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# Use of augmented reality learning media to improve higher-order thinking skills in kinematics material

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Learning Media; Augmented Reality; Higher Order Thinking Skills; Kinematics;

**Abstract**

This study aims to analyze the effect of using augmented reality (AR) on higher-order thinking skills of high school students in kinematics material. In addition, students' opinions about this application were examined. The research method used is a mixed method with The Embedded Design model. The population in this study were all 11th-grade students, totaling 200 students divided into five classes. Furthermore, the sample was selected by purposive sampling of 80 students from grade 11 of SMAN 4 Kota Serang. This study will be divided into two, namely, the experimental class and the control class. The experimental class used AR applications during kinematics learning activities, while the traditional method was used for the control class, namely, not using AR applications during kinematics learning activities. The results show that students have higher-order thinking skills than the control group. This result is proven by the N-Gain value, namely in the experimental class; the AR application learning process has an N-Gain value of 0.69. In the control class, the learning process without using the AR application has an N-Gain value of 0.48. The students who participated in AR learning stated that they were motivated and felt happy learning kinematics. The implications of this study indicate that using AR applications is considered effective as a medium for learning kinematics material.

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## Introduction

Kinematics is a branch of physics that studies the basic concepts of mechanics to understand further physics concepts (Araujo et al., 2008). The causes of the difficulties students experience when studying kinematics concepts, namely when visualizing them in real life (Hasanah, 2020). Kinematics material will be more difficult when the learning topic discusses abstract concepts and cannot be observed by the unaided eye. Kinematics material is considered abstract because it can only be visualized through a particular picture or diagram. Therefore, to help students understand kinematics material, learning activities can use technological developments to help visualize things that cannot be observed directly to improve students' higher-order thinking skills.

Higher-order thinking skills (HOTS) are characterized as a person's high-level considering abilities (Haryadi & Pujiastuti, 2022a). HOTS makes a individual or person investigate unused data and after that connect it to the data he has found and put away in his memory, which at that point creates this data to fathom an existing issue (Heni Pujiastuti & Haryadi, 2023b). HOTS is closely related to considering aptitudes concurring to the cognitive, full of feeling, and psychomotor spaces, which are fundamentally to the educating and learning prepare (Haryadi et al., 2021). Learning targets on the cognitive perspective concurring to the bloom level is separated into Low Order Thinking Skills (LOTS) and High Order Thinking Skills (HOTS). Where Parcels incorporates recollecting, understanding, and applying. In the interim, HOTS gives investigation, assessment, and creation (Krathwohl, 2002). HOTS gets to be a procedure for higher-order thinking with students encouraged to form data and concepts in ways that make sense to understudies (Jansen & Möller, 2022; Weinberger & Zohar, 2005). HOTS can persuade understudies to look for data and interest freely by connecting it to existing realities in fathoming issues (H. Huang et al., 2022). Through HOTS, understudies can increment their considering action (Yang, 2015). HOTS can be utilized to make strides and keep up students' capacity to fathom issues (Lee & Choi, 2017).

HOTS is the same as LOTS which is a learning technique or method that is now starting to be implemented in Indonesian schools. LOTS only explore the ability to remember, understand, and apply the material taught by students. While HOTS includes the ability to solve problems, the ability to think creatively, the ability to think critically, the ability to argue, and the ability to make decisions. HOTS is very important, the skill to connect, manipulate, and transform existing knowledge and experience critically and creatively to make decisions in solving problems in new situations (Sinclair et al., 2004). HOTS could be a metacognitive handle that can instruct students how to utilize perception and idea-generation strategies in considering (Y.-M. Huang et al., 2022). The development of learning media technology that has developed great potential in the world of education has changed the way a person learns, obtains information, adapts information, and so on. Educational media improves education quality and is very important in the teaching and learning process. Interactive learning media, as one of the educational media, is learning that uses information and communication technology that makes it easier for an educator to convey material or information to students. Interactive learning media can facilitate an educator in developing learning techniques to produce maximum results. Interactive media can improve the teaching and learning process, which previously only used books and lectures. An educator can be creative in making the teaching and learning process fun. Likewise, for students, with interactive media, it is hoped that they will find it easier to absorb information quickly and efficiently.

