Design and Validation of Augmented Reality-Based Student Worksheets for Polyhedra Material in Improving Students' Spatial Abilities

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Abstract

This study aims to develop and test the quality of augmented reality-based student worksheets (*LKPD*) that can improve students' spatial abilities. This type of research is development research using the Plomp development model, which consists of the initial investigation stage, design, realization, tests, evaluations, revisions, and implementation. The data collection techniques used in this study were observation, interviews, questionnaires, and tests. The instruments used were expert validation sheets, observation sheets, interview guidelines, teacher and student response questionnaires, learning outcomes tests, pre-test questions, and student spatial ability post-test questions. The validation results by design experts and Student Worksheet material experts were 89.09% and 92%, respectively, in the very valid category. In addition, the practicality of Student Worksheets seen from the teacher response questionnaire of 80.00% was classified as practical, and the score of the student response questionnaire in small group trials with 9 students was 81.11% in the very practical category. The effectiveness was shown by 77% of students completing the learning outcomes test, 19 students experiencing moderate spatial ability improvement, and 3 students experiencing high spatial ability improvement, with a percentage of *N*-Gain effectiveness obtained 61.8% with moderately effective criteria. Based on the results of the study, it can be concluded that augmented reality-based Student Worksheets for polyhedra materials that have been developed are suitable for use as learning teaching materials to improve students' spatial abilities.

Keywords: Augmented reality, *LKPD*, spatial ability, students worksheets

INTRODUCTION

Geometry is one of the fields of mathematics that studies points, lines, planes, and spaces as well as properties, measures, and relationships with each other (Nur'aini et al., 2017). In learning geometry, students need mature concepts so that students can use their geometry skills, such as visualizing, recognizing different shapes and spaces, describing images, and sketching geometric shapes (Nopriana, 2015).

This shows the importance of students having visual and spatial skills in learning geometry, especially in polyhedra materials. Because many question materials cannot be realized in the actual form of the building in polyhedra materials, so they can only be

visualized or depicted in two-dimensional form. According to research by Nasution (2017) which suggests that spatial abilities are very important to improve because each student must try to develop his spatial sensing abilities which are very useful in understanding relations and properties in geometry to solve problems in mathematics and problems in everyday life. But in reality, the spatial abilities possessed by students are still not optimal. This was revealed through research conducted by Siswanto and Kusumah (2017), namely the lack of imagination to visualize the components of three-dimensional shapes, making it difficult for students to arrange space and solve problems.

This is also based on the results of observations made at an Islamic private junior high school at Jambi City, Indonesia. Researchers conducted a pre-test by giving 5 points of spatial ability questions in class VIII B to 22 students to see the spatial abilities of students. It is known that the average value of students' spatial ability is 37.9 out of a maximum score of 100. A sample of students' pre-test answers can be seen in Figure 1.
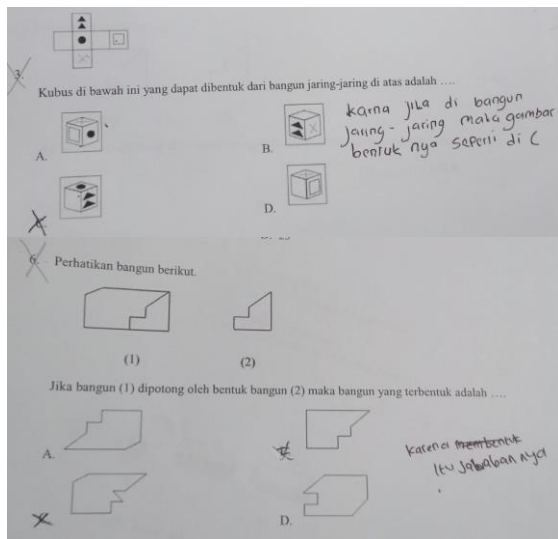

Figure 1. Student's Pre-test Answer Sample

From the students' pre-test answers in Figure 1, it can be seen that students have not been able to expose spatial indicators. There are several answer errors where students cannot visualize a cube net that has an identity on its side and orients an object.

In addition, based on the results of interviews with grade VIII mathematics teachers, it was found that the factor that caused the low spatial ability of students was due to the lack of interest of students in mathematics lessons. In the learning process, teachers still use conventional methods where teachers play a more active role in delivering learning material that makes students less enthusiastic about following learning. Teachers also rarely use technology-based media in the learning process. Therefore, it is hoped that additional teaching materials will support students in the learning process so that they become more active and interested in polyhedra materials.

