International Journal of Advanced and Applied Sciences, 10(12) 2023, Pages: 7-18

Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

Hybrid learning impact with augmented reality to improve higher order thinking skills of students

Heni Pujiastuti [1, *], Rudi Haryadi [2]

[1]*Department of Mathematics Education, Faculty of Training Teachers and Education, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia*
[2]*Department of Physics Education, Faculty of Training Teachers and Education, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia*

ARTICLE INFO

Article history:
Received 24 July 2023
Received in revised form
8 November 2023
Accepted 9 November 2023

Keywords:
Augmented reality
Geometry
Hybrid learning
Higher order thinking skills

ABSTRACT

The purpose of this study was to determine the effectiveness of using hybrid learning with augmented reality to improve the high-level thinking skills of junior high school students in the area of geometry. In addition, the effects of hybrid learning with augmented reality on students' motivation to study geometry are also examined. This research technique uses a sequential mixed methods approach, combining quantitative and qualitative methods in sequence. Quantitative approaches were used in the first phase to collect quantifiable data, and qualitative methods were used in the second phase to explore the results of the first phase. A two-group pretest-posttest design is the quantitative research method used. In order to establish an experimental class and a control class, the research sample was selected using the cluster random sampling method. In addition, while the control class uses hybrid learning without augmented reality, the experimental class takes advantage of it. Interviews and observation sheets are used in the qualitative design dimensions. The quantitative part of the data shows that students who receive hybrid learning with augmented reality have higher order thinking skills (HOTS) in terms of ideas in geometry than students who receive hybrid learning without augmented reality. The HOTS N-Gain scores from hybrid learning with augmented reality are 0.62, while the HOTS N-Gain scores from hybrid learning without augmented reality are 0.43, both of which support this conclusion. In addition, according to the findings in the qualitative dimension, students are more motivated and engaged in learning when using augmented reality applications than when they are not. These qualitative findings suggest that augmented reality software can be successfully used as a teaching tool for geometry topics.

1. Introduction

Geometry is one of the concepts of mathematics that must be studied in the 2013 curriculum in Indonesia. This knowledge helps students identify shapes and spaces around them. Understanding geometric concepts and models can provide new perspectives for students (Chen et al., 2022). Students must have a solid understanding of geometry to use their geometric skills, such as visualization, recognition of diverse forms and spaces, describing pictures, drawing shapes, dotting certain labels, and the capacity to distinguish between geometric shapes that are similar and different from one another (Yao, 2020; Zhang and Shi, 2020). Understanding geometry is designed to introduce students to simple geometric shapes by adjusting them to the level of students' thinking (Alqahtani and Powell, 2017; Komatsu et al., 2017).

Several things that support the implementation of this research have been carried out through preliminary research using observation and interview methods to the ten best schools in the city of Serang, Banten, Indonesia. The results show that students struggle to visualize images, especially three-dimensional shapes. Furthermore, we interviewed teachers with the development that the media used to explain Geometry concepts in schools is mostly still in the form of conventional media in the form of LKS (Student Work Sheets) and book

* Corresponding Author.
Email Address: henipujiastuti@untirta.ac.id (H. Pujiastuti)
https://doi.org/10.21833/ijaas.2023.12.002
Corresponding author's ORCID profile:
https://orcid.org/0000-0002-2968-4990

packages that do not attract students' learning interest. Apart from that, sometimes PowerPoint media is also used, but it is only partially capable of displaying good visualization because it is still a 2D image.

Learning outcomes in geometry learning also encountered several problems, including students' difficulties in understanding higher order thinking skills (HOTS) on flat-sided geometric concepts. Obtained percentage data of 68.97% of students had difficulty in comparing flat-sided geometrical nets, 41.48% of students had trouble identifying elements of flat-sided geometrical shapes, 89.66% of students had a problem applying geometrical properties flat side, and 87% of students had difficulty in changing story questions into image form. So, image representation is the main problem.

Generally, in the learning process, most students only memorize the general formula of geometric shapes without knowing how the basic concept is to find the formula (Ben-Dor and Heyd-Metzuyanim, 2021; Ko and Rose, 2022). So, when there is a question development with the HOTS category, students have difficulty working on it. This is reflected in the 2022 PISA (Program for International Student Assessment) scores in the field of mathematics for Indonesian students, which are classified as concerning because they are below the standard score set. The questions used in the test are based on HOTS questions. This happens because solving HOTS questions requires more than rote memorization and applying the basic concepts. High mathematical visualization abilities are needed to discover this concept, so a media that can help students is required. Therefore, we need a learning innovation technology so that the material presented is more attractive to students' interest and motivation to learn. The presence of innovative technology in learning media, which supports the learning process, is believed to improve HOTS.