Global demands require the world of education to always adapt technological developments to efforts to improve the quality of education, especially adjustments to the use of information and communication technology for the world of education, especially in the learning process. This increasingly rapid technological development is utilized in such a way as to support the learning process, one of which is Android technology using Augmented Reality.

Augmented Reality (AR) is a technology that can incorporate virtual objects in two or three dimensions into a real environment and then displays and projects them in real-time (Eder et al., 2020; Pilati et al., 2020; Sorko et al., 2020). AR is a technology that incorporates virtual objects, both 2D and 3D, into a real environment and then projects these virtual objects in real-time (Lindner et al., 2019; Martín-Gutiérrez et al., 2015). Augmented Reality is a combination of real and virtual objects in a real environment, runs interactively in real-time, and there is integration between objects in three dimensions: virtual objects are integrated into the real world (Oranç & Küntay, 2019; Vargas et al., 2020; Vorraber et al., 2020). Augmented Reality can also be said to have the following characteristics: combining real and virtual environments, running interactively in real-time, and integrating into three dimensions (3D) (Iftene & Trandabăt, 2018; van Lopik et al., 2020; Zheng et al., 2020).

AR aims to take the real world as a basis by combining several virtual technologies and adding contextual data to clarify the understanding of humans as users. This contextual data can be audio commentary, location data, historical context, or other forms. At this time, AR has been widely used in various fields such as medicine, military, manufacturing, entertainment, museums, educational games, education, and others (Masood & Egger, 2019).

In making AR, several important components needed in the manufacture and development of AR applications are as follows (Mota et al., 2018; Thees et al., 2020; Yip et al., 2019):

1) Computer functions as a device that controls all processes in an application. This computer is adjusted to the conditions of the application to be used. Then the application output will be displayed through the monitor or cellphone screen.
2) Marker serves as an image (image) that will be used by the computer for the tracking process when the application is used. The computer will recognize the position and orientation of the marker and will create virtual objects in the form of 3D objects.
3) Camera is a device that functions as a recording sensor. The camera is connected to the computer and will process the image captured by the camera. If the camera captures an image that contains a marker, the application on the computer will recognize the marker. Then the computer will calculate the position and distance of the marker. Then, the computer will display a 3D object above the marker.

In general, AR functions to visualize an object simultaneously (real-time). More specifically, the AR functions are as follows: (1) combining physical objects and digital interfaces, (2) creating manipulations of virtual object models (Escalada-Hernández et al., 2019). The AR work scheme lies in the video or camera used in AR applications to capture image markers that are identified first. After the position and orientation of the marker are detected, the calculation results are entered into the matrix. This matrix is then used to determine the virtual camera relative to the marker.

Based on some of the definitions above, it can be said that augmented reality is a technology that can combine virtual objects as if they were real, or 2-dimensional objects are transformed into 3-dimensional ones. Augmented Reality (AR) is not new in the world of technology. This technology has grown rapidly due to its attractive use and ease of activity for users.

Abstract concepts in an object model can be visualized using AR technology to help improve user understanding of these abstract objects. Augmented Reality technology can be used to help clarify the delivery of material in the learning process. Using Augmented Reality technology, abstract objects that cannot be observed with the unaided eye can be visualized into three-dimensional objects that look more real (Nithin & Bhooshan, 2016). It is hoped that it can increase students' higher-order thinking skills and positively affect student learning motivation.

Using technology in learning activities is expected to help students more easily understand kinematics material because by utilizing technology, learning activities can be designed to be interesting and fun learning for students to increase learning motivation and make students not easily bored when learning activities are in progress. Technology is also expected to improve the quality of learning and motivate students to improve their higher-order thinking skills (Baylor & Ritchie, 2002).

Based on preliminary research results through interviews with one of the physics teachers at school, it was shown that physics learning activities on kinematics material in class only used textbooks and student worksheets provided by the school. Even if you only rely on textbooks and LKS, the learning activities are considered less effective because they seem monotonous and boring for students. Therefore, innovations are needed to improve students' higher-order thinking skills, one of which is by utilizing Augmented Reality technology in the kinematics learning process.