One of the additional teaching materials that can be used in learning is the Student Worksheet. Pawestri and Zulfiati (2020) said that Student Worksheets are learning resources in the form of task sheets, instructions for completing assignments, and learning assessments that must be completed by students, and prepared by the basic competencies that must be achieved. Herawati, et al. (2016) said that to optimize Student Worksheets both in terms of appearance and quality of learning, a transformation based on the convergence of information and telecommunications technology (ICT) is needed.

One technology that can support spatial capabilities is Augmented Reality. Research conducted by Sara and Danawak (2021) stated that the use of learning media using augmented reality (AR) in building space learning can improve students' understanding and contextual skills, especially spatial abilities. Augmented reality technology has now been widely developed to create learning media that is specifically to be operated via smartphones. As stated by Rusnandi et al. (2015), the use of Augmented Reality (AR) as a learning medium can be used as a prop for modeling the geometry of building spaces that are represented visually in three-dimensional form.

Several studies that have been conducted previously show that the development of augmented reality-based learning media can help students understand the material, increase students' interest in learning, and is suitable for use as a tool in learning (Destriana et al., 2021; Rexa, 2018; Suganda & Fahmi, 2020). According to research by Mustaqim and Kurniawan (2019), through augmented reality, teachers can create learning media that are fun, interactive, and easy to use. Research conducted by Tiyasari and Suliworo (2021) creates augmented reality-based playing cards using applications that operate using laptops. The difference between this study and previous research is that in this study researchers developed Student Worksheet teaching materials to improve students' spatial abilities

by utilizing smartphones in operating augmented reality. Whereas in previous studies making augmented reality-based learning media that were not associated with mathematical abilities and the operation of augmented reality still using laptops.

Based on the problems described above, in improving the spatial ability of students, additional augmented reality-based teaching materials are needed that allow students to see abstract objects in 3D and more real. The purpose of this study is to develop augmented reality-based Student Worksheet teaching materials for building flat-side space materials to improve students' spatial abilities.

METHOD

This research is included in the type of research and development. According to Martianingtiyas (2019), Research and Development is the right research used to be able to improve the quality of the level of education by developing or producing a certain product. The Plomp development model was chosen to be used in this study because according to Rochmad (2012), The Plomp model is considered more flexible and flexible than the Four-D model. After all, each step contains development activities that can be adjusted to the characteristics of the research. The Plomp development model consists of five phases, namely (1) preliminary investigation, analyzing the causes of problems found; (2) design phase, designing products and research instruments; (3) realization/construction phase, producing Student Worksheet products (worksheets) into printed teaching materials that will be distributed to test subjects; (4) test, evaluation and revision phases, the development of Student Worksheets with expert validation, small group trials to determine the responses of teachers and students, and field trials to determine the effectiveness of the developed Student Worksheets; and (5) implementation phase.

This research was conducted at an Islamic private junior high school at Jambi City,

Indonesia, on October 13 – November 8, 2022, with class VIII A subjects totaling 22 people. The types of data used are qualitative data and quantitative data with data collection techniques in the form of observations, interviews, questionnaire sheets, and tests.

Data collection instruments are conducted to test three quality product assessment criteria which include valid, practical, and effective. The research instruments used are grouped based on aspects of product quality criteria seen in Table 1.

Table 1. Research Instruments Based on Measured Product Quality Criteria

Quality Criteria	Instruments
Valid	Material content validation sheet
	Design validation sheet
Practical	Worksheets practicality sheet by teachers
	Worksheets practicality sheet by students
	Interview sheet
	Observation sheet
Effective	Learning outcome test sheet
	Spatial ability test sheet

The validity and practicality data that have been obtained are then analyzed descriptively quantitatively, then the data is described with data frequency analysis techniques using formulas (1) and (2).

$$\text{Validity Level} = \frac{\text{number of scores per indicator}}{\text{the maximum scores of the indicators}} \times 100\% \text{ (1)}$$

$$\text{Practicality Level (p)} = \frac{\text{scores of all students}}{\text{maximum score}} \times 100\% \quad (2)$$

The validity data and practicality data obtained are summed and converted into qualitative data with five criteria as shown in Table 2.

