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The Impact of 3D Geometry Assisted 6E Instructional Model to Improve 3D Geometry Thinking Skills of Junior High School Students

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Abstract: This study aims to reveal the impact of the 6E Instructional 3D geometry model (6E I3DGM) design in improving students' 3D geometric thinking skills. The approach in this study uses a mixed approach. The reason for choosing this approach is that researchers want to get a more comprehensive understanding of this research problem. In this study, the participants involved in this study were (1) junior high school mathematics teachers; (2) grade VIII junior high school students in one of the public junior high schools in Indramayu Regency. In addition, there are three methods of collecting data in this study, namely observation, documentation, tests, which were analyzed using qualitative and quantitative data analysis. Qualitative data analysis using Miles and Huberman (2014) modification consists of data collection, data reduction (data reduction), data display (data display), and conclusion drawing (verification). The statistical test used in this study used an independent t-test. The results of this study conclude that the 6E I3DGM design can improve students' 3D geometric thinking skills. This is because students (1) can activate students' prior knowledge; (2) can relate previous knowledge with prior knowledge; (3) can explore 3D geometry problems; (4) can facilitate the process of constructing new concepts of 3D geometry into students' memory; (5) able to elaborate 3D geometry knowledge acquired in other contexts; (6) can evaluate the acquired knowledge in order that the 3D geometry knowledge possessed by students is stored in cognitive structures for a long period of time.

Keywords: 6E instructional 3D geometry model, 3D geometry thinking skills, junior high school students.

▪ INTRODUCTION

The geometry teaching curriculum in the school is based on the study of Euclid's geometry (Sinclair & Bruce, 2015). In general, the study of geometry in schools is related to the point, length, width, size, shape, position, and properties of geometric objects, space, area, volume, and transformation of spatial objects (Clements, 1998; Crompton et al., 2018; Mammarella, 1998). Giofr, & Caviola, 2017). The National Council of Teachers of Mathematics (NCTM, 2000) divides the study of geometry in schools into two, namely two-dimensional (2D) geometry and three-dimensional (3D) geometry. 2D geometry is concerned with a flat plane or two-dimensional shape that has length and width (Roveto, 2011). Meanwhile, the object of the study of 3D geometry is related to geometric shapes that have length, width, and height (Roveto, 2011), such as cubes, spheres, cubes, cones (Koester, 2003).

In Indonesia, geometry material gets a sizable portion in the mathematics curriculum at the school level (Sudirman & Martadiputra, 2020). However, the results of TIMSS reports from year to year show that students' mastery of 3D geometry concepts is still unsatisfactory. In 2007 for the geometry domain about drawing a rectangle with two adjacent sides, it got a score of 395 (Mullis et al, 2008).

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Furthermore, in 2011 for the geometry domain about Determining the number of cubes in a stack with some hidden, it got a score of 377 (Mullis et al, 2011). Whereas in 2015 for the geometry domain about identifying the largest volume of the four rectangular prisms represented pictorially, it got a score of 394 (Mullis et al, 2015). This is an estimate of the average achievement of Indonesian students for the geometry domain based on a range of values from 0 to 1000. The results of student geometry achievement in Indonesia are still below the average score of 500.

The results of TIMSS in the geometry domain are related to the results of a preliminary study conducted by researchers at one of the public junior high schools in Indramayu Regency, West Java, Indonesia. Based on the achievement of the average value of mathematics subjects, especially on the topic of geometry and measurement on the national exam, it is not as expected. In 2017 the percentage of students' mathematics achievement (%) was 52.51 and geometry achievement was 45.30. Meanwhile, in 2018 the percentage of achievement (%) in mathematics was 50.21 and geometry was 46.10. Furthermore, in 2019 the percentage of achievement (%) in mathematics was 59.08 and geometry was 50.59. This shows that the average math score on the national exam for the last three years of schooling as the population in this study is still in the low category. On the topic of geometry and measurement material which is the focus of attention, it shows that the percentage of mastery of geometry and measurement is still below the average for mathematics subjects as a whole. This achievement indicates that students still experience problems in understanding or thinking geometry.