Several studies in education have also been conducted and have shown positive results that Augmented Reality technology can be appropriately applied in the physics learning process (Haryadi & Pujiastuti, 2022b). The results of other studies show that learning media based on augmented reality technology influences the concept of food security (H Pujiastuti & Haryadi, 2020). Then other research shows increased student learning outcomes in mathematics learning based on augmented reality technology (Heni Pujiastuti & Haryadi, 2023a). The results of further research indicate that the developed augmented reality-based learning media can improve understanding of the earth and natural science material (Lindner et al., 2019). Based on the problems and research results of SMAN 4 Kota Serang, this study explains how much influence augmented reality applications have in learning Kinematics to improve students' higher-order thinking skills.

## Method

### 1. Research Design

The research design uses mixed methods with the embedded design model, whereas the quantitative research method is used as the primary method in this model. The qualitative research method is used as a secondary method, meaning that the combination of quantitative research methods and qualitative research methods focuses more on one research method, which is used as the primary method (which has a higher weight) than the second method (which has a complementary weight). The embedded design model's purpose is to collect data simultaneously or sequentially. Still, there is a link between qualitative data which acts as a secondary method in supporting and complementing quantitative data, which acts as a primary method. The stages of conducting research can be described in Figure 1 (Creswell, 2013).

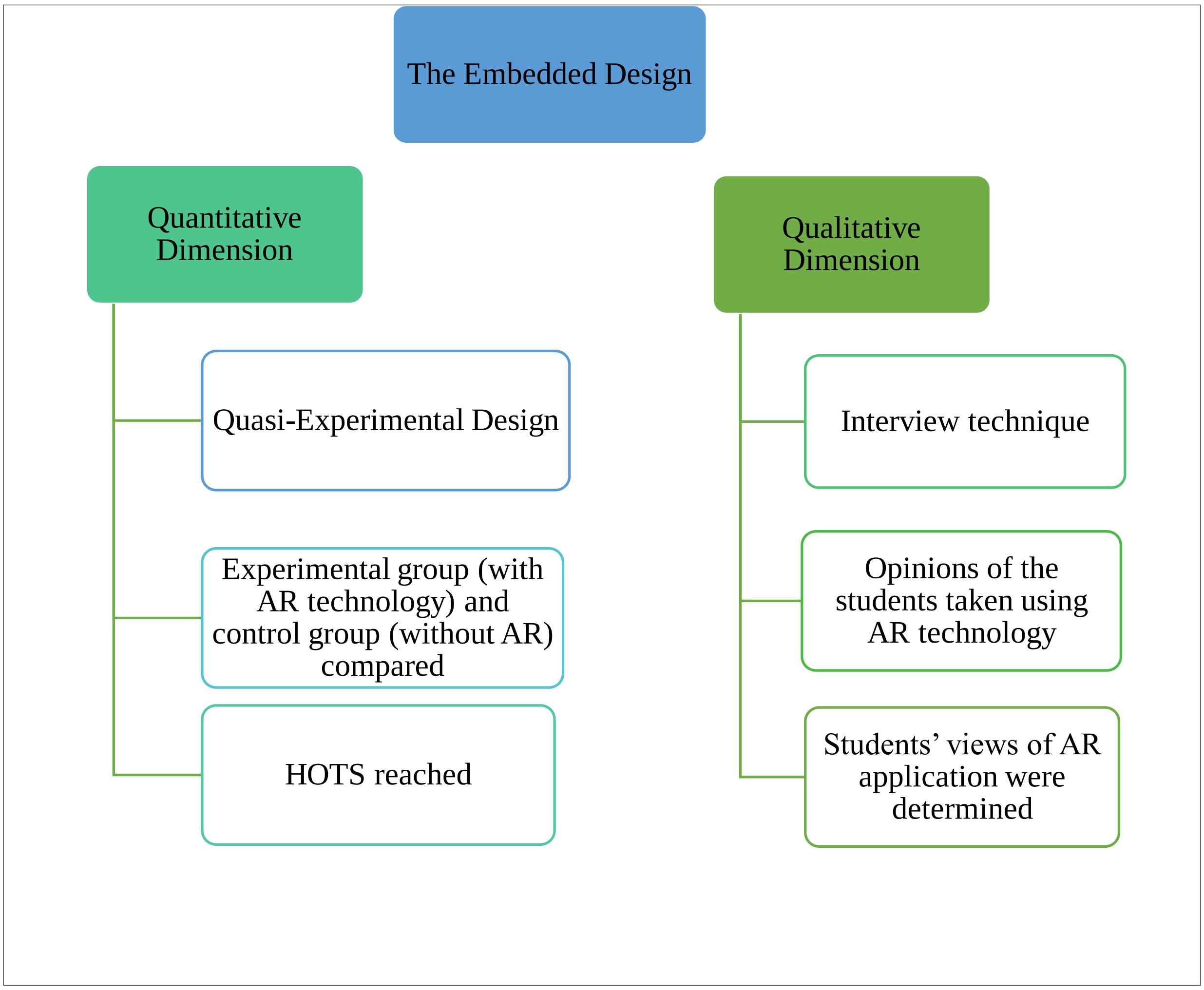



**Figure 1.** Research Method

The following describes the stages of the research design carried out. In the first week, pretest questions were carried out in the experimental and control classes. The results of the pretest are to determine students' initial abilities towards higher-order thinking skills in the kinematics material to be studied. Then in the second week until the fifth week, it is continued by giving treatment in the form of learning using augmented reality in the experimental class and giving treatment in the form of learning without using augmented reality in the control class. After the treatment, in the sixth week, they gave posttest questions to determine the effect on students' higher-order thinking skills. They gave a questionnaire to determine students' responses to using augmented reality applications implemented in learning activities.