Table 2. Convert Quantitative to Qualitative Data for Valid and Practical

Percentage	Criteria
81% - 100%	Very valid/practical
61% - 80%	Valid/practical
41% - 60%	Moderately valid/practical
21% - 40%	Invalid/practical
0% - 20%	Very invalid/practical

(Source: Arikunto, 2010)

While effectiveness data can be seen from learning outcomes tests and spatial ability tests. The completeness of the learning outcome test is assessed based on scoring guidelines with the score obtained being at or above the value of the Mininal Completeness Criteria (KKM) for mathematics subjects set at the school where the research took place, which is 70. Augmented reality-based Student Worksheets are declared effective if at least 70% of test subjects are completed. To calculate the percentage of students who are complete, use formula (3).

$$Completeness\ (f) = \frac{number\ of\ students\ who\ completed}{the\ number\ of\ students\ who\ attended} \times 100\% \quad (3)$$

The improvement of spatial ability is seen through spatial ability tests. Ningsih (2019) divides spatial ability into five aspects which are then designed as an indicator of spatial ability which can be seen in Table 3.

Table 3. Spatial Capability Indicator

No.	Indicator	Description
1.	Spatial Perception	The ability to imagine the location of objects observed horizontally or vertically.
2.	Visualization	The ability to show the rules of change or displacement of the arrangement of a shape either three-dimensional to two-dimensional or vice versa.
3.	Mental Rotation	Ability to rotate two-dimensional and three-dimensional objects precisely and accurately.
4.	Spatial Relation	The ability to understand the arrangement of an object and its parts and their relationships to each other.
5.	Spatial Orientation	The ability to change the shape or position of a geometric object viewed from various points of view.

Data from the spatial ability test is calculated using the *N*-Gain calculation with the formula (4).

$$\text{N-gain} = \frac{\text{posttest score} - \text{pretest score}}{\text{max score} - \text{pretest score}} \times 100\% \quad (4)$$

After obtaining the value using the formula (4), the value will be categorized using the criteria shown in Table 4.

Table 4. Categories of N-Gain Effectiveness Interpretation

N-Gain	Criteria
< 40	Ineffective
$40 - 55$	Less effective
$56 - 75$	Moderately effective
> 76	Effective

(Source: Nashiroh et al., 2020)

Augmented reality-based Student Worksheets are said to be effective if the percentage of N-Gain is obtained with the criterion of "effective enough".

RESULTS AND DISCUSSION

The results of the development carried out in this study are producing augmented reality-based Student Worksheets for building materials for polyhedra in class VIII. Research and development of augmented reality-based Student Worksheets is carried out by following the steps of the Plomp development model which consists of five phases, namely (1) Preliminary Investigation Phase, (2) Design Phase, (3) Realization Phase, (4) Test, Evaluation, and Revision Phase, and (5) Implementation Phase.

At the Preliminary investigation stage, researchers conducted a pre-test in class VIII B of the school to determine the spatial ability of students by providing five questions. The question sample can be seen in Figure 2.
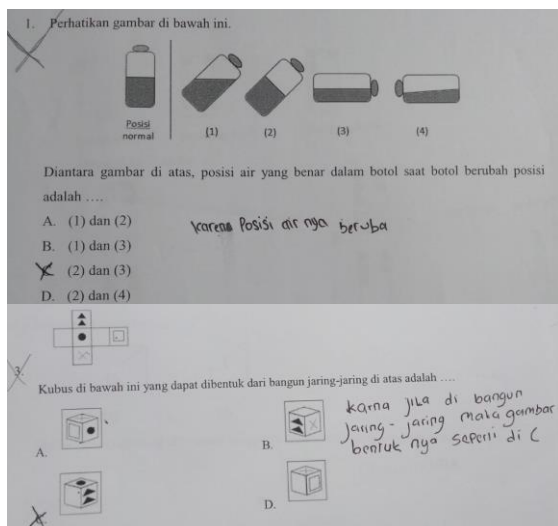
Figure 2. Pre-test Question Sample

Based on the pre-test answers, it can be seen that students have not been able to explain spatial ability indicators in building flat-side spaces. There are several student answer errors, such as students have not been able to perceive the depth of a space building by looking at the tilt or not of building space against vertical or horizontal references, seeing the composition of an object after being manipulated in position, determining the shape of the building after building space rotated, relating or connecting each element of building space and orienting by looking at the shape of the space building from various sides. After the test, the average score of students' spatial ability was 37.9. This proves that the spatial abilities of most learners need to be improved. Because this spatial ability is important for students to master, especially in geometry material. Research by Oktaviani in Saputri (2017) suggests that spatial skills play an important role in students' ability to solve geometry problems.