In this study, the 6E IG3DM design is a 3D geometry learning instruction which consists of six phases, namely elicit in 3D geometry, engage in 3D geometry, explore in 3D geometry 3D, explain in 3D geometry, elaborate in 3D geometry and evaluate in 3D geometry. Each phase has its own purpose in growing the ability to think 3D geometry. The elicit in 3D geometry phase aims to activate students' prior knowledge about 3D geometry material. The engage in 3D geometry phase aims to connect prior knowledge to new concepts. Meanwhile, the explore in 3D geometry phase aims to construct new concepts and facilitate students' 3D geometry thinking. Furthermore, the explain in 3D geometry phase aims to improvise and confirm the new knowledge that students have acquired. The elaborate in 3D geometry phase aims to facilitate the process of internalization and assimilation of new concepts into students' memory. The last phase, namely evaluate in 3D geometry, aims to evaluate students' 3D geometry thinking skills.

Researchers believe that the 6E IG3DM design can improve 3D geometric thinking skills because it is supported by previous studies such as Tezer & Cumhur (2017) which concluded that teaching with the 5E learning model can improve students' mathematics learning achievement. In addition, Turan & Matteson (2021) concluded that the 5E learning model can help increase student engagement and participation in the learning process. Meanwhile, Fazelian, Ebrahim, & Soraghi (2010) concluded 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.

▪ METHOD

Research design

The approach in this study uses a mixed approach. The reason for choosing this approach is because researchers want to get a more comprehensive understanding of this research problem. While the chosen design is exploratory sequential. The exploratory sequential design begins with qualitative data collection and analysis, and then proceeds with quantitative collection and analysis (Creswell & Clark, 2018). The qualitative research process aims to produce a 6E instructional 3D model (6E I3DGM) learning design. While the quantitative stage aims to see the impact of 6E I3DGM in improving students' 3D geometric thinking skills.

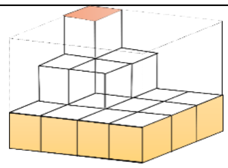
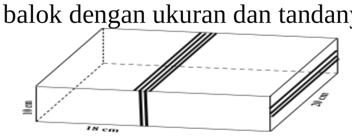
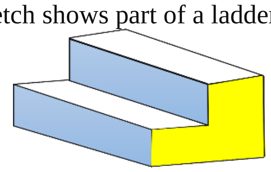
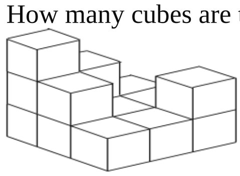
Participants and Research Site

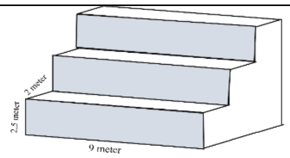
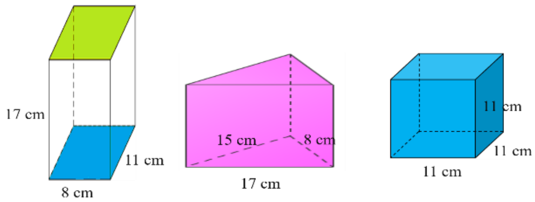
The participants involved in this study were (1) junior high school mathematics teachers; (2) junior high school students. Meanwhile, the target for field testing is all eighth-grade students in one of the public junior high schools in the Indramayu Regency, in the 2020/2021 academic year. One of these public junior high schools was chosen because it was one of the first schools to use the 2013 national curriculum (Kurtilas) from 164 public/private junior high schools in the Indramayu Regency.

Data collection

There are three methods of collecting data in this study, namely observation, documentation, and tests. In this study, the 3D geometric thinking ability test (TKBG3D) was used to measure students' ability to (1) identify the elements and properties of 3D geometry. (2) Identify and construct 3D geometric webs. (3) Draw and translate representations of various 3D geometric views. (4) Determine the edge structure of the 3D geometry object. (5) Determine the area and volume of 3D geometry objects. (6) Comparing two 3D geometry objects based on their characteristics. This capacity is an indicator of TKBG3D (Pittalis & Christou, 2010; Pittalis, Mousoulides & Christou, 2010; Pittalis & Christou, 2013). An example of a 3D geometric thinking ability test instrument can be seen in Table 1.