## 2. Population and Research Sample

The population used in this study were 11$^{th}$-grade students at a senior high school in Serang City for the 2021-2022 academic year. The research sample comprised 80 students from grade 11 of SMAN 4 Kota Serang. The students share a similar cultural and technological profile. Students have never seen or used AR technology before. The sample in this study was taken freely according to the needs and design of this study, and the sample consisted of two classes. One class was given learning treatment using AR to function as an experimental class, and the other class did not receive treatment and functioned as a control class.

## 3. Research Instruments

This study used instruments of higher-order thinking skills assessment sheet tests on Kinematics material and observation sheets to obtain data on students' learning motivation in AR. On the HOTS assessment sheet, ten essay questions have been developed. Before being used in the research class, the instrument was first tested to determine the level of validity, discriminatory power, difficulty level, and reliability index. The trial was conducted in 1 class of 40 students, and the results met the requirements.

## 4. Quantitative Stage

The first phase of the research was divided into two groups, one as the experimental group and one as the control group. The subjects of this study were 80 high school students from two classes. One class of 40 students was randomly assigned to an experimental group, and then they were given lessons using augmented reality. One other class of 40 students was the control group, which studied without augmented reality. N-gain (normalized gain) is used to measure the increase Higher-Order Thinking Skills between before and after learning Kinematics Materials. N-gain is formulated as follows (R.R. Hake, 1999; Richard R. Hake, 1998):

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

Information:

$N - g$ = N-gain

$S_{pos}$ = Posttest Score

$S_{pre}$ = Pretest Score

$S_{maks}$ = Ideal Maximum Score

Equation 1 is the individual N-gain, and the average N-gain is calculated by dividing everyone's N-gain amount by the number of individuals. N-gain interpretation consisted three categories including high ($g \geq 0{,}7$), moderate ($0{,}7 \leq g \leq 0{,}3$), and low ($g < 0{,}3$).

