PAEDAGOGIA
Jurnal Penelitian Pendidikan
http://jurnal.uns.ac.id/paedagogia

DOI: 10.20961/paedagogia.v27i1.83957
Vol. 27, No. 1, 2024, pp. 52-62
p-ISSN 0126-4109
e-ISSN 2549-6670

Geometry Representation Abilities: What is The Impact of Using The 6E-Instructional Model Integrated with Augmented Reality?

Sudirman*, Ardi Dwi Susandi

Master of Mathematics Education, Universitas Terbuka, Tanggerang Selatan, Indonesia

Keywords
Augmented reality, Representation 3D geometry, 6E Instructional Model

Article history
Received: 26 January 2024
Revised: 4 February 2024
Accepted: 10 February 2024
Published: 27 February 2024

*Corresponding Author Email:
sudirman.official@ecampus.ut.ac.id

doi: 10.20961/paedagogia.v27i1.83957

Abstract: This research aims to analyze the impact of the 6E-Instructional Model Integrated Augmented Reality in improving students' 3D geometric representation abilities. A type of quasi-experimental design, one group pretest-posttest, is used for objective research of answers. The subjects of this research were 8th-grade students at a private school in Indramayu Regency, Indonesia, totaling 288 students divided into eight classes. Based on this number, one class of class VIII B was selected as the research sample. Furthermore, the research instrument uses a geometric representation ability test. In addition, the data obtained from the test results were analyzed using the paired sample t-test. The research concluded that AR technology can be integrated into constructivist learning, including 6E Instructional Mode. Furthermore, based on the paired sample t-test, it was concluded that using 6E-IM integrated AR increased the 3D geometric representation abilities of class VIII students in one of the private schools in the Indramayu Regency. Therefore, this research provides a foundation for advanced learning in mathematics, especially regarding integrated technology and learning models.

How to cite: Sudirman, S & Susandi, A.D. (2024). Geometry Representation Abilities: What is The Impact of Using The 6E-Instructional Model Integrated with Augmented Reality?. *PAEDAGOGIA*, *27*(1), 52-62. doi: 10.20961/paedagogia.v27i1.83957

INTRODUCTION

The ability to represent three-dimensional (3D) geometry is crucial in developing students' mathematical abilities (Pittalis & Christou, 2010; Medina-Herrera et al., 2019; Alghadari et al., 2020). 3D geometric representation is not only limited to the ability to recognize and understand objects in space but also includes in-depth visualization skills of the structure and relationships between these objects (Elia et al., 2018; Cho & Suh, 2019). Ability representation geometry three dimensions (3D) is the ability to describe, visualize, and understand objects in a room in three dimensions (Sudirman et al., 2023; 2023). Additionally, Pittalis and Christou (2010) explain that the ability to represent 3D is based on the concepts of coding and decoding. Coding refers to skills in interpreting representation from form 3D geometry, in particular in matter-identifying elements structural (point corner, surface plane, edge, etc.) in various modes of representation, such as perspective mode (blurred or transparent) and orthogonal modes and decoding refers to ability interpret traits 3D geometry of representation 2D geometry. This ability can also be applied application-wide in various fields, including design, architecture, science, computer graphics, and engineering. Because of that, the ability to represent 3D geometry matters in mathematics and discipline knowledge. It helps individuals understand and work with the concepts involved in three dimensions: volume, surface, angle, and geometric transformation.

Even though representation skills are essential for students, the Trends in International Mathematics and Science Study (TIMSS) report explains difficulties in representing geometric objects, especially 3D geometry. This can be seen in Table 1.

Table 1. *Average Achievement in Mathematics and Geometry in TIMSS*

Year	TIMSS average		Geometry Domain Description
	Mathematics	Geometry	
2007	397	395	Draw a rectangle with two adjacent sides.
2011	386	377	Determines the number of cubes in a stack with some hidden.
2015	397	394	Identify the largest volume of the four rectangular prisms represented pictorially.

Source: Mullis *et al.* (2008); Mullis *et al.* (2011); Mullis *et al.* (2015)

Table 1 relates the estimated average achievement of mathematics and geometry concepts mastery for Indonesian students based on the value range from 0 to 1000. The geometry domain 2007 is related to drawing rectangles with two adjacent sides. The test questions can be seen in Figure 1.3, which reveals that the Indonesian students' geometry achievement score is 395, below the average score of 500. The students' geometry achievement results confirm a problem with Indonesian students' ability to represent 2D and 3D geometric objects. Apart from that, based on preliminary research results, researchers focused on the representation of students' 3D geometry. The results of the analysis of student answers can be shown in Table 2.