Tabel 1. Description of 3D Geometry Thinking Ability Test Questions

Indicator	Description of test questions	Example
Recognition of 3D shapes' properties	Identify the properties of 3D geometry	 Find the number of students' cubes whose sides are not painted!
Recognition and construction of nets	Constructing block nets	Jika diketahui balok dengan ukuran dan tandanya.  Make at least three different nets for the block.
Drawing and translate representations of different views of 3D solids	Translation of an orthogonal view to a perspective drawing.	The following sketch shows part of a ladder.  Draw the front, side and top view!
Structuring 3D Arrays of cubes	Counting the number of cubes and the length of the edges of the unit cube arrangement	How many cubes are there in the following picture! 
Calculation of the volume and	Calculating surface area and volume	Determine the surface area and volume of the following figure!

the area of solids		
Comparison of 3D shapes properties	Comparing geometric volumes based on their properties	Look at the following picture. If a prism is cut into small pieces and arranged at an angle, it will still have the same volume.  Show that the volumes of the two prisms are equal!

Data analysis

The data analysis used is qualitative and quantitative data analysis. Qualitative data analysis consists of data collection, data reduction (data reduction), data display (data display), and conclusion drawing (verification). The statistical test used in this study used an independent t-test.

▪ RESULT AND DISCUSSION

Design

The design of the 6E Instructional 3D Geometry Model (6E IG3DM) in this study is designed to help students carry out the construction process of thinking 3D geometry. The construction process in 3D geometric thinking is facilitated by the elicit, engage, explore, explain, elaborate and evaluate phases. In the elicit in geometry 3D phase it is easier to activate students' prior knowledge. This phase is important because it is a prerequisite in carrying out the 3D geometry thinking process. A student will be able to think 3D geometry well, if he has good initial knowledge. Furthermore, after students have activated their initial knowledge, the next phase is the phase of engaging in 3D geometry. The engage in 3D geometry phase bridges students in the formation of new concepts in the structure of understanding they already have. In this phase, students are invited to connect the initial knowledge that already exists in the student's memory structure into the new knowledge that students will learn. In this phase, students are invited to interpret the importance of the new concepts they are learning. After students are ready to receive new knowledge, the next phase students are invited to explore 3D geometry problems. In this phase, it facilitates the process of constructing new concepts of 3D geometry into students' memory. The next phase is explaining in 3D geometry. In this phase, students are invited to communicate the results of the exploration process. This phase aims that the knowledge of 3D geometry that students get will be well internalized if students are able to explain their knowledge. The next phase is elaborate in 3D geometry. In this phase, students are invited to elaborate the knowledge of 3D geometry obtained in other contexts. This phase aims to make 3D geometry knowledge stored in memory stored for a long time. In the last phase, evaluate in 3D geometry. In this phase, students evaluate the acquired knowledge in order that the 3D geometry knowledge that students have is stored in cognitive structures for a long period of time.

In this study, four considerations were made to design the 6E Instructional 3D Geometry Model (6E IG3DM). The first consideration is related to the characteristics of geometric materials, especially 3D geometry. The second consideration is related to the consideration that the subjects involved are students. The third consideration is related to content knowledge. The fourth consideration is to facilitate the students' 3D geometry thinking process. In addition, adding one phase, namely the elicit phase. This phase pays attention to the importance of previous knowledge as a provision to learn the next knowledge. Based on these considerations, a didactic design (6E I3DGM) was drawn up with the following stages:

Figure 1. Design of 6E Instructional 3D Geometry Model (6E I3DGM)