## 5. Qualitative Stage

a. AR Application Usage Observation Sheet

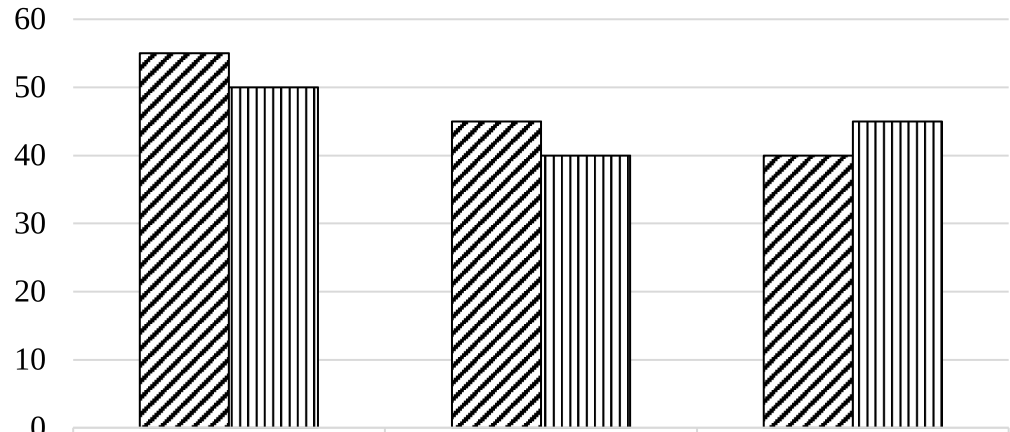
The observation sheet for using the AR application is an observation activity to record aspects of the skills used during the learning activities in the experimental class. The observation sheet used is 15 assessment aspects with a Likert scale of 1 to 4. The observer will fill in observation results during the learning activity. The observation sheet contains indicators of skills in using AR applications, namely observing, classifying, and interpreting. In this study, the observation was carried out by involving two observers by taking data from four groups. Each observer will observe two groups.

b. Interview

They are learning motivation data obtained through interviews. Interview activities are carried out to get information directly by asking questions between the interviewer and the interviewee. In fact, both can be carried out simultaneously, where interviews can be used to dig deeper into the data obtained from observations. In this case, the interviewees know and deeply understand the problems of student learning motivation. The object of the interview here is teachers and students at one of SMAN 4 Kota Serang, Banten.

**Results and Discussion**

In Figure 2, we can see the average results in each experimental and control class. The pretest is implemented at the beginning of learning before being given the learning process in class. Both classes need to become more familiar with augmented reality applications.




| | Analyze | Evaluate | Create |
|---|---|---|---|
| Experiment | 55 | 45 | 40 |
| Control | 50 | 40 | 45 |

**Figure 2.** Pretest Data

Furthermore, in Figure 3, the results of the posttest are obtained. When students are given posttest questions, they receive treatment (treatment) in learning so that they already understand the concepts of physics in kinematics material.