The researchers also conducted interviews with mathematics teachers who taught in grade VIII of the school, obtained information from teachers that one of the problems of students in learning mathematics is the lack of interest of students in mathematics lessons, one of the factors for the occurrence of these problems is the learning resources used in the learning process only in the form of mathematics package books for the 2013 curriculum and Colorless printed Student Worksheets purchased from the school. In the learning process, teachers also rarely use technology-based media because teachers are less proficient in operating technology. Then in the spatial geometry material, the teacher only uses props in the form of a space frame provided by the school with demonstration techniques without involving students directly in its use. That makes some students less enthusiastic about learning.

One solution carried out by researchers to overcome low spatial abilities and help students understand the concept of building a polyhedron is by designing augmented reality-based Student Worksheet teaching materials for building polyhedra materials. The use of augmented reality technology is used to help students visualize 3D and 2D shapes. As stated by Azuma in the research of Arifin, et al. (2020) augmented reality technology makes it possible to combine the real and virtual worlds by displaying three-dimensional objects in the real world through the camera media so that the camera looks as if the 3D object exists in the real world and AR also allows to display illustrations that are difficult to realize concretely. In addition, the use of augmented reality can also increase students' interest in learning because students will be actively involved in the operation of augmented reality using smartphones. By the opinion of Destriana (2021) in his research learning using Augmented Reality media can increase students' interest in learning.

Furthermore, in the design phase, researchers designed Student Worksheets using the Canva application. The results of the augmented reality-based Student Worksheet design for the polyhedra material can be seen in Figure 3.

In the Student Worksheet which is designed, there is a marker to see the animation of the three-dimensional shape display needed in research by spatial ability indicators. The first indicator is spatial perception, seen in the display of Figure 4 students will count many small cubes contained in the framework by

looking from the vertical or horizontal sides. According to the indicators of Ningsih (2019) Which says that spatial perception is an ability that requires the location of objects that are being observed horizontally or vertically.
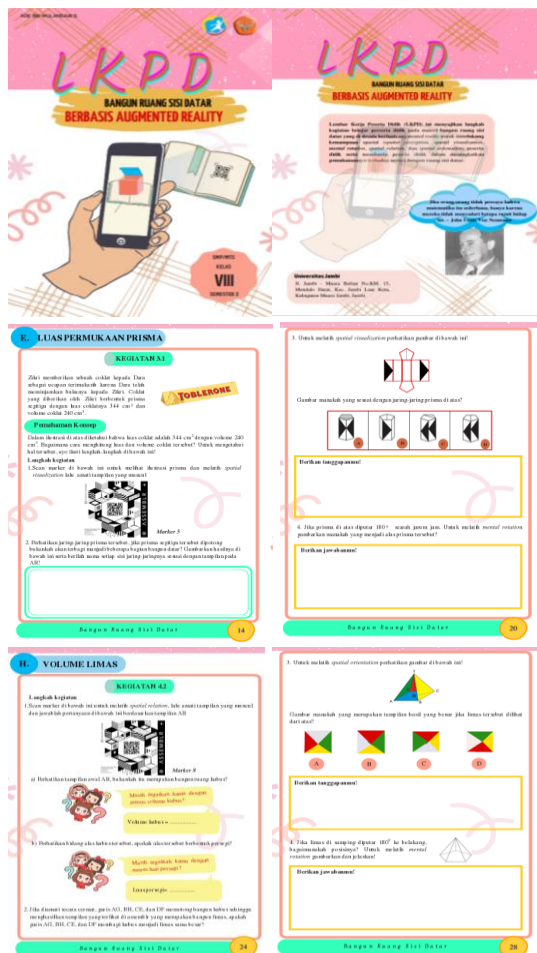

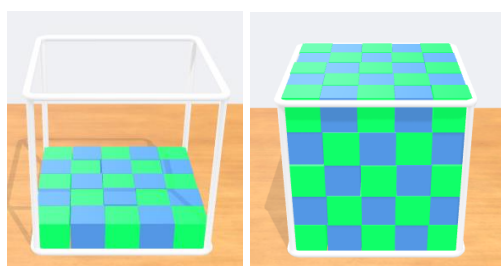Figure 3. Student Worksheet Design Display

Figure 4. Augmented Reality Spatial Perception Display

The second indicator is spatial visualization, seen in the display of Figure 5 students will see a change in the shape of the cube into a web of cubes. According to the indicators of Ningsih (2019), spatial visualization is the ability to show the rules of change or movement of the arrangement of a building either three-dimensional to two-dimensional or vice versa.
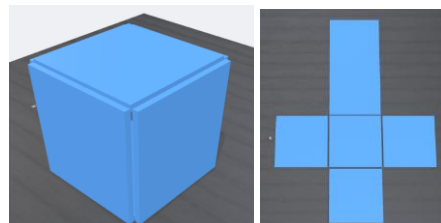