HOTS are essential abilities that need to be mastered through the learning process (Kao et al., 2017; Ung et al., 2022). HOTS is a decision-making process that excels beyond memorization, facts, and concepts (Tsai et al., 2016; Lee and Choi, 2017; Birgili and Demir, 2022). An appropriate learning style is required to facilitate the mastery of HOTS in students (Baylor and Ritchie, 2002; Brečka et al., 2022). One of the HOTS can be improved through mastery learning with the help of Android interactive multimedia. Students' HOTS influence the development of education in communicating in tertiary institutions (Baylor and Ritchie, 2002; Brečka et al., 2022). The higher the HOTS, the better the use of everyday language (Yang, 2015; Huang et al., 2022). If students already have HOTS, they will work well with a team when they enter the world of work (Mamun et al., 2020; Jansen and Möller, 2022). In order to succeed in the 21st century, students need to have a variety of skills, including 1) analysis, 2) assessment, 3) decision-making and critical thinking, 4) problem-solving, and 5) creativity and creative thinking. The skills of analysis (C4), evaluation (C5), and creation (C6) are indicators for gauging HOTS talents (Klein et al., 2000; Jyothi et al., 2012; Chang-Kredl and Colannino, 2017).

AR (Augmented Reality) learning media innovation technology can assist in spatial visualization to improve students' HOTS abilities. But until now, multimedia learning using AR technology has been very limited. Meanwhile, AR technology is up-and-coming and has advantages if it is applied to the learning process to replace visual aids. Therefore, this research was conducted to facilitate the learning process of geometry, attract students' interest, and provide new experiences in interacting through learning media. Mastery of AR is very important for a teacher. The use of AR in the ongoing learning process will create a new condition that can support the effectiveness of the process itself. Smartphone is one of the technological advances from the development of cellular phones. Currently, as many as 95% of students use smartphones. Of course, this is an opportunity in education to develop technology to assist the hybrid learning process. One of them is developing innovative technology for learning media based on augmented reality, which can create effective, efficient, and practical learning conditions for students and teachers. In the context of geometric visualization, AR technology exists as a technology that can improve HOTS capabilities.

AR is defined as something that can combine real and virtual objects in one spatial thing (Bujak et al., 2013; Ibáñez and Delgado-Kloos, 2018; Yip et al., 2019). It is also interactive in real time and can display geometric shapes in three dimensions. Over the past decade, this technology has developed rapidly. Now, AR is running on smartphones (Bujak et al., 2013; Ibáñez and Delgado-Kloos, 2018; McLean and Wilson, 2019; Oyman et al., 2022). There are many advantages of using smartphone technology to support AR applications. Mobile AR is perfect for ideas like "learning everywhere," where everyone is learning all the time, wherever they are, and when they need to (Bujak et al., 2013). Mobile AR can also help student learning activities by utilizing their smartphones to display more attractive 3D and 2D image illustrations (El Sayed et al., 2010; Lee et al., 2016; Yang et al., 2023; Yang and Wang, 2023).

AR technology can be used as a learning medium to overcome learning difficulties in image representation problems and improve student learning outcomes (Pujiastuti and Haryadi, 2023). Based on the research, it was found that 2D images, textbooks, and presentation slides can be designed into AR-based learning media so that they become more interactive (Pujiastuti and Haryadi, 2020). Besides that, the results of other studies concluded that student learning outcomes with AR media were more significant than students who used conventional lecture learning methods (Haryadi and Pujiastuti, 2022; Pujiastuti and Haryadi, 2022). In this study, for the AR camera to be able to display objects from all points of view, in the surface area material, variations of other nets were made to make animations on volume explanations so that users were more interested and could be understood better. Learning is currently entering the era of hybrid learning. Seeing today's rapid technological developments, of course, hybrid learning can have a positive impact on the learning process in schools if appropriately used (Arrosagaray et al., 2019; Mumford and Dikilitaş, 2020). Education must be able to produce generations that are innovative, creative, and competitive (Pujiastuti et al., 2020a). The role of the teacher must be able to take advantage of technological developments creatively and innovatively to maximize the learning process (Pujiastuti et al., 2020b). Teachers must facilitate students' learning to find the core of learning independently (Haryadi and Pujiastuti, 2020).

Hybrid learning aims to provide the most effective and efficient learning experience (Klašnja-Milićević et al., 2018; Zydney et al., 2020; Hartnett et al., 2023). The hybrid composition often used is 50/50, meaning that from the allocated time, 50% is for face-to-face learning activities, and 50% is done online learning. Some use a 75/25 composition, meaning 75% face-to-face and 25% online learning. Likewise, 25/75 can be done, representing 25% face-to-face and 75% online learning. Considerations for determining whether the composition is 50/50, 75/25, or 25/75 depending on the competency analysis to be produced, subject objectives, student characteristics, face-to-face interactions, online learning delivery strategies or a combination, features, learner location, characteristics and teaching capabilities, and available resources (Cheng et al., 2023; Guo and Jin, 2023; Wang et al., 2023). The teacher can determine the most appropriate learning composition (presentation) based on the cross-analysis of these various considerations (Jossan et al., 2021). However, the main concern in designing learning composition is the provision of learning resources suitable for various characteristics of students so that they can learn more effectively, efficiently, and interestingly. In the following learning scenario, of course, you must decide for which purposes face-to-face learning is carried out and which parts are offline and online.