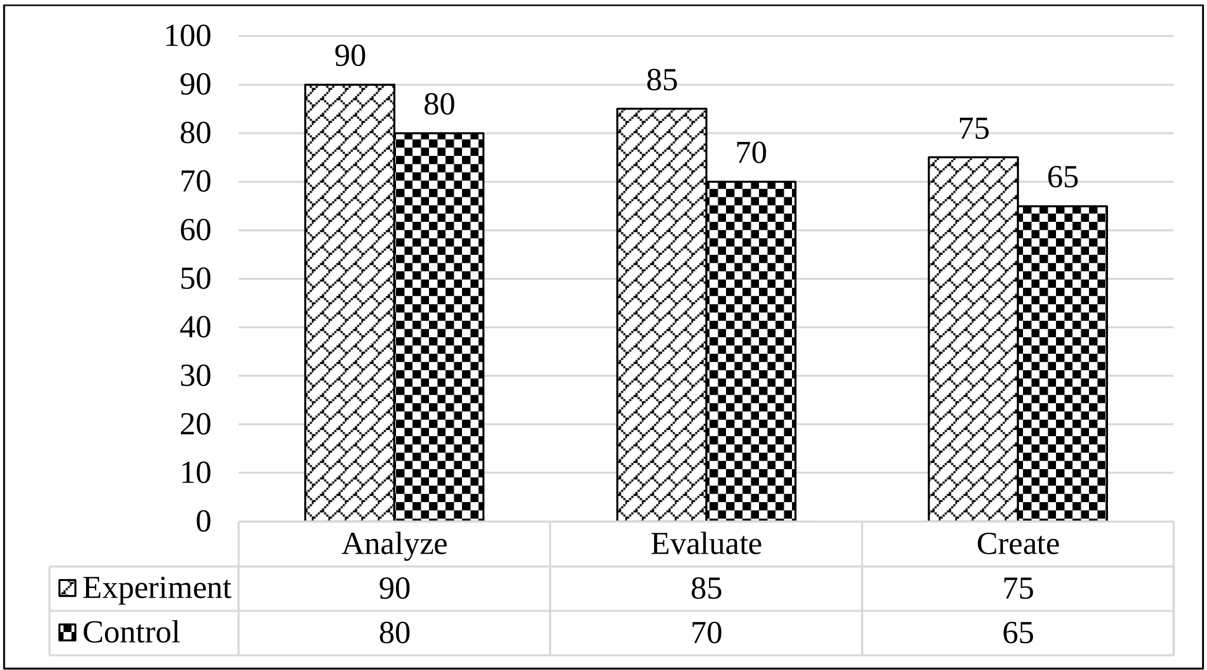



**Figure 3.** Posttest Data

In Figure 3, there is a change in value after getting the learning process (treatment). The students have started to understand the concepts of Kinematics that have been taught. Changes in the values of the two classes have increased, but of course, there are differences between the experimental and control classes. This happens because the experimental learning class uses augmented reality, while the control class gets learning without augmented reality. Furthermore, the overall results of high school students' N-gain higher-order thinking skills can be seen in Figure 4.

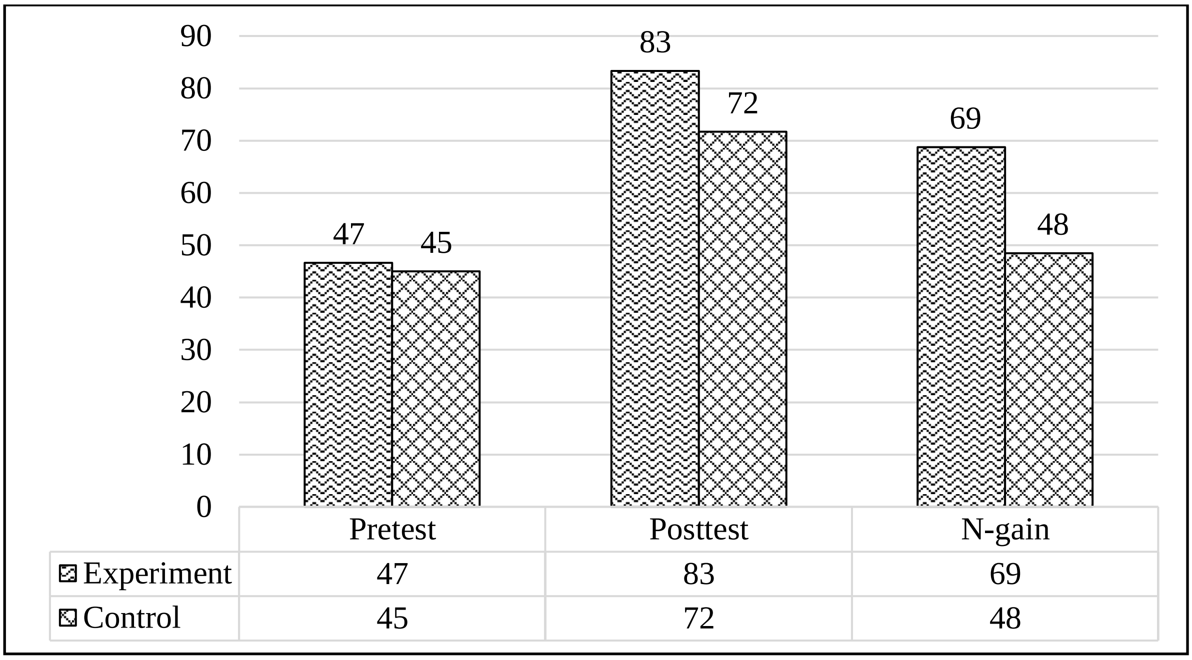
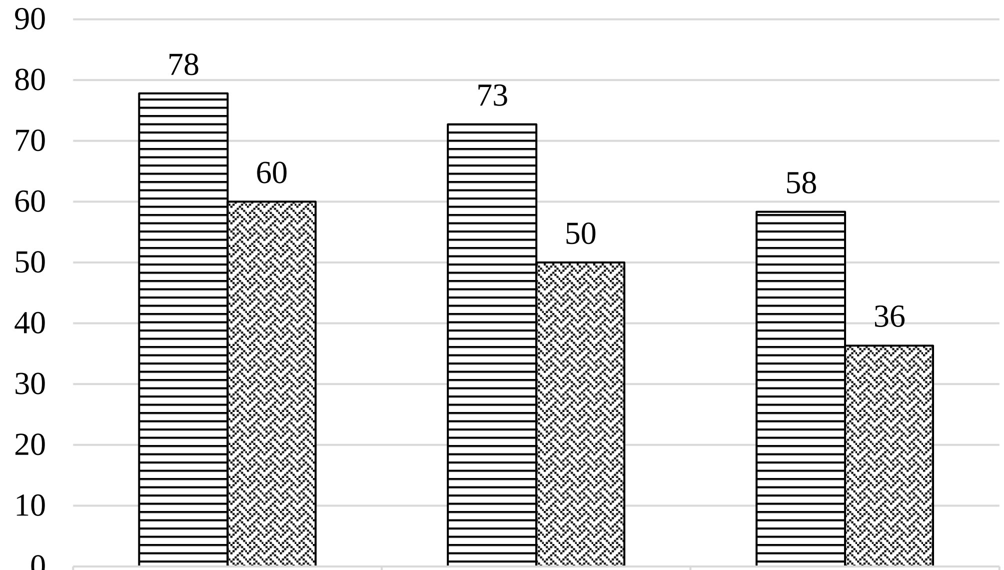