Table 2. Proportion of student answers

No.	Question Indicator	Proportion Correct	Wrong Proportions
1	Identify elements and geometry properties	11.11	88.89
2	Constructing nets from getting up specified space.	8.33	91.67
3	Draw part 2D geometry is formed from 3D geometry.	16.67	84.33
4	Determine many cubes from the get-up specified geometry.	13.89	86.11

In Table 2, regarding the percentage of students' answers, only a few could answer the questions correctly. For question number 1, only 4 out of 36 students, or 11.11% of students, could answer correctly, and the remaining 32, or 88.99%, answered incorrectly. For question number 2, only 3 out of 36 students, or 8.33% of students, answered correctly, and the remaining 33 out of 36 students, or 91.67% of students, answered incorrectly. Furthermore, for question number 3, only 6 out of 36 students, or 84.33 students, answered correctly, and the remaining 30 out of 36, or 84.33%, answered incorrectly. Apart from that, for question number 4, only 5 out of 36 students, or 13.89% of students, answered correctly, and the remaining 31 out of 36 students, or 86.11 students, answered incorrectly. The high percentage of students' errors in solving problems on 3D geometry material indicates that students experience difficulties in carrying out various representation tasks in 3D geometry.

One learning model that has potency and can help students increase their ability to represent geometry is the 6E-Instrutional Model (6E-IM). 6E-IM consists of six phases: elicit, engage, explore, explain, elaborate, and evaluate. The reason for using 6E-IM is because, based on results research previously explained that 6E-IM or 5E-IM can help students in Junior High School understand draft geometry (Alshehri, 2016; Omotayo & Adeleke, 2017; Tezer & Cumhur, 2017). Apart from that, there are phases in learning. This facilitates formation ability representation 3D geometry. For example, the aim elicitation phase is to activate students' prior knowledge about material 3D geometry and help them grow confidence in their abilities. The engage phase is purposeful, connecting prior knowledge to draft new. The explore phase aims to construct a new draft and facilitate the road through 3-D geometry. The explain phase is to help students carry out a process of improvisation and confirmation of newly acquired knowledge. The elaborate phase aims to facilitate the internalization and assimilation of the draft new to the memory student. The evaluation phase aims to evaluate the ability to think about students' 3D geometry.

Additionally, 6E-IM provides a framework for comprehensive work for designing experience structured and in-depth learning. When this Model is combined with AR technology, students can experience learning math more dynamically and excitingly. Several previous research results have revealed that the 5E/6E learning model can interact with specific technology or technological products, as Siwawetkul & Koraneekij (2018) concluded that the use of the 5E learning model on mobile technology has had a positive effect on reasoning abilities, intrinsic motivation, reasoning behavior, and achievements. Grau et al. (2021) concluded that using the 5E learning model can have a long-term impact on students' learning context. Lin et al. (2020) The research results show that the 6E learning model positively influences middle school students' attitudes toward technology and technological investigation abilities. However, this influence is not statistically different from the control group who used problem-solving teaching strategies. Furthermore, Lin et al. (2023) have integrated the STEAM-6E Model with Virtual Reality Instruction; the results of their research concluded that for students who have two holistic and sequential cognitive styles, there are significant differences in learning motivation regarding intrinsic goals, extrinsic goals, task value, control beliefs, self-efficacy, and test anxiety. Furthermore, Hsiao et al. (2023) research results concluded that gamification with the 6E Instructional model can help students develop self-ability in middle school students' computer programming, IoT knowledge, hands-on skills, and behavior patterns.

Based on previous research, the 6E learning model has not been integrated with augmented reality technology. Apart from that, based on the results of previous research, no research has looked at the impact of the 6E Instructional model in improving 3D geometric representation abilities. Therefore, it aims to analyze the effect of using the 6E Instructional model integrated with augmented reality in improving junior high school students' 3D geometric representation abilities.

METHOD

Research design

The design used in this research is quasi-experimental, one group pretest-posttest type. This type of research is used because the researcher only wants to evaluate the impact of the intervention on one group without a comparison control group. In addition, this design was used in research because researchers had difficulty forming a control group that met the criteria. In addition, the research process lasted four weeks. Next, at the fifth meeting, a post-test was carried out.

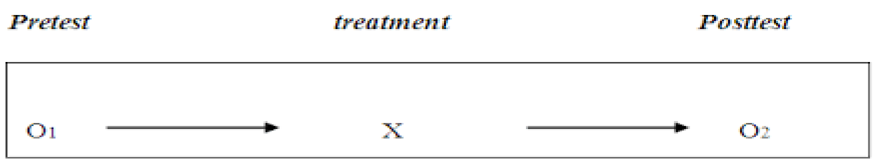

Figure 1. one group pretest-posttest design

Population and Sample

The population in this study were all students in class VIII of junior high school in one of the private schools in Indramayu Regency, totaling 288 students (8 classes). Based on this number, 1 class, namely class VIII B, was selected as the sample for this research. Sampling was carried out considering that the existing population was huge, so it was impossible to examine the entire population, so a representative population was formed. The sample of this research was chosen with a purposive sampling technique. Purposive sampling is a technique or method of taking samples based on consideration of linkages with goals and objects to be researched without considering the similarity opportunity of every member population other for taking a sample from eight classes chosen one class purposively, that is class VIII B as a sample in this study.