The learning phases of Hybrid Learning refer to direct learning, which consists of the planning, implementation, and assessment stages (Pedaste et al., 2015). The implementation phase consists of the introduction, core, and closing (Abdullah and Zakaria, 2013; Soler et al., 2017). Direct and hybrid learning differ in the main or core learning phases (Bosica et al., 2021; Bygstad et al., 2022). The difference is that in direct learning, information is transferred by the teacher directly face-to-face in class (Kusumawati, 2020; Murad et al., 2020). In hybrid learning, the teacher's information is transmitted directly in class and delivered directly through information technology networks (Gounden et al., 2015; Xu et al., 2021). Face-to-face using information technology can be designed online or delay the structure. Hybrid Learning needs to be planned, implemented, and evaluated to get learning outcomes as expected (Olsson et al., 2013; Rademaker et al., 2021).

The ability to implement hybrid learning depends on a number of factors, including the availability of certain resources and infrastructure, such as an internet network, as well as the professional development of teachers in using ICT. Additionally, students must have the necessary skills to use computers and the internet (Genlott and Grönlund, 2016; Letchumanan et al., 2020; Mardhatillah, 2020). Hybrid Learning is also often called blended learning, which, in principle, takes advantage of the strengths of face-to-face and online learning while covering the weaknesses in each learning (Basogain et al., 2018; Boelens et al., 2018; Naidoo and Singh-Pillay, 2020).

Based on the description of the background above, the formulation of the problem in this study can be broken down as follows: 1) Students' mastery of HOTS is still low; 2) Various components of preparation for implementing hybrid learning are inadequate; 3) The available learning tools have not fully accommodated the needs of hybrid learning, including the need for media availability that is in accordance with the hybrid learning mode of learning; 4) The availability of learning media based on Augmented Reality is inadequate. In general, the media used in learning is only limited to media that meets the needs of the material content. In this case, it still needs to be fully ready for hybrid learning.

This study was limited to grade 8 junior high school students with an average age of 13 years. The material is also limited to Geometry concepts, mainly geometric shapes. While the objectives of this research include:

1. Knowing the results of testing the effectiveness of using AR applications to support learning Geometry in the hybrid learning process on higher order thinking skills of middle school students.
2. Describe AR products as a support for learning Geometry in the hybrid learning process for higher order thinking skills of middle school students.

2. Method

2.1. Research design

This study uses a sequential mixed method with a combination of quantitative and qualitative methods sequentially (Creswell and Creswell, 2017). The first stage was carried out using quantitative methods to obtain measurable data. The second stage used qualitative methods to explore the findings obtained from the first stage. Fig. 1 describes the stages of conducting the research.

2.2. Population and research sample

The population of this study was all junior high school students, grade 8, in the city of Serang, Banten, Indonesia. The research was conducted in 2022. The entire population consists of 200 students divided into five classes with the distribution according to Table 1.