**Figure 4.** HOTS N-Gain data

Figure 4 shows that the HOTS N-Gain results from the learning process using the augmented reality application have values of 0.69 and 0.48. This indicates that HOTS students who get the learning process using augmented reality are in the moderate category. This medium category also shows that the learning process without using augmented reality gets the same category. However, based on the results of the N-Gain, the learning process using augmented reality is greater and effective for increasing higher-order thinking skills (HOTS) than the learning process without using augmented reality. Furthermore, the results of each HOTS aspect can be seen in Figure 5.




| | Analyze | Evaluate | Create |
|---|---|---|---|
| Experiment | 78 | 73 | 58 |
| Control | 60 | 50 | 36 |

**Figure 5.** N-gain HOTS for each indicator

Based on the results in Figure 5, the learning process using this augmented reality application can increase students' HOTS. At the analyze stage, the N-gain obtained is 78% or 0.78. Based on the N-gain results obtained, the analysis aspect of 0.78 is included in the high category. This result is different from the learning process without using augmented reality applications which obtain an N-gain value of 60% or 0.60. These results show the medium category. It can be said that the Kinematics learning process using augmented reality applications can make students analyze well. The analysis stage is the capacity to recognize, partitioned and separate the components or components of a reality, concept, supposition, suspicion, theory, or conclusion and look at each component to see whether there are inconsistencies. At this arrange, students can appear the relationship between different thoughts by comparing these thoughts with guidelines, standards, or methods that have been considered. The comes about of other thinks about moreover state that analytical ability may be a person's capacity to break down the material into parts and interface one portion to another so that he can know the material clearly (Lee & Choi, 2017; Lin et al., 2021; Yeh, 2012).