Data collection

In this study, data collection techniques using tests were used. The test instrument in this research is a test sheet in the form of a description relating to class VIII geometry material to test representation abilities in 3D geometry. In research, this indicates the ability to represent 3D geometry, referring to Pittalis & Christou (2013), which divides 3D geometric representation into decoding and coding. Decoding refers to interpreting structural elements and properties of 3-D geometric shapes in plane representation. In contrast, coding refers to the construction of plane representations and 3D shape meshes and is related to the process of translating from one mode of representation to another; as for the description of the test to measure the ability to represent 3D geometry, as shown in Table 3. The validity of the 3D Geometry representation ability test is shown in Table 4.

Table 3. Test to measure 3D geometric representation abilities

Ability	Task Description
Construction representation characteristic 3D geometry	1. Identify elements and properties of 3D geometry
Construction of nets	2. Identify nets 3D geometry
	3. Constructing nets 3D geometry
Translate	4. Translation from an orthogonal view to a picture perspective.
	5. Translate the picture perspective to view orthogonally.

Table 4. Validity of 3D Geometry Representation Ability Test Items

No		Correlation							Inf.	Category
			X_1	X_2	X_3	X_4	X_5	X_{tot}		
1	X_1	Pearson Correlation	1					0,46**	Valid	Medium
		Sig. (2-tailed)						0,044		
2	X_2	Pearson Correlation		1				0,874**	Valid	Very High
		Sig. (2-tailed)						0,000		
3	X_3	Pearson Correlation			1			0,79**	Valid	High
		Sig. (2-tailed)						0,002		
4	X_4	Pearson Correlation				1		0,539**	Valid	Medium
		Sig. (2-tailed)						0,018		
5	X_5	Pearson Correlation					1	0,705**	Valid	Very high
		Sig. (2-tailed)						0,000		
		N					19	19		

Table 4 shows that question items 1-5, which X1-X5 symbolizes, are valid because of the Sig value. (2-tailed) < α = 0.05, with the validity category of questions number 2 and 5 being high, while the validity category of question items number 1 and 4 is medium, and number 3 is in the high category. Furthermore, to calculate the reliability of the items, the Spearman-Brown correlation. The test results with SPSS statistics 25 give a Spearman-Brown Coefficient value of 0.802, which means that the 3D representation ability test items are reliable.

Data analysis

The quantitative data for this research comes from the pre-test and post-test results. Pre-test data was obtained from test results before treatment was carried out, while post-test data was obtained after treatment was carried out. Next, normalized N-Gain data determines the increase in students' 3D geometric representation abilities. The following formula calculates the normalized gain test.

$$CapN - gain = \frac{\text{post-test score - pre-test score}}{\text{ideal maximum score - pre-test score}}$$

After all students' n-gain scores were known, data on increased students' 3D representation abilities were grouped into three categories (Hake, 1999), as shown in Table 5.

Table 5. *N-Gain Category*

Interval N-Gain Score	Category
$g \geq \bar{x} + s$	High
$\bar{x} - s \leq g < \bar{x} + s$	Medium
$g < \bar{x} + s$	Low

In addition, before being analyzed inferentially, the pre-test and post-test data were tested for normality. After meeting normality, an alternative test was used in the form of a paired sample t-test, which was used to analyze the average differences before and after the treatment of the experimental group.

RESULT AND DISCUSSION

AR integrated 6E-IM design.

By general channel, AR-integrated 6E-IM learning can be seen in Figure 2. Implementation 6E-IM learning integrated AR inside the class can classified into three stages, namely (1) stage initial, (2) core stage, and (3) stage closing. The beginning stage consists of two phases, viz elicit and engage. The core stage consists of three phases: explore, explain, and elaborate. At a stage, closing consists of the evaluation phase.

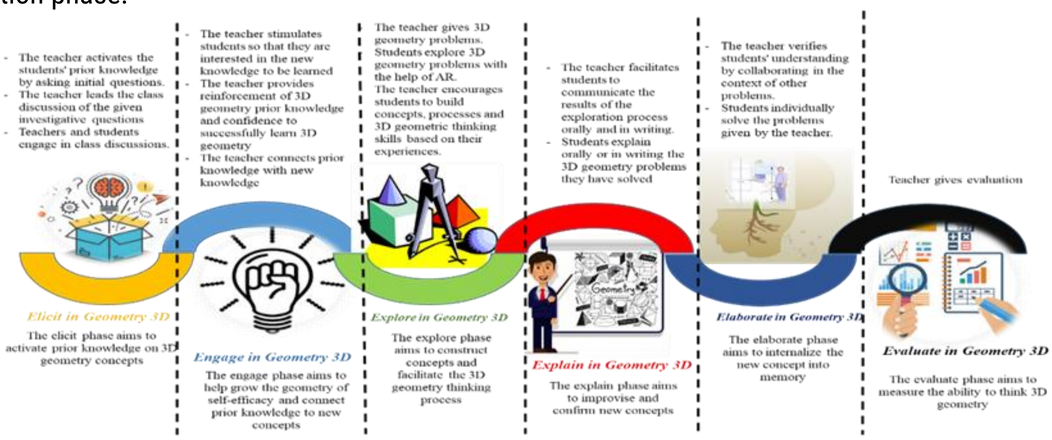

Figure 2. AR-integrated 6E-IM learning flow

Learning occurs over five meetings using the school curriculum's Learning Implementation Plan (RPP). Four meetings are for delivering material, and one meeting is for evaluation. The distribution of material at each meeting can be seen in Table 6.

Table 6. Material Distribution

Meeting	Material
1st meeting	Identify the elements and properties of prisms, cuboids, and cubes.
2nd meeting	Drawing triangular prisms, cuboids, and cubes.
3rd meeting	Create nets of triangular prisms, cuboids, and cubes.
4th meeting	Connecting the properties of triangular prisms, cuboids, and cubes in making nets
5th meeting	Evaluation

On research Currently, the learning process takes place face-to-face. At the first meeting, the material studied by students was identifying elements and properties from prism triangles, cuboids, and cubes. The researcher requested that students see and remember to identify things like cupboards, tents, piggy banks, packaging chocolate Toblerone, can Dongguan, data, and so on. After observing things, students requested to write a Name representation from things mentioned in the table provided. Based on students' answers, it appears that students can represent these objects well, for example, a cardboard box, which is represented as a cube; a triangular tent, which is represented as a triangular prism; a cupboard, which is represented as a block, a teapot cake which is presented as a pyramid shape, a piggy bank which is presented as a tube, and birthday hat represented as cone shape.

After the elicit phase, students are invited to enter the engage phase. By the objectives, in this phase, students are asked to connect geometric objects such as a tent in the shape of a triangular prism, an aquarium in the shape of a block, and a dice in the shape of a cube with the material that will be studied at this first meeting. For example, in the shape of a dice, students are asked to understand the dice's angles, outline, and surface. Next, students are asked to write the names of the parts of the dice and their geometric representation. In this phase, most students respond by answering questions given by the teacher. Even though some students still need correction in writing their explanations, the researchers believe that students can connect previous knowledge with the knowledge they will learn.

In phase explore, the researcher requested students direct their cell phones to the image-created marker (See Figure 3). On the material, identify elements and properties from prism triangles, cuboids, and cubes; there are six created images as markers. The first and second markers are related to identifying elements from shaped objects (See Figure 4).

Figure 3. Tent Marker

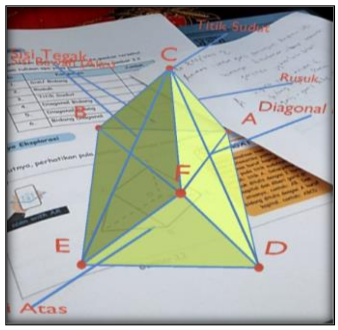

Figure 4. Tent Animation

When students direct the camera on the image, you can see some students are incapable of directing the camera, which is inaccurate and makes 3D animation not appear. However, when the teacher asks the student to direct it with the right, the visible student already brings up the 3D animation. 3D animation that appears on the camera can be seen in Figure 4. In the animation, students can see parts from the tent represented in a shaped prism triangle like point angle, line segment, plane, plane diagonal, and space diagonal.

After students explore the image markers tent, the researcher requests students and their groups to open the teaching materials page. Furthermore, to discuss, communicate, and fill in the answer in the table elements, the prism triangle is by the animation that appears on the marker. In the table, students were requested to write many point angles, edges, planes, plane diagonals, space diagonals, and plane diagonals. Analysis results to answer student seen that student Already capable of answering with Correct. Students can already determine elements in prism triangles like Lots point corners, there are 6, ribs, there are 9, and fields, there are 5. Students must understand that a prism triangle has a space diagonal and a plane diagonal.

Besides, after the student observed many elements (dot corners, edges, planes, diagonal planes, space diagonals, and diagonal planes) shaped tents prism triangle, students requested to do more observations related to the trait's prism triangle. To understand the material traits prism triangle, students requested a formerly direct camera on the image markers, as in Figure 5.

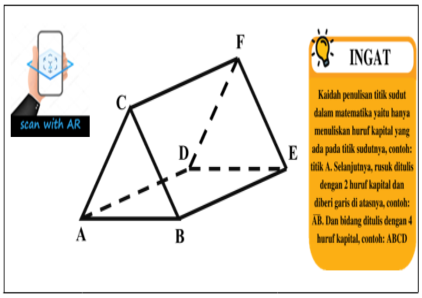

Figure 5. *Markers* prism triangle

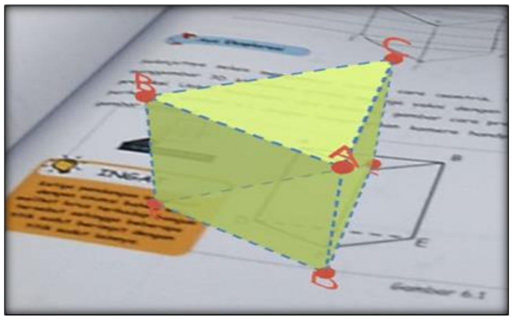

Figure 6. 3D animation

After that, students requested to notice elements in detail from the prism triangle (See Figure 6). There is 3D animation that appears on the camera student, as seen in Figure 6. Apart from observing the image-shaped objects prism, students are also asked to observe form aquarium as seen in Figure 7.

Figure 7. *Markers* Aquarium

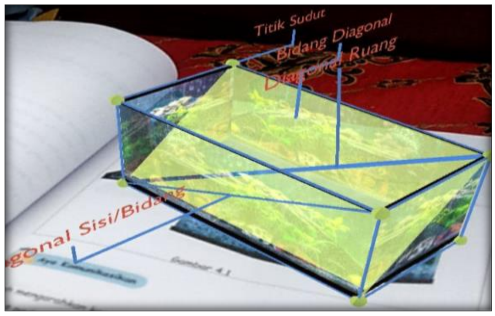

Figure 8. *Marker* Aquarium

The student requested a direct camera cell phone in the picture markers aquarium. After that, students are asked to pay attention to the number of corner points, edges, planes, plane diagonals, and space diagonals on the cell phone camera (Figure 8). When observing 3D animation from the aquarium, students were seen moving the camera's direction and trying to see the 3D animation that appeared in the image correctly. After the 3D animation appeared, students began to see various points of view in detail. Several students immediately noted the many elements that appeared on the camera. Some students only focus on paying attention. After completing observing the 3D animation, students are asked to write down the results of their observations in the table in the material Just.

After observing 3D animation that represents cube ABCD, EFGH, the student requested to write Lots point angles, edges, planes, plane diagonals, space diagonals, and plane diagonals in the available tables. Answer one student can see in Figure 9.

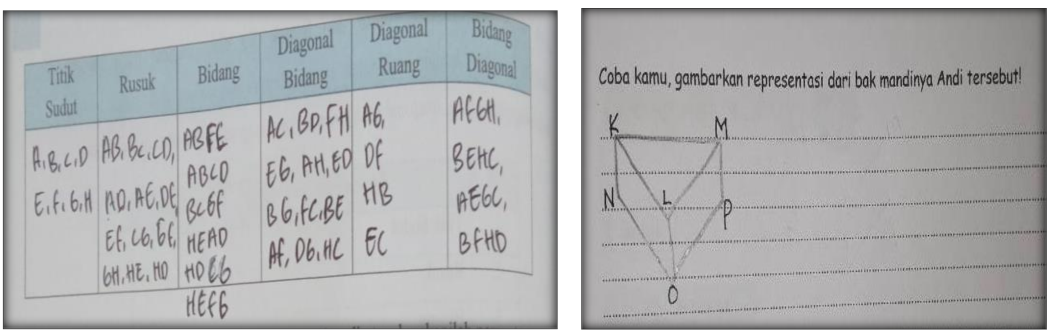

Figure 9. One Student's Answer in Understanding the Properties of Cubes

In phase evaluation, students requested a notice problem room class with a direct camera *cellphone* on *marker* like Figure 10.

Figure 10. Shape Evaluation

Figure 11. Animation Form Evaluation

After that, students requested to notice angles, edges, planes, plane diagonals, space diagonals, and plane diagonals, the 3D shape of the space class that appears on the cell phone camera. Form 3D animation is possible, as seen in Figure 10. In the evaluation, students were requested to draw from the 3D geometry of the space class and provided names from every point in the corner. After that, students requested to identify the edge, plane, plane diagonal, space diagonal, and plane diagonal.

Test result

Before testing with paired sample t-tests previously tested for data normality, data normality testing in this study used the Kolmogorov-Smirnov test using the SPSS version 25 with a significance level of 5%. The normality test results using SPSS version 25 can be seen in Table 7.

Table 7. Normality Test Results

Tests of Normality							
	Class	Kolmogorov-Smirnov [a]			Shapiro-Wilk		
		Statistics	df	Sig.	Statistics	df	Sig.
Ability to understand representations	Pre-Test Experiment	. 169	34	. 089	. 941	34	. 064
	Post-Test Experiment	. 305	34	. 097	. 672	34	. 076

a. Lilliefors Significance Correction

Kolmogorov-Smirnov is 0.169 and sig or p-value = 0.089. Because 0.089 > α, thus the pre-test data for experimental class students is usually distributed. The analysis results show that the Shapiro-Wilk statistic is 0.941 and the p-value is 0.064 > 0.05, which means accepting Ho and rejecting Ha, so it can be concluded that the data is usually distributed. Meanwhile, for the post-test data, the statistical value for Kolmogorov Smirnov was 0.305, and sig or p-value = 0.097. Thus, student data is usually distributed. From the analysis results, it can also be seen that the statistic for Shapiro-Wilk is 0.672 and the p-value 0.076 > 0.05, which means it can be concluded that the post-test population data of experimental class students is normally distributed.

Table 8. Paired Sample Test Results t-test

Paired Samples Test									
		Paired Differences					t	df	Sig.
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre_test - Post_test	-46.471	6.993	1.199	-48.911	-44.030	-38.746	33	.000

The Sig value is known based on Table 8f the Paired Samples Test output above. (2-tailed) i.e., equal to 0.000 < 0.05, H_0 is rejected, and H_a is accepted. So, there is a difference in the average ability of students' 3D geometric representation after using 6E-IM integrated AR. So, using 6E-IM has an integrated impact on improving the ability to represent students in 3D geometry class VIII in one private school sector in the Regency Indramayu.

Discussion

This study's results align with what was concluded by Fazelian et al. (2010) that the 5E learning design integrated with GeoGebra software can be used in 3D geometry learning and improve students' ability to understand 3D geometry material. Furthermore, according to Fazelian et al. (2010), 5E designs can be integrated with certain technologies, such as using GeoGebra software to teach polygon recognition and the regular rotation of 3D geometry. Another thing explains that 5E learning is integrated with GeoGebra software and has many advantages, developing the capacity and quality of students (Fazelian et al., 2010). Students' interest in using 5E is better than that of traditional learning (Fazelian et al., 2010). This is because the 5E design facilitates students' developing learning abilities, discovering for themselves, and constructing knowledge independently. Then Tezer & Cumhur (2017) showed that using 5E-IM in geometric materials can improve students' performance and problem-solving efficiency. Then, research by Lin et al. (2023), which integrates Virtual Reality Instruction into the STEAM-6E Model, research findings show there are significant differences in learning motivation regarding intrinsic goals, extrinsic goals, task value, control beliefs, self-efficacy, and test anxiety among those who use it Virtual Reality Instruction to in STEAM-6E Model with those who do not use.

Furthermore, in line with what Yaniawati et al. (2023) concluded, the AR application is designed to help teachers explain and explore 3D geometry concepts with material menus and evaluation functions. Therefore, mobile augmented reality has potential as a pedagogical resource and can improve students' understanding of geometric concepts and learning attitudes (Yaniawati et al., 2023). Sudirman et al. 's (2020; 2021; 2022) research results conclude that using AR applications can help students or prospective mathematics teachers understand material geometry as well as help increase attitudes in following the learning process. This aligns with the research of İbili et al. (2019), who concluded that using augmented reality in learning 3D geometry can increase the ability to think about students' 3D geometry. Research results also align with Gargrish et al. (2021), which reveal that learning geometry-based augmented reality effectively increases ability retention memory among students in 3D geometry. Apart from that, Rohendi & Wihardi (2020) conclude that mobile augmented reality can help teachers improve their understanding of students ' room three dimensions and increase the ability of spatial junior high school students. Auliya and Munasiah (2020) conclude that AR use in learning geometry is effective for increasing the attitude of students and understanding draft students' 3D geometry.

Limitations, advantages, and opportunities for further research

Limited time and budget resources affect the depth of research and the number of samples that can be taken. Additionally, variability in students' initial abilities, interests, and skill levels may be a factor influencing the results of this study. The advantages of this research are that using the 6E learning model and integrating augmented reality creates innovation in learning approaches, increasing students' interest in 3D geometry material. In addition, augmented reality can increase student engagement in learning, motivating them to be more active and explorative. Further related research opportunities could explore the long-term effects of using this learning model, including retention of student knowledge and understanding. In addition, the research can be adapted for other subjects, thereby analyzing the effects of using the 6E Instructional Model Integrated Augmented Reality in various learning contexts.

CONCLUSION

Research results. This concludes that AR technology can integrate learning-based constructivism as one of 6E-IM learning. Integration into 6E-IM is likely carried out in the explore and evaluate phase. AR can help students construct understanding through direct activity observation of a 3D shape in the explore phase. In the evaluation phase, AR can help the students understand the questions and potentially reduce misunderstandings in finishing problems with the material 3D geometry.

Furthermore, based on testing, the use of 6E-IM integrated AR impacts the improvement ability representation of students in 3D geometry class VIII in one school private sector in the Regency Indramayu. Implications from the study This is that integrating the 6E learning model with AR can be considered a method of learning innovative potential to increase the effectiveness in teaching mathematics, particularly in matter representation geometry. Additionally, the study's results can give a base for advanced study in learning mathematics, especially related to integration technology and learning models. The results of this research have implications that schools and educational institutions can encourage the integration of augmented reality technology as an integral part of learning strategies. In addition, the implications of this research also include encouragement for further research. Further research could explore aspects such as long-term impact, adaptation to other subjects, and the influence of contextual factors on learning outcomes.

REFERENCES

Alghadari, F., Herman, T., & Prabawanto, S. (2020). Factors affecting senior high school students to solve three-dimensional geometry problems. *International Electronic Journal of Mathematics Education*, *15*(3), em0590. https://doi.org/10.29333/iejme/8234

Cho, J. Y., & Suh, J. (2019). Understanding spatial ability in interior design education: 2D–to–3D visualization proficiency as a predictor of design performance. *Journal of Interior Design*, *44*(3), 141-159. https://doi.org/10.1111/joid.12143

Elia, I., van den Heuvel-Panhuizen, M., Gagatsis, A. (2018). Geometry Learning in the Early Years: Developing Understanding of Shapes and Space with a Focus on Visualization. In: Kinnear, V., Lai, M., Muir, T. (eds) Forging Connections in Early Mathematics Teaching and Learning. *Early Mathematics Learning and Developmen*t. Springer, Singapore. https://doi.org/10.1007/978-981-10-7153-9_5

Fazelian, P., Ebrahim, A. N., & Soraghi, S. (2010). The effect of the 5E instructional design model on learning and retention of sciences for middle-class students. *Procedia - Social and Behavioral Sciences*, *5*, 140–143. https://doi.org/10.1016/j.sbspro.2010.07.062Gargrish, S., Kaur, D. P., Mantri, A., Singh, G., & Sharma, B. (2021). Measuring effectiveness of augmented reality-based geometry learning assistant on memory retention abilities of the students in 3D geometry. *Computer Applications in Engineering Education*, *29*(6), 1–14. https://doi.org/10.1002/cae.22424

Grau, F.G.I., Valls, C., Piqué, N., & Ruiz-Martín, H. (2021). The long-term effects of introducing the 5E model of instruction on students' conceptual learning. International Journal of Science Education, 43(9), 1441-1458. https://doi.org/10.1080/09500693.2021.191835

Hake, R.R. (1999). Analyzing Change/Gain Scores. Dept. of Physics Indiana University. http://www.physics.indiana.edu

Hsiao, H. S., Chen, J. C., Chen, J. H., Chien, Y. H., Chang, C. P., & Chung, G. H. (2023). A study on the effects of using gamification with the 6E model on high school students' computer programming self-efficacy, IoT knowledge, hands-on skills, and behavioral patterns. *Educational technology research and development*, 1-29. https://doi.org/10.1007/s11423-023-10216-1

İbili, E., Çat, M., Resnyansky, D., Şahin, S., & Billinghurst, M. (2019). An assessment of geometry teaching supported with augmented reality teaching materials to enhance students' 3D geometry thinking skills. *International Journal of Mathematical Education in Science and Technology*, *51*(2), 224–246. https://doi.org/https://doi.org/10.1080/0020739X.2019.1583382

Ishehri, M. A. (2016). The Impact of Using (5E's) Instructional Model on Achievement of Mathematics and Retention of Learning among Fifth Grade Students. *IOSR Journal of Research & Method in Education*, *6*(2), 43–48. https://doi.org/10.9790/7388-06214348

Lin, K. Y., Hsiao, H. S., Williams, P. J., & Chen, Y. H. (2020). Effects of 6E-oriented STEM practical activities in cultivating middle school students' attitudes toward technology and technological inquiry ability. *Research in Science & Technological Education*, *38*(1), 1-18. https://doi.org/10.1080/02635143.2018.1561432Lin, Y. H., Lin, H. C. K., Wang, T. H., & Wu, C. H. (2023). Integrating the STEAM-6E Model with Virtual Reality Instruction: The Contribution to Motivation, Effectiveness, Satisfaction, and Creativity of Learners with Diverse Cognitive Styles. *Sustainability*, *15*(7), 6269. https://doi.org/10.3390/su15076269