The constructivist theory model has proven successful in the process of conceptual change through various instructional models so that it can produce appropriate understanding, cognitive structures, learning strategies (Alshehri, 2016). The 6E Instructional 3D Geometry Model is a learning development of the 5E Instructional Model. The 5E Instructional Model was first developed by Rodger W Bybee in 1997 (Ramaligela et al, 2019). The 5E Instructional Model is mostly implemented in the field of science, but currently in the field of mathematics education it has been widely used and studied (Tezer & Cumhur, 2017). This is understandable because the 5E Instructional Model is considered one of the best approaches recommended for teaching in a constructivist learning approach (Omotayo & Adeleke, 2017) which facilitates how knowledge is constructed (Eisenkraft, 2003) through the process of engage, explore, explain, elaborate. and evaluate (Eisenkraft, 2003). This model is called the 5E instructional cycle model because each stage starts with the letter "E" (Tezer & Cumhur, 2017). Eisenkraft extends the 7E learning model from the 5E learning model developed by Bybee. The learning process takes place offline. The learning process is carried out in the classroom. The following describes the learning process at one of the meetings.

Elicit Phase

At the beginning of the meeting the teacher opened with greetings and a little apperception to start learning. The students answered the greeting from the Master.

Next, the teacher invites students to recall the material in the following meeting. The teacher recalls the previous material. Students respond by remembering the previous material and answering questions from the teacher. Next, the teacher continues to explore students' previous knowledge by asking questions related to the previous material. There are some students who answer the teacher's questions. Then the teacher asks students to form groups and explain to students the purpose of forming groups. The teacher explains the purpose of forming groups to make it easier for students in the 3D geometry learning process, so that students can communicate and cooperate with each other in each group and can make it easier for students to do the exercises given by the teacher.

Engage Phase

In the engage phase, it aims to link the previous material with the material that will be studied by students. The teacher gives directions to each group to write down the questions that the teacher will ask. The first question students were asked to make a cube. Then the second question, the students were instructed to make four cubes into a single cube. The last question students were asked to write the formula for the volume of a cube. Next, students work on the questions given by the teacher. Students write down each question the teacher mentions. The teacher allows students to get information through books and the internet to answer any questions the teacher gives. Students follow the teacher's directions by opening books and the internet to answer each question. The teacher observes each group, when it feels like all groups have finished the teacher asks all students whether the task given by the teacher has been completed. Each group advanced one by one starting from group 1 to group 12. Both groups 1 to group 12 presented the answers to the teacher's questions that they got from books and the internet. After all groups have presented the results of their discussions, the teacher gives appreciation to all groups and straightens out if there is an explanation from the group whose answers are not quite right, so that students can know the real answer.

Explore phase

In the explore phase, the teacher directs students to open the 3D geometry textbook that the researcher has made. Then, the teacher asked the students to work on the questions in groups. In this problem, students are instructed to count the number of unit cubes, unit size (p x l x t) and volume (V). Students are asked to complete and answer the questions correctly (See Figure 1). There were some students who answered the 4th question incorrectly because the students had incorrectly determined the number of cube-shaped picture units. It is possible that the student who answered incorrectly did not remember that the cube must have every side the same.