Furthermore, from the results of evaluating the N-gain obtained from the learning process using the augmented reality application, a value of 73% or 0.73 is obtained. These results indicate that the ability to conclude is in the high category. While the evaluation results of N-gain obtained from the learning process without using augmented reality applications obtain a value of 50% or 0.50. These results indicate that the ability to evaluate is in the medium category. These results indicate that the learning process using augmented reality applications can give students better evaluation abilities than the learning process without using augmented reality applications. At this evaluation stage, students can provide an assessment of the answers and methods used, criticize the work steps, and re-test several questions on kinematics material.

Then, at the create stage, the N-gain obtained from the learning process using the augmented reality application obtains a value of 58% or 0.58. From the results of the N-gain, the ability to create is included in the medium category. This medium category is also obtained from the learning process without using augmented reality applications, namely 36% or 0.36. From these comes about, students can generalize an thought or point of view on something, plan a way to unravel issues, and organize components or parts into modern structures that have never existed. At the make arrange, students can combine work steps into a unused unit, plan work strategies, and discover or portray answers in other shapes for a few questions.

Furthermore, in the qualitative dimension, the observations made in assessing the learning process using augmented reality applications can be seen in Table 1.

**Table 1**. The Results Of Learning Observations Using Augmented Reality

| No | Statement | Accomplishment (%) |
|---|---|---|
| 1 | Learning is done using augmented reality | 100 |
| 2 | Enthusiasm of students in participating in learning using augmented reality | 84 |
| 3 | Student interest in the media used | 88 |
| 4 | Students are orderly in learning using augmented reality | 93 |
| 5 | Enthusiasm of students in doing assignments on the augmented reality application from the teacher | 90 |

Next, the results of interviews with students regarding using augmented reality applications during the learning process occur. The following interview results can be seen in Table 2.

**Table 2**. Results of Student Interviews on Learning Using Augmented Reality

| No | Statement | Response (%) | |
|---|---|---|---|
| | | Yes | No |
| 1 | I like learning using augmented reality | 87 | 13 |
| 2 | The motivation conveyed inspires enthusiasm for learning. | 84 | 16 |

| | | | |
|---|---|---|---|
| 3 | The learning process using augmented reality adds enthusiasm to learning. | 88 | 12 |
| 4 | The learning atmosphere using augmented reality is very fun. | 93 | 7 |
| 5 | The learning process by using augmented reality makes me more independent. | 90 | 10 |
| 6 | I am interested in participating in learning activities with augmented reality. | 92 | 8 |

The high student response to Augmented Reality learning media will facilitate learning. The learning process using Augmented Reality can increase enthusiasm for learning. This Augmented Reality learning media can make students learn independently to explore their respective abilities later.

The student response data states that students are happy with Augmented Reality learning media. The reason students express joy, motivation, and enthusiasm is that students understand concepts better by using Augmented Reality learning media. By using or applying Augmented Reality learning media, students can discuss, ask questions, criticize the work of others, have a fun learning atmosphere, and be happy to respond to student questions. This result is also in line with the research results (Rahmat, 2019) that learning media is an important factor in the success of the learning process. Furthermore (Miarsyah, 2020) also said that the ultimate goal of the learning process depends on the learning model applied.

## Conclusion

Based on the results of the discussion above, the experimental class obtained an N-Gain score with high criteria and medium criteria. Therefore the N-Gain yield is higher. This significant increase was because students in the experimental class applied to learn using augmented reality. Meanwhile, if seen from the control class, the N-Gain values obtained by students are all moderate criteria. In the control class, there was an increase in students' higher-order thinking skills. Still, the N-Gain obtained was lower than in the experimental class. In other words, the increase in the results of students' higher-order thinking skills obtained by the control class was insignificant. This happened because the control class did not use augmented reality learning media.

Further research is needed to determine the effectiveness of the Augmented Reality application and its effect on student learning outcomes. It is recommended that further researchers research developing physics teaching materials using Augmented Reality technology for different materials according to school needs to enrich Augmented Reality technology-based teaching materials for physics subjects.

## Credit Authorship Contribution Statement

**Rudi Haryadi**: Conceptualization, Methodology, Software, Visualization, Formal analysis, Writing – original draft, Writing – review & editing. **Heni Pujiastuti**: Conceptualization, Methodology, Formal analysