD."
R : "So how many sides of the cube are there?"
S : "There are 6."

Based on the interviews, the student is still confused when asked to scan the barcode on the side of the cube. Likewise, when asked to name the sides of the cube, the student still looked confused in identifying the sides of the cube from the image displayed by the AR application.

Problem 2: Calculating the length of the diagonal of the plane and the space

At this stage, the student is asked to calculate the length of the diagonal of the field and the space of the cube that is known in the problem, then write the answer on the answer sheet. Following figure 9 are the answers given by the student.



Translation of the figure:
From the side picture on the side find

a. the length of edge BC = 5 cm
b. the length of diagonal AC

$$AC = \sqrt{AB^2 + BC^2}$$
$$= \sqrt{5^2 + 5^2}$$
$$= \sqrt{25 + 25}$$
$$= \sqrt{25 \times 2}$$
$$= 5\sqrt{2}$$

c. the length of the diagonal of the space plane AP

$$\begin{aligned} AC &= \sqrt{AC^2 + CP^2} \\ &= \sqrt{5\sqrt{2} + 5^2} \\ &= \sqrt{50 + 25} \\ &= \sqrt{75} \\ &= \sqrt{25 \times 3} \\ &= 5\sqrt{3} \end{aligned}$$

Figure 9. Answer to question number 2

Based on Figure 9, the student is able to identify, determine, and calculate the length of the diagonal of the plane and space. Then the researcher asked about the concepts used through interviews as follows.

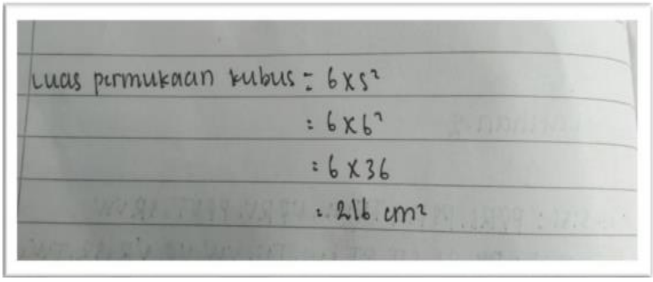
R : "How to do this, how come the result is 5 root 2, can you explain it?"

S : "Because it uses the Pythagorean formula, what is being asked about the length of the diagonal of the AC plane here, it is known that the length of AB = 5, BC = 5, while the length of AC is not known. So AC = root of AB squared plus BC squared. AB is 5 so 5 squared plus 5 squared, the root of 25 plus the root of 25 equals the root of 50. The root of 50 is 25 times 2 and the result is 5 roots of 2.

From the interviews, the student can solve problems and know the strategies used to solve problems. Then at work, the student looks so fast in solving problems and mastering the strategy. However, the student has a little difficulty in identifying the diagonals of planes and spaces using AR applications.

Problem 3: Calculating the area of a cube

At this stage the student is asked to calculate the area of the cube that is known in the problem, then write the answer on the answer sheet. Following are the answers given by the student.



Translation of the figure:

Surface area of the cube $= 6 \times s^2$

$= 6 \times 6^2$

$= 6 \times 36$

$= 216\ cm^2$

Figure 10. Answer to question number 3

Based on Figure 10, the student can understand and solve the problem of the area of a cube by using the formula for the surface area of a cube. The student can determine the side of the cube and its length to calculate the required area. Based on these answers, it can be said that student does not experience difficulties when answering questions in the form of pictures. It shows that the AR application makes it able to understand the given material. The following is an interview excerpt showing that students can understand the material given.

R : "Try scanning the barcode of the cube's edge, now you don't know how many sides there are. Suppose the side is 6, what is the approximate area?

(Students feel confused)

R : "It's okay to get caught."

R : "What is the result?"
S : "216."
R : "Please explain how?"
S : "It is known that the side is 6, eu… the area of the cube is asked, the formula for the area is 6 times s squared. 6 is clicked on the side 6 so 6 times 6 times 6, 6 times 36 equals 216."

Based on these interviews, the student can solve problems and present the answers that have been done. It shows that the student has mastered the material. However, the student is still a little confused when they see images that appear from AR applications.

Discussion

Based on the first findings at the implementation stage (Figure 2) show that the student is still confused about identifying the sides of the cube after the application raises the cube framework. At this stage, the student is still hesitant when asked to name the sides of the cube and cannot correctly name all the sides. In addition, the student also looked confused when scanning barcodes on teaching materials. The student needs quite a long time when scanning barcodes for the cube skeleton to appear. It shows that the student is not yet skilled in using AR applications.

The second finding at the implementation stage (Figure 3) shows that the student can recognize and name the cube's edges even though there are still edges that are not mentioned. The student can only identify some parts; not all of them have been identified. At this stage, the student still looks confused when asked to observe the skeleton of the cube to determine the edge of the cube. It also shows that the student is not yet skilled in using AR applications.