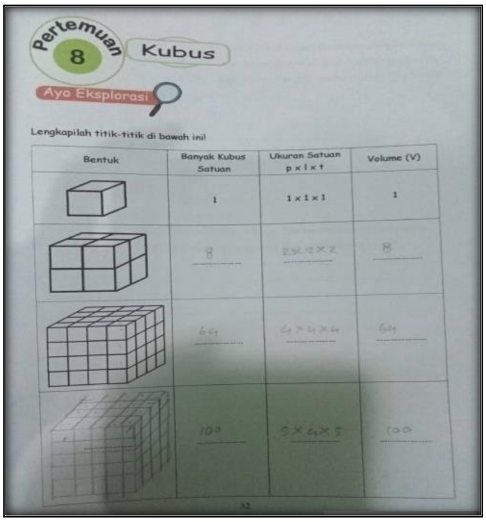


Figure 2. Result Explore Phase

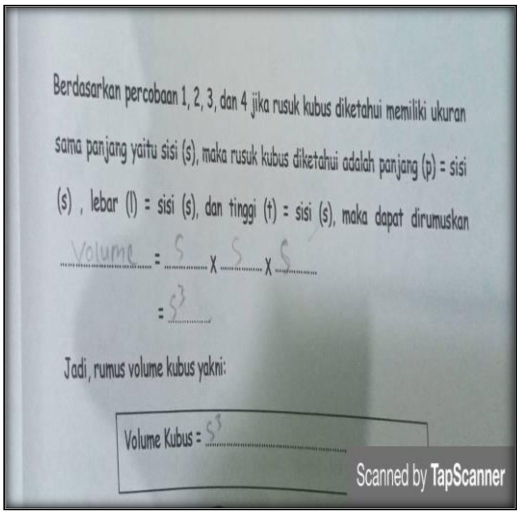


Figure 3. Result Explore Phase

Explain Phase

Next, each group worked on the questions and discussed together with their respective groups. After all groups have completed all the questions in the geometry textbook, then the teacher asks one representative of each group to present the answers that have been answered and give reasons for the answers that have been answered. Students follow the directions given by the teacher, so that each group appoints one representative to come forward. After the group representatives present, the teacher gives another group the opportunity to refute or ask questions. Group members who are presenting can help their friends who come forward to answer questions from other groups. Furthermore, after completing the presentation, the teacher gives appreciation to all groups and confirms if the answers are correct, as well as straightens out students' answers that are not quite right so that students know the real answer. The presentation process took place the same for the other groups from group 1 to group 12. After all students finished presenting, then the teacher gave the opportunity for all students to ask about the material that had been studied together today, if there was something that was not understood.

Elaborate Phase

In the eloborate phase the teacher gives new problems to students in groups to be solved together in their respective groups. The purpose of this eloborate phase is to strengthen students' knowledge of the material being taught, as well as to ensure that all students understand the lessons that are currently taking place. The questions that the teacher gives are questions that are in the student worksheets that the researchers have made. The teacher instructs students to open page 33 of the book and asks students to work on the questions in the “Let's Elaborate” section. Furthermore, there are several students who answered correctly. It can be seen in Figure 3

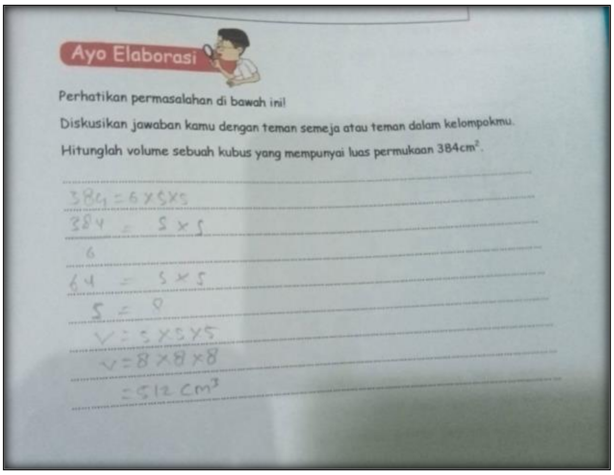


Figure 4. Result Elaborate Phase

Evaluate Phase
Furthermore, in the evaluation phase, the teacher asks students what they have learned today. Students answer at the same time drawing several cubes into a single cube shape. Then the teacher asks questions related to the material that has been studied by students. Students answer the volume of the cube seen from the number of cubes and the unit size of the cube. Then the teacher asked again, is there anything else? Then, students answer the story questions about calculating the volume of a cube. After that the teacher gave another question, namely what is the formula for the volume of a cube. Students answer S x S x S. Then the teacher gives appreciation for the students' answers. The teacher explains that the intent and purpose of the teacher is to repeat the question as a teacher evaluation material, whether students can understand today's lesson. If students can understand today's lesson, it means that today's lesson is complete. However, if students are still lacking in understanding today's learning, the teacher means that they will improve at the following meeting.

I3DGM 6E learning impact
In this study, to determine the effect of the 6E I3DGM design, it was tested on two classes that became the object of research. The things described are the pretest and posttest mean, the pretest and posttest standard deviation, the normalized gain, which is presented in Table 2.

Table 2. Descriptive Statistics of Pretest, Posttest and Gain KBG3D

Descriptive Statistics	6E I3DGM			Conventional		
	Pretest	Posttest	$\langle g \rangle$	Pretest	Posttest	$\langle g \rangle$
$\bar{X}$	16	34.36	0.43	13.84	25.89	0.27
SD	7.64	11.71	0.19	7.74	11.01	0.16
N		22			19	

The average value of pretest, posttest and KBG3D gain can be depicted in the form of a bar chart as shown in Figure 5. Some things that can be explained from the descriptive statistics in Table 2 and Figure 5. relating to the students' KBG3D data are as follows:

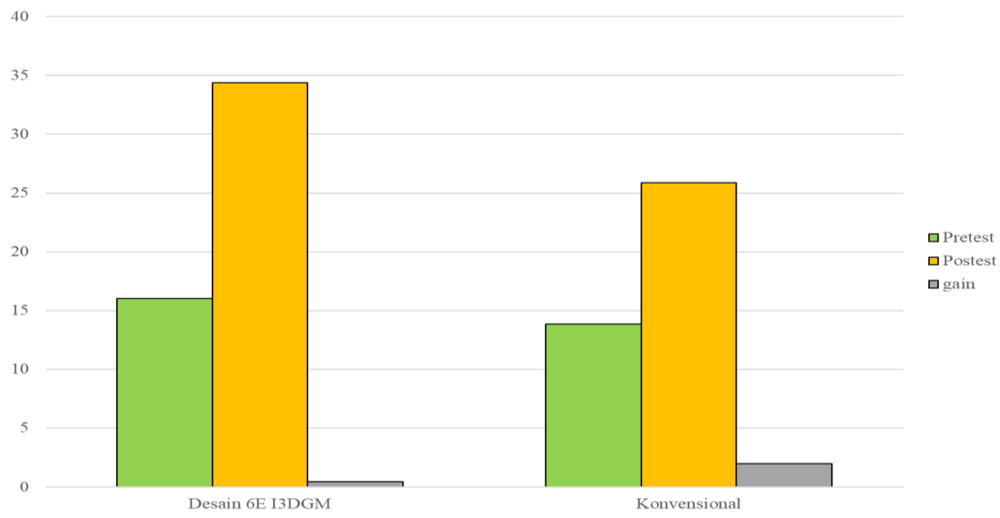


Figure 5. Descriptive Statistics of Pretest, Posttest and Gain Graph KBG3D

The average KBG3D pretest score of students who learn using the I3DGM design is 16. Meanwhile, those who use conventional learning are 13.8. The average KBG3D pretest score shows that there is a difference in students' KBG3D pretest based on learning, but the difference is very small. The average post-test score of KBG3D students who learn to use the 6E I3DGM is 34.36 and those who use the conventional model are 25.89. Descriptively the difference in the average posttest KBG3D scores of students who learn to use the 6E I3DGM integrated AR and conventional design is 8.47. Therefore, descriptively it is said that there is a difference in the average posttest KBG3D score between students who learn to use the 6E I3DGM, and the conventional model.

Furthermore, the magnitude of the increase (normalized gain value) of KBG3D students who learn to use the 6E I3DGM is 0.43 and the magnitude of the increase in KBG3D of students who learn to use the conventional model is 0.27. While the difference in the magnitude of the increase in the KBG3D of students between those using 6E I3DGM learning and conventional learning is 0.16. Descriptively, it shows the difference in the improvement of KBG3D between students who learn to use d6E I3DGM, and conventional ones. Furthermore, to ensure that there is a significant difference between those using the 6E I3DGM design and the conventional model, an independent t-test was conducted. After testing the assumptions of normality and homogeneity are met. Then analyzed using the independent t-test as shown in Table 3.