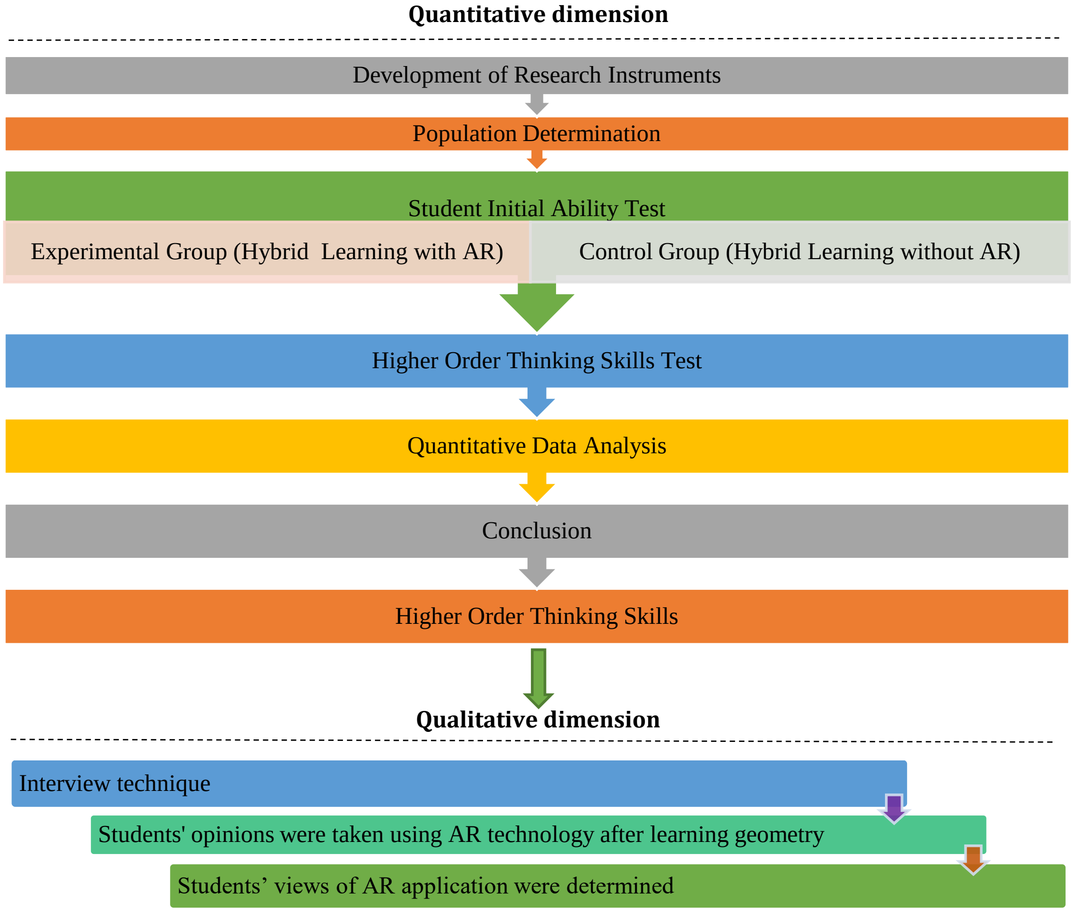


Fig. 1: Research method

Table 1: Distribution of the study population

Class	A	B	C	D	E
Number of students	39	41	41	40	39

The placement of students in the class is not determined based on certain rules. Students are free to choose a class according to the capacity provided. This independent placement has implications for the absence of superior-inferior classes in terms of academic ability. The research sample was selected using the cluster random sampling technique to determine one experimental and one control class. Of the five available classes, one was selected as the experimental class and 1 class as the control class. Furthermore, the experimental class received lectures on hybrid learning with AR, and the control class received lectures on hybrid learning without AR.

2.3. Research instruments

In order to gather information on students' happiness with utilizing AR, this research employed tools, including observation sheets and examinations of higher order thinking abilities on evaluation sheets for ideas in geometry. Ten essay questions that were designed have been included on the HOTS evaluation form. The instrument was evaluated for validity, discriminating power, difficulty, and dependability index before being employed in the research class. The experiment was run in one class with 40 pupils.

2.4. Validity of question items

The validity of the items from a test is the accuracy of measuring what an item owns in measuring what should be measured through the item. An item is said to be valid if it has great support for the total score. Following are the results of testing the validity of the test items for students' initial abilities, the results of which are presented in Table 2.

2.5. Reliability

Reliability refers to the consistency of scores the same person achieves when tested again with the same test on other occasions. To test the reliability of the test using the Alpha formula. Based on these calculations, the question reliability index was obtained at 0.753. If the questions that do not meet the good validity criteria, namely number 9, are omitted, then a reliability index of 0.785 is obtained and meets the high category reliability criteria.

Table 2: Results of testing the validity of items testing students' initial ability

Number	1	2	3	4	5	6	7	8	9	10
Validity index	0.534	0.513	0.442	0.458	0.427	0.467	0.407	0.406	-0.102	0.484
Criteria	V	V	V	V	V	V	V	V	I	V

V: Valid; I: Invalid

2.6. Difficulty level

Analysis of the difficulty level is intended to determine whether the question is classified as easy or difficult. The difficulty level is a number that indicates how difficult or easy a question is. The calculation results are presented in Table 3.

Table 3: Results of testing the difficulty level of items testing students' initial ability

Number	1	2	3	4	5	6	7	8	9	10
Difficulty index	0.87	0.67	0.65	0.25	0.83	0.87	0.85	0.57	0.83	0.23
Criteria	E	M	M	D	E	E	E	M	E	D

D: Difficult; M: Moderate; E: Easy

2.7. Discriminatory power

A question's capacity to discriminate between pupils with high capabilities and those with poor abilities is referred to as its discriminating power. Table 4 displays the results of the different power criterion calculations.

Table 4: Results of the test of discriminatory power items on students' initial ability trial

Number	1	2	3	4	5	6	7	8	9	10
Discriminatory power index	0.22	0.59	0.43	0.59	0.27	0.22	0.22	0.54	0.13	0.43
Criteria	En	G	G	G	En	En	En	G	B	G

G: Good; En: Enough; B: Bad

Based on the consideration of validity, difference in power, difficulty level, and reliability index, they chose nine items, namely numbers 1, 2, 3, 4, 5, 6, 7, 8, and 10. The nine items have a Cronbach's Alpha reliability index of 0.797. Furthermore, the initial ability test instruments were given in the experimental and control classes. The initial ability test results were used as the basis for the two research classes and for grouping students' initial abilities into high, medium, and low categories in the two research classes.

2.8. Quantitative stage

One group served as the experimental group and the other as the control group throughout the initial study phase. There were 82 junior high school students from two classes that participated in this study. A class of 41 students was divided into an experimental group and given a hybrid learning system with augmented reality as their teacher. The control group is another class of 41 students, which learns with hybrid learning without AR. The difference between the N-gains (posttest-pretest scores) of the experimental group and the control group was used to calculate the impact of the experimental therapy. N-gain should look like this (Hake, 1998):

$$N - gain = \frac{S_{Post} - S_{Pre}}{S_{Max} - S_{Pre}} \quad (1)$$

where,

$N - g$ = N-gain
S_{pos} = Posttest score
S_{pre} = Pretest score
S_{maks} = Maximum score

The average N-gain is derived by dividing the sum of each person's N-gains by the total number of people, where Equation 1 represents the individual N-gain. In Table 5, the N-gain interpretation is shown.

Table 5: Interpretation of N-gain values

N-gain score	Criteria
g ≥ 0.7	High
0.7 ≤ g ≤0.3	Moderate
g < 0.3	Low

The two group pretest-posttest methodology was employed in this study, which also used a quantitative research methodology. Fig. 2 shows the flow of how the research was conducted (Gall et al., 2003).

Before engaging in any learning activities, students were asked to assess their implementation competency at the beginning of the meeting. They also take a pretest to gauge their understanding of the fundamentals of geometry. In hybrid learning classrooms, every student takes part in the learning activities. They must watch the pre-class videos and do the homework assignments at home. As a result, the experimental group's pupils learn through in-class conversation and the Augmented Reality operational guidance system. In contrast, the instructor assisted the control group's pupils in completing worksheets and discussing them in class. Students have 210 minutes over the course of two weeks to complete their learning tasks. The identical educational materials, including images and videos, were used by both groups. Additionally, the educational material that the instructor delivers is the same material that the Augmented Reality guiding system uses.

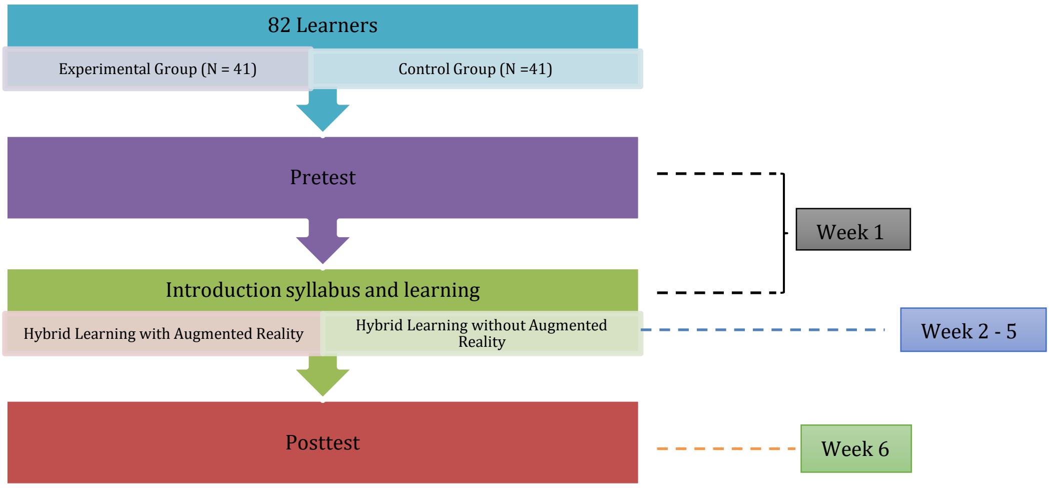


Fig. 2: Quantitative dimension design

2.9. Qualitative stage

2.9.1. AR application usage observation sheet

An observation activity to document specifics of the abilities utilized throughout the learning activities in the experimental class is the usage of the AR application observation sheet. At this point, observations are made on the gaps and challenges that still exist when using augmented reality for hybrid learning of geometry concepts. The observation sheet is a checklist that will be completed by the observer throughout the learning session. The observation sheet includes markers of competence in watching, categorizing, and interpreting when using AR apps. In this study, data were collected from four groups by two observers as they observed. Two groups will be observed by each observer.

2.9.2. Interview

The interview instrument in this study was conducted on students. The interviews aimed to obtain an overview of students' motivation to learn about hybrid learning with augmented reality in Geometry concepts.