The third finding at the implementation stage (Figure 4) shows that the student can recognize and mention the corner points of the cube. The student managed to name all the corner points correctly. Each corner point marked in pink and named in capital letters makes it easier for the student to identify all the corner points on the cube. It shows that the student can already understand the cube's points with the help of AR applications.

The fourth finding at the implementation stage (Figure 5) shows that the student can correctly identify and name the side diagonals of the cube. However, the student did not manage to name all the side diagonals of the cube. The students still look confused when identifying the side diagonals on the cube frame displayed via smartphones. It shows that the student is still not skilled in using AR applications.

The results of the first, second, and fourth findings are because AR application is a new thing for the student, so the student still needs much practice to use the media in learning to be more skilled. At the implementation stage, the student is still adjusting to new media in the form of teaching materials assisted by AR applications. It is in line with the opinion that there are types of students who adapt quickly, but there are also students who need a long time to adjust (Saputra & Muharammah, 2020). Therefore, the student with the type in this study still needs time to adjust to AR applications to use them optimally.

Next, the fifth finding at the implementation stage (Figure 6) shows that the student cannot identify the diagonal plane of the cube. After being asked to observe the skeleton of a cube in which one of the diagonal areas is marked with a pink color, it turns out that the student could not correctly name the diagonal of the cube. Apart from being unskilled in using AR applications, information was also obtained from the student that the three-dimensional images that appeared were still not clear. Hence, the student felt confused in identifying the parts of the cube. It shows the importance of using three-dimensional image objects in studying mathematical material such as geometry. With pictures, students can be helped to improve their understanding. It is in line with the research results by Damayanti et al. (2018) and Wardani et al. (2013), which show that image media can improve students' understanding and learning outcomes because pictures can explain material through visual communication symbols.

Three-dimensional images generated by AR applications can help students understand the parts of a flat side like a cube. Without images, geometric objects for students are still seen as abstract and difficult to imagine. The abstract of the geometric object is precisely one of the causes of students' lack of understanding in studying it, so this material is considered difficult by students (Wahyudi et al., 2018). Therefore, AR applications help visualize geometric objects concretely through virtual three-dimensional objects similar to real objects, in real-time, right on top of the flat plane image on paper. Students can also observe objects directly while studying the parts of abstract spatial structures.

Next, the results of the sixth study at the implementation stage (Figure 7) showed that the student could correctly identify and name the diagonals of the cube space. The student can name the four diagonals of the space owned by the cube after understanding the information and examples given. It shows that the student can understand the diagonal part of the cube space by using AR applications.

At the problem-solving stage, there are three findings. The first finding (Figure 8) shows that the student can solve problems in writing. The AR application helps the student identify the parts of the cube requested in the problem so that the student can write down all the sides, edges, and corner points of the known cube wholly and correctly. However, based on the results of the interviews, it turns out that the student is still confused when asked to scan the side barcode of the cube. Likewise, when asked to name the sides of the cube, students still looked confused in identifying the sides of the cube from the image displayed by the AR application. It shows that the student can solve problems in writing, but when asked questions, students still find it difficult to answer.

The second finding (Figure 9) shows that the student can solve problems correctly. However, the student has difficulty identifying the diagonals of planes and spaces using AR applications. In observing the three-dimensional images raised by the AR application, the student needs accuracy and foresight to be able to determine the diagonals of fields and spaces correctly. Even though they had difficulties at the beginning, the answers written by the student was correct.

The third finding (Figure 10) shows that the student can understand and solve the problem of the area of the cube. The student also does not have difficulty answering questions in the form of pictures. It shows that the AR application helps the student understand and solve the problems given. It is indicated by the student's answers when given questions related to the shape of a flat plane in the form of a cube. These results align with Estheriani and Muhid (2020) and Sungkur et al. (2016), which state that AR can help students understand difficult material such as geometry, so it can help students understand complex mathematical concepts. Through AR, students can recognize the parts of a cube starting from the sides, edges, and vertices and the diagonals it has, such as side diagonals and space diagonals. Students can visualize it in the form of a two-dimensional image to make it easier when solving problems.

Based on the results obtained, the AR application designed by Hanan et al. (2018) can be used as a digital learning media to help students learn and understand the problems of building a flat plane like a cube. As stated in his research, AR applications have the potential to renew mathematics teaching materials, especially in learning to construct flat planes using three-dimensional objects, so that learning becomes more interesting. However, the three-dimensional space generated by the AR application that he has designed is still not clear to students, making students confused in identifying the parts of the cube.

Conclusion

The implementation of AR applications can make it easier for the student to understand abstract geometric objects and make it easier for the student to solve mathematical problems related to two-dimensional shapes to be used as digital learning media students. However, the student still had a little difficulty using the application and was a little confused when identifying the parts of the cube because the image of the shape generated by the application was still unclear. This research implies that AR applications can make students' spatial abilities better.

Conflicts of Interest

We declare that no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely by the authors.

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