Table 3. Independent t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means			
KBG3D		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
	Equal variances assumed	2.035	.162	2.778	39	.008	.15801

Based on Table 3. shows that the *t* value is 2.778 and the probability value is 0.008. When compared to the value of sig. with a significance level of 0.008 <0.05, it is concluded that Ho rejects, which means that there is a significant difference in the increase in KBG3D students who learn to use the 6E I3DGM and conventional learning designs.

This study concludes that the 6E I3DGM design can improve students' 3D geometric thinking skills. The design of the 6E Instructional 3D Geometry Model (6E IG3DM) in this study is designed to help students carry out the construction process of thinking 3D geometry. The construction process in 3D geometric thinking is facilitated by the elicit, engage, explore, explain, elaborate and evaluate phases. In the elicit in geometry 3D phase it is easier to activate students' prior knowledge. Furthermore, after students have activated their initial knowledge, the next phase is the phase of engaging in 3D geometry. After students are ready to receive new knowledge, the next phase students are invited to explore 3D geometry problems. In this phase, it facilitates the process of constructing new concepts of 3D geometry into students' memory. The next phase is explaining in 3D geometry. In this phase, students are invited to communicate the results of the exploration process. The next phase is elaborate in 3D geometry. In this phase, students are invited to elaborate the knowledge of 3D geometry obtained in other contexts. In the last phase, evaluate in 3D geometry. In this phase, students evaluate the acquired knowledge in order that the 3D geometry knowledge that students have is stored in cognitive structures for a long period of time.

The results of this study are also in line with Tezer & Cumhur (2017) who concluded that teaching with the 5E learning model can improve students' mathematics learning achievement. In addition, Turan & Matteson (2021) concluded that the 5E learning model can help increase student involvement and participation in the learning process. Meanwhile, Fazelian, Ebrahim, & Soraghi (2010) concluded that the 5E learning design has a significant effect. Furthermore, according to Fazelian, Ebrahim, & Soraghi (2010) the 5E design can also be integrated with certain technologies such as using GeoGebra software. In addition, the use of 5E design can also be used for teaching polygon recognition and regular rotation of 3D geometry. Another thing is that learning with 5E which is integrated with GeoGebra software has many advantages, developing the capacity and quality of students. Students' learning interest using 5E is better than traditional learning. This is because the 5E design facilitates students to develop learning skills, find out for themselves and construct knowledge independently.

▪ CONCLUSION

The results of this study conclude that the 6E I3DGM design can improve students' ability to represent 3D geometric objects, construct 3D nets, determine the spatial structure of 3D geometric objects, calculate surface area and volume of 3D geometry and compare the volume of 3D geometry. This ability is an indicator of students' 3D geometric thinking ability. Therefore, the use of the 6E I3DGM design can improve the 3D geometric thinking ability of junior high school students. This is because in the elicit in 3D geometry phase, students can activate their prior knowledge. Activation of students' initial abilities is important because students' thinking activities start from their initial knowledge. In addition, in the engage in 3D geometry phase, students can connect their initial abilities to the knowledge that they will learn. This is because the tendency of students when studying the material must be related and interested in the information that students already have. Furthermore, in the explore in 3D geometry phase, students can explore 3D geometry problems so that students can find and construct new knowledge that students learn. Then, in the explain in 3D geometry phase, students can communicate the knowledge they have gained in the exploration phase. In addition, this phase aims to facilitate students to carry out the process of constructing new concepts of 3D geometry into memory. Meanwhile, in the elaborate in 3D geometry phase, students can internalize the knowledge of 3D geometry they have acquired into the context of other problems. It is intended that new knowledge that has been stored in memory will become stronger. In the last phase, namely evaluate in 3D geometry, students can evaluate the knowledge gained with the aim that the knowledge of 3D geometry already possessed by students can be stored properly in students' cognitive structures for a long period of time. Because of these things, the researcher believes that the 6E I3DGM design has the potential to be used to teach 3D geometry at the junior high school level and can improve students' understanding of 3D geometry.

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