Figure 5. Augmented Reality Spatial Visualization Display

The third indicator, mental rotation, is seen in the display of Figure 6 students will see changes in the three-dimensional shape when it is rotated. According to the indicators of Ningsih (2019) mental rotation is the ability to rotate two-dimensional and three-dimensional objects precisely and accurately.
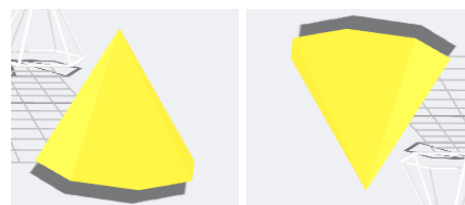

Figure 6. Augmented Reality Mental Rotation Display

The fourth indicator of spatial relations, seen in the display of Figure 7, students will see the pieces of the spatial construct and understand the arrangement of the corner points of the spatial construct. According to the indicators of Ningsih (2019), spatial relation is the ability to understand the arrangement of an object and its parts and their relationships with each other.
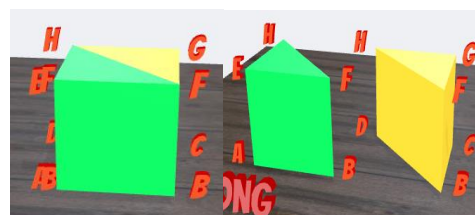

Figure 7. Augmented Reality Spatial Relation Display

The fifth indicator of spatial orientation, seen in the display of Figure 8 students will see the shape of the spatial building from various points of view. According to the indicators of Ningsih (2019) which states that spatial orientation is the ability to observe and identify the shape or position of a geometric object viewed from various points of view.

Furthermore, in the realization phase, augmented reality-based Student Worksheets are produced into printed teaching materials that will be distributed to test subjects after the augmented reality-based Student Worksheets are validated by material experts and design experts.
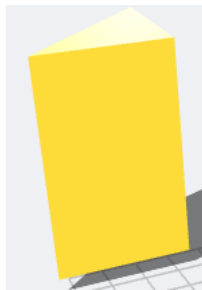

Figure 8. Augmented Reality Spatial Orientation Display

Validity of Worksheets Based on Augmented Reality

The assessment of the validity of augmented reality-based Student Worksheets was carried out by one material expert and one design expert, both of whom are mathematics lecturers at Jambi University. The validity of the material on the augmented reality-based Student Worksheet has a percentage of 92% with a very valid category. The validity of the augmented reality-based Student Worksheet design has a percentage of 89.09% with a very valid category. This can be seen from the validity assessment indicator, where the shapes and letters used can be read clearly, the cover used, as can be seen in Figure 9, is attractive, and the illustrations used are related to the topic discussed. In the characteristic aspect of Student Worksheets, it can be said that the use of augmented reality in Student Worksheets can stimulate student activeness in learning help

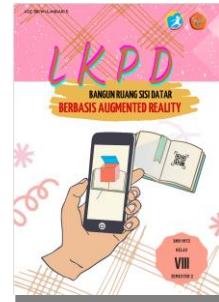students understand the material, and can stimulate students' spatial abilities.

Figure 9. Worksheets Cover Display

Practicality of Worksheets Based on Augmented Reality

The practicality of augmented reality-based Student Worksheets is assessed from the responses of teachers and students as well as observations made in product trials. In individual trials, researchers observed teachers to see the difficulties that occur in operating augmented reality. In observation activities, it can be seen that teachers are less able to scan markers to see the shape of space, for that researchers need help in scanning available markers. So that teachers can assess teaching materials for augmented reality-based Student Worksheets. The results of teacher responses to augmented reality-based Student Worksheets in individual trials obtained a percentage of the practicality of 80% with the practical category. The process of augmented reality performance during individual trials can be seen in Figure 10.

Figure 10. The Process of Augmented Reality Performance in Individual Trials

Furthermore, in a small group trial, 9 students of grade VIII B were directed to learn using augmented reality-based Student

Worksheets, and then researchers made observations and interviews to see the difficulties faced by students. Based on the results of the interview, it is known that students do not experience difficulties when operating augmented reality because there are clear instructions, visualization of building space looks more real with a 3D view so that they can see the building of space from various sides. The results of student responses in small group trials obtained a percentage of 81.11% with a very practical category. The process of augmented reality performance during small group trials can be seen in Figure 11.