Medina-Herrera, L., Castro Pérez, J., & Juárez Ordóñez, S. (2019). Developing spatial mathematical skills through 3D tools: augmented reality, virtual environments and 3D printing. *International Journal on*

Interactive Design and Manufacturing, *13*, 1385-1399. https://doi.org/10.1007/s12008-019-00595-2
Mullis, I.V.S, Martin, M. O., & Foy, P. (2008). TIMSS 2007 International Mathematics Report. In *International Association for the Evaluation of Educational Achievement (IEA) Published*. Retrieved from http://isc.bc.edu/timss2003i/mathD.html
Mullis, Ina V.S, Martin, M. O., Foy, P., & Arora, A. (2011). *TIMSS 2011 International Results in Mathematics*. Boston: TIMSS & PIRLS International Study Center.
Mullis, Ina V.S, Martin, M. O., Foy, P., & Hooper, M. (2015). *TIMSS 2015 International Results in Mathematics*. Retrieved from http://timss2015.org/timss-2015/science/student-achievement/distribution-of-science-achievement
Omotayo, S. A., & Adeleke, J. O. (2017). The 5E Instructional Model: A Constructivist Approach For Enhancing Students' Learning Outcomes In Mathematics. *Journal of the International Society for Teacher Education*, *21*(2), 15–26.
Pittalis, M., & Christou, C. (2010). Types of reasoning in 3D geometry thinking and their relation with spatial ability. *Educational Studies in Mathematics*, *75*(2), 191–212. https://doi.org/10.1007/s10649-010-9251-8
Pittalis, M., & Christou, C. (2013). Coding and decoding representations of 3D shapes. Journal of Mathematical Behavior, 32(3), 673–689. https://doi.org/10.1016/j.jmathb.2013.08.004
Rohendi, D., & Wihardi, Y. (2020). Learning Three-Dimensional Shapes in Geometry Using Mobile-Based Augmented Reality. *International Journal of Interactive Mobile Technologies*, *14*(9), 48–60. https://doi.org/10.3991/ijim.v14i09.13035
Siwawetkul, W., & Koraneekij, P. (2018). Effectof 5E instructional model on mobile technology to enhance reasoning ability of lower primary school students. *Kasetsart Journal of Social Sciences*, *41*(1), 40–45. https://so04.tci-thaijo.org/index.php/kjss/article/view/234874
Sudirman, S., Kusumah, Y. S., Martadiputra, B. A. P., & Runisah, R. (2023). Epistemological Obstacle in 3D Geometry Thinking: Representation, Spatial Structuring, and Measurement. *Pegem Journal of Education and Instruction*, *13*(4), 292-301. https://doi.org/10.47750/pegegog.13.04.34
Sudirman, S., Rodríguez-Nieto, C. A., Dhlamini, Z. B., Chauhan, A. S., Baltaeva, U., Abubakar, A., ... & Andriani, M. (2023). Ways of thinking 3D geometry: exploratory case study in junior high school students. *Polyhedron International Journal in Mathematics Education*, *1*(1), 15-34. https://doi.org/10.59965/pijme.v1i1.5
Sudirman, S., Kusumah, Y. S., & Martadiputra, B. A. P. (2022). Investigating the Potential of Integrating Augmented Reality into the 6E Instructional 3D Geometry Model in Fostering Students' 3D Geometric Thinking Processes. *International Journal of Interactive Mobile Technologies*, *16*(6), 61-80. https://doi.org/10.3991/ijim.v16i06.27819
Sudirman, S., Kusumah, Y. S., & Martadiputra, B. A. P. (2021). Augmented reality blended learning instruction: the impact on growing motivation, attitudes, and knowledge in 3D geometry. *Turkish Journal of Computer and Mathematics Education, 12*(4), 674-683.
Sudirman, S., Mellawaty, M., Yaniawati, P., & Indrawan, R. (2020). Integrating local wisdom forms in augmented reality application: Impact attitudes, motivations and understanding of geometry of pre-service mathematics teachers'. *International Journal of Interactive Mobile Technologies (iJIM)*, *14*(11), pp. 91–106. https://doi.org/10.3991/ijim.v14i11.12183
Tezer, M., & Cumhur, M. (2017). Mathematics through the 5E Instructional Model and Mathematical Modelling: The Geometrical Objects. *EURASIA Journal of Mathematics Science and Technology Education*, *13*(8), 4789–4804. https://doi.org/10.12973/eurasia.2017.00965a
Yaniawati, P., Sudirman, S., Mellawaty, M., Indrawan, R., & Mubarika, M. P. (2023). The potential of mobile augmented reality as a didactic and pedagogical source in learning geometry 3D. *Journal of Technology and Science Education*, *13*(1), 4-22. https://doi.org/10.3926/jotse.1661