3. Results and discussion

The comparison results from the N-gain pretest for the experimental and control groups in hybrid learning with Geometry concepts can be seen in Fig. 3.

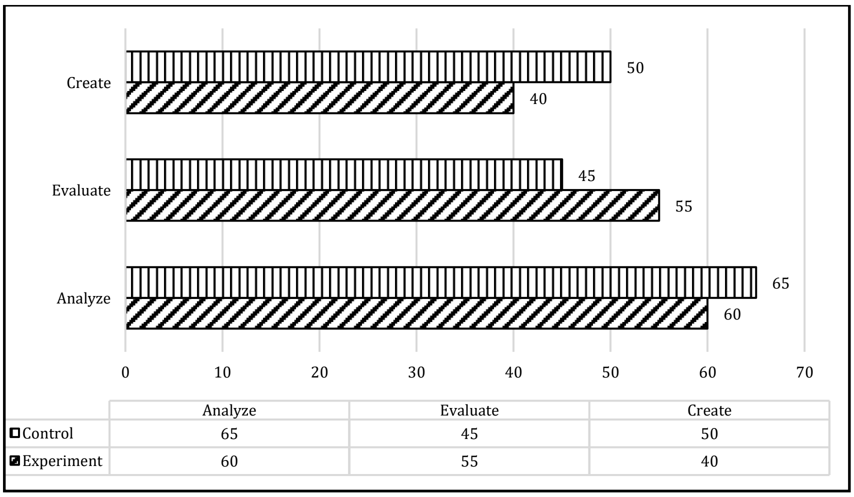
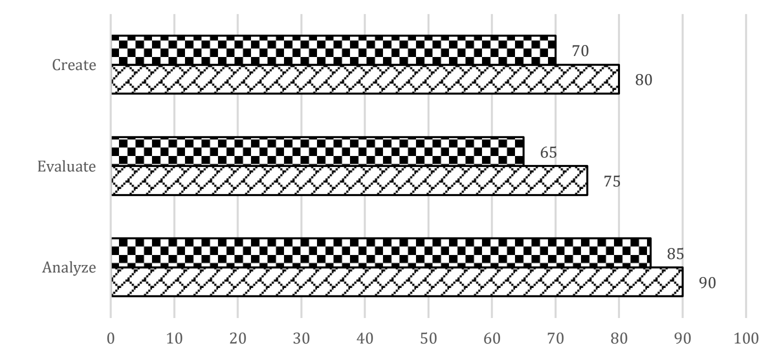


Fig. 3: Pretest data from hybrid learning

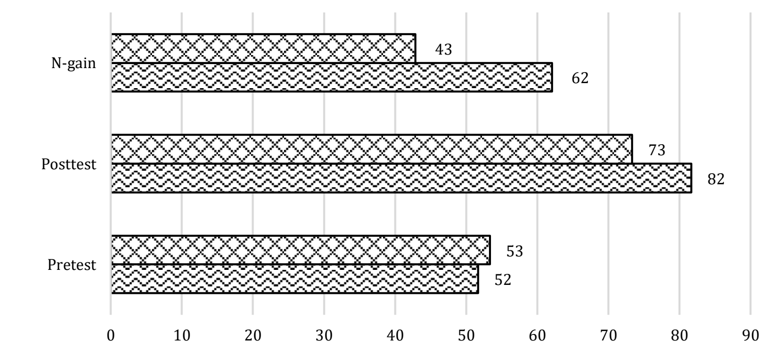
The average outcomes for each experimental and control class are displayed in Fig. 3. Prior to receiving the hybrid learning approach, the pretest was administered at the beginning of the learning process. Additionally, the posttest results from the hybrid learning approach are shown in Fig. 4.

A change in value following hybrid learning is seen in Fig. 4. The taught geometry idea is beginning to make sense to the kids. Although there have been more changes in the two classes' values, there are still discrepancies between the experimental and control classes. As opposed to the control class, which received hybrid learning without augmented reality, the experimental class received treatment utilizing hybrid learning with augmented reality. Additionally, students in junior high school who participated in hybrid learning with and without augmented reality therapy may view the overall outcomes of N-gain higher order thinking skills in Fig. 5.



	Analyze	Evaluate	Create
Control	85	65	70
Experiment	90	75	80

Fig. 4: Posttest data from hybrid learning

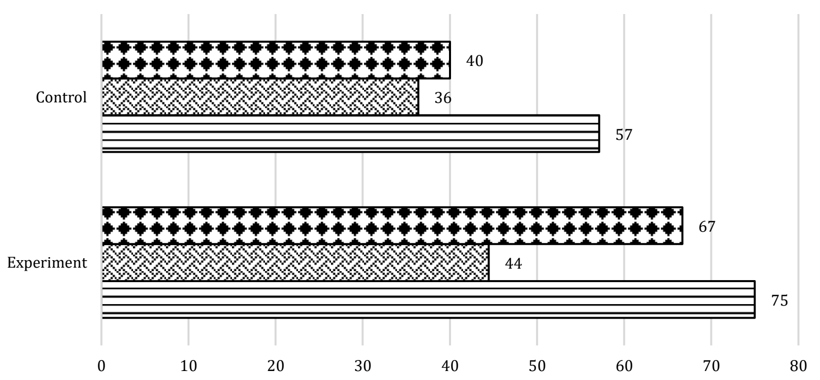


	Pretest	Posttest	N-gain
Control	53	73	43
Experiment	52	82	62

Fig. 5: N-gain HOTS from hybrid learning with and without augmented reality

Fig. 5 illustrates the HOTS N-Gain findings for hybrid learning with and without augmented reality, which are both 0.62 and 0.43, respectively. This suggests that HOTS students who benefit from augmented reality-hybrid learning are in the moderate range. This medium category demonstrates how hybrid learning may be successful without augmented reality. To increase higher order thinking abilities (HOTS), hybrid learning with augmented reality is more comprehensive and comparably successful than hybrid learning without augmented reality, according to the N-Gain results. The learning process is made more student-centered via hybrid learning using augmented reality. In order to assess how well students have understood the Geometry ideas covered, instructors can adjust the content and scope of the learning material by utilizing hybrid learning with augmented reality. Furthermore, Fig. 6 displays the outcomes for each HOTS component.

Based on the findings in Fig. 6, students' HOTS may be raised by teaching geometry using a hybrid learning approach that incorporates augmented reality. The N-gain at the analysis stage was 75%, or 0.75. The analytical aspect 0.75 falls under the high group based on the N-gain results. The hybrid learning sans augmented reality treatment, which got an N-gain value of 57% or 0.57, had a different outcome. The medium category is shown in these results. One may argue that augmented reality and hybrid learning help pupils analyze properly. A fact, concept, opinion, assumption, hypothesis, or conclusion can be broken down into its component parts or pieces and examined to determine if there are any conflicts during the analysis step (Saadé et al., 2012; Tsybulsky and Muchnik-Rozanov, 2019). The analysis places a strong emphasis on describing the primary content in order to identify the connections between each section that is ordered methodically (Scott et al., 2018; Mallawaarachchi et al., 2023). By dissecting the content into its component pieces, they are analyzing it and explaining how those elements interact with one another, form an overall structure, or serve a particular function. At this point, students can demonstrate the connections between different concepts by contrasting them with standards, guidelines, or practices that have been examined. In addition, students' analytical abilities have improved, enabling them to creatively apply geometry concepts to novel contexts. According to the findings of previous research, analytical ability is the capacity to dissect a subject into its component components and relate them together in order to comprehend the concepts.



	Experiment	Control
Create	67	40
Evaluate	44	36
Analyze	75	57

Fig. 6: N-gain HOTS for each indicator

In addition, the evaluation of the N-gain from hybrid learning with augmented reality yielded a value of 44%, or 0.44. These findings suggest that the capacity for conclusion belongs to the adequate group. The N-gain assessment findings for hybrid learning without augmented reality, however, were 36% or 0.36. These findings suggest that the category of evaluative ability is medium. These findings imply that augmented reality-enhanced hybrid learning can improve students' assessment skills more than traditional hybrid learning. Making choices based on established criteria is what is meant by assessing at this point. The cognitive processes of analyzing and critiquing judgments produced in accordance with criteria are included in the evaluating category (Mamun et al., 2020; Strasser et al., 2021). Here, the term "ability to evaluate" refers to pupils' capacity to make accurate assumptions or judgments in light of the circumstances or body of knowledge at hand. Students can evaluate the techniques and answers employed at this evaluation stage, critique the work procedures, and retest a number of questions on the principles of geometry.

It receives a 67% or 0.67 value at the generate N-gain stage from hybrid learning with augmented reality. The capacity to produce falls into the medium group according to the N-gain statistics. This middle category, which is 40% or 0.4, is likewise achieved through hybrid learning without augmented reality. Students can develop solutions to issues, generalize ideas or perspectives, and arrange components into previously unimagined structures based on these findings. Students can combine work steps into a new unit, develop work processes, and find or explain solutions to a number of questions during the creation stage. The capacity to blend materials to create a singular structure is known as creativity (Mamun et al., 2020). A creative person can come up with several answers to a problem, design a solution, or create something entirely new (Howe and Xu, 2013; Kulikovskikh et al., 2017). This is because students need a more authentic atmosphere. After all, AR is only limited to Maya's (pseudo) vision. Furthermore, the results from the qualitative dimension, namely on the observation sheet, show that students can analyze, evaluate, and create from the learning process. In hybrid learning with augmented reality, teachers can create a positive learning environment and empower students to realize effective and innovative classroom management to produce students with HOTS abilities.

An essential part of learning is hybrid learning using augmented reality. The findings of the observation sheet demonstrate the benefits of using hybrid learning with augmented reality, including the following: a) hybrid learning with augmented reality is very helpful in the learning process so that learning objectives are more easily achieved; b) hybrid learning with augmented reality can provide helpful information for students in the learning process; c) hybrid learning with augmented reality can provide student learning motivation, avoid boredom, and will increase student engagement.

Hybrid learning with augmented reality can help clarify procedures, relationships, and the overall state of what is being designed. Furthermore, the advantages of hybrid learning with augmented reality include:

a) Clarify the functional relationship between a particular system's various components, elements, or elements.
b) The procedures to be followed in carrying out activities can be identified precisely.
c) With the existence of hybrid learning with augmented reality, the various activities it covers can be controlled.
d) If the activities are ineffective and unproductive, Hybrid learning with augmented reality will make it easier for educators to identify component elements that experience obstacles.
e) Identifying ways to make changes if the opinion needs to follow what has been formulated.

f) Using hybrid learning with augmented reality, educators can organize student assignments into an integrated whole.

Hybrid learning with augmented reality is a determining factor in the success of the learning process. Augmented reality applications can stimulate teachers to think about pedagogical strategies. This is also in line with the research results showing that the effectiveness of using AR applications guided by educators can activate student learning. Furthermore, identifying learners' learning styles can be an initial guide in developing a more effective and conducive learning-teaching environment for learning higher order thinking skills.

Then, the results of interviewing students on their learning motivation in hybrid learning with augmented reality can be seen in Table 6.

Table 6: Results of students' motivation toward hybrid learning with augmented reality

No	Statements	Response (%)	
		Yes	No
1	I like hybrid learning with augmented reality	87	13
2	The incentive expressed arouses interest in learning	84	16
3	The process of hybrid learning with augmented reality adds enthusiasm to learning	88	12
4	There is an update on learning activities, teaching materials, learning media, and learning atmosphere using hybrid learning with augmented reality	93	7
5	Hybrid learning with augmented reality makes me more independent in learning activities	90	10
6	Activities combining hybrid learning and augmented reality are of interest to me	92	8

The high motivation of students toward hybrid learning with augmented reality will facilitate the learning process. The learning process using Augmented Reality can increase enthusiasm for learning. Hybrid learning with augmented reality can make students learn independently to explore their respective abilities later.

The quantitative dimension data states that students are happy with hybrid learning with augmented reality. The reason students expressed joy, motivation, and enthusiasm was that students better understood the concept of Geometry by using hybrid learning with augmented reality. Students are allowed to discuss, ask questions, and criticize the work of others; the learning atmosphere is fun, and they happily respond to student questions. This result is also in line with the results of other studies that use augmented reality applications to be an essential factor in the success of the learning process (Joo-Nagata et al., 2017; Yang et al., 2023).

4. Conclusion

The results showed that students who studied geometry using hybrid learning with augmented reality (experimental group) performed better in higher order thinking skills when compared to students who studied geometry using hybrid learning without augmented reality (control group). Overall, it was discovered that students in the experimental group were more successful than those in the control group despite the fact that both student groups demonstrated week-to-week gains in their success scores. In addition, after four weeks of study, students in the experimental group understood analysis, evaluation, and creation better than those in the control group. Higher order thinking skill scores were found to be significantly lower in the control group than in the experimental group. These scores were below average as compared to those obtained during the initial weeks of implementation. The experimental group's students were shown to be more passionate about learning than those in the control group. At the conclusion of the implementation, interviews with students in the experimental group produced findings that corroborated the study's conclusions. The students expressed the following opinions: that augmented reality applications made geometry concepts more enjoyable and exciting, that this increased learning motivation for geometry concepts, and that students wanted to use augmented reality tools on other materials. Finally, students in the experimental group experienced satisfaction in participating in augmented reality activities. The interview results also concluded that students were relaxed about using augmented reality applications.

Based on the research results, the suggestions for further research development are as follows:

1. The effect of using hybrid learning with augmented reality at different school grade levels should be investigated further by extending this research to other classes.
2. This research focuses on higher order thinking skills as skills that must be possessed in the 2013 curriculum in Indonesia. This capability needs to be expanded on other aspects.
3. A mixed model was used to create this study. To get more detailed data, future studies should concentrate on either the qualitative or quantitative components. In this study, the demographic traits of pupils have not yet been examined. Future studies might compare student success rates by looking at factors like gender, learning styles, and socioeconomic status among students.
4. The concept used is only geometry concepts, so it needs to be done on other concepts.

Acknowledgment

We thank the Institute for Research and Community Service, Sultan Ageng Tirtayasa University (LPPM Untirta), for providing research grants under the Professorship Acceleration Program (PPGB) scheme.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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