Figure 11. The Process of Augmented Reality Performances in Small Group Trials

The practical results of the Student Worksheet based on observations made in field trials with 4 meetings obtained a practicality percentage of 83.78%. The results of the augmented reality-based practicality assessment are presented in Table 4.

Table 4. Practical Results of Worksheets Based on Augmented Reality

Aspects	P%	Criteria of practicality
The practicality of worksheets by teachers (ease of use, the efficiency of learning time, has the same equivalence)	80%	Practical
Practicality of worksheets by students (ease of use, efficiency of learning time, having the same equivalence)	81,11%	Very practical
The practicality of worksheets based on observation of teaching and learning activities	83,78%	Very practical

Based on Table 4, augmented reality-based Student Worksheets are said to be practical because learning using augmented reality-based Student Worksheets makes it easier for teachers to deliver learning material which is with the Student Worksheets teachers only acts as facilitators, learning time is more efficient and students can learn according to their abilities, and augmented reality-based Student Worksheets can be used as companion teaching materials that help teachers in explaining the material to build flat side rooms. This is in line with research by Rexa (2018) which states that the use of augmented reality-based worksheets is very feasible to be used as a tool in student learning. In addition, the use of augmented reality technology in the Student Worksheet makes it easier for students to see changes in building space in 3D and more real.

As for the comments and suggestions given by the teacher, the practice questions have not been able to measure children's knowledge, preferably the practice questions need to be sorted from knowledge, application, and reason. Then the comments given by students in small group trials of augmented reality-based Student Worksheets, on average, students claimed to be happy to learn using augmented reality-based Student Worksheets because of the use of augmented reality technology operated using smartphones so that students feel more interested in following the learning process. This is in line with research by Destriana et al. (2021), which states that learning using augmented reality media can increase students' interest in learning.

The Effectiveness of Augmented Reality-Based Worksheets

Assessment of the effectiveness of augmented reality-based Student Worksheets can be seen from the learning outcomes test instrument and the student spatial ability test instrument. The effectiveness of augmented reality-based Student Worksheets from the provision of learning outcome tests totalling 5 questions, obtained the results of 17 students who completed or had obtained scores above

the minimum completeness criteria (KKM) and 5 incomplete students. It can be seen from the work on the learning outcomes test that most students have been able to find the surface area of the pyramid with known circumference of the base and height of the pyramid, find the volume of the cube with the surface area of the cube known, find the surface area of a prism without a lid with known diagonal length of the base and height of the prism, find the surface area of the cube and beam with known side length, and find the combined volume of towers composed of prism and pyramid buildings. This shows that 77% of students can achieve the value of learning completeness criteria. It is in line with research by Ervana and Martini (2019) who said that the use of augmented reality-charged LKS is effective in improving student learning outcomes.

Based on the results of the spatial ability test obtained from 22 students, 19 students experienced moderate spatial ability improvement, and 3 students experienced high spatial ability improvement with an *N*-Gain effectiveness percentage obtained of 61.8% with the category of quite effective. The spatial ability of students seems to increase after using augmented reality-based Student Worksheets because in using these Student Worksheets students' spatial abilities are honed when seeing objects through augmented reality technology where objects that are usually seen in 2D in books will look 3D with the help of augmented reality technology and students can also see changes in space building nets directly, besides that in this augmented reality-based Student Worksheet there are also practice questions to hone students' spatial skills. The results showed that there was an increase in the average pre-test score with the post-test so the spatial ability of students increased with the use of augmented reality-based Student Worksheets. In line with research conducted by Arifin et al. (2020) which states that augmented reality technology can improve spatial abilities in the learning process, especially in space geometry material. It is in line with research conducted by Herman, et al (2023) which states that the use of learning media with augmented reality is effective in learning because students can see real and directly imagine the results of the learning process. Augmented reality learning media helps students visualize abstract concepts to understand and structure an object more effectively.

CONCLUSION

The results of the design and validation of augmented reality-based Student Worksheets for polyhedra materials in improving students' spatial abilities based on material validation and design are very valid according to material experts and design experts, practical based on teacher responses and very practical based on student responses, and quite effective based on the results of pre-test and *post-test* spatial abilities. Based on these results, augmented reality-based Student Worksheets on polyhedra materials are suitable for use in learning to improve students' spatial abilities. Thus, the development of augmented reality-based learning media using more supportive applications such as Vuforia, ARcore, and World Brush is suggested for future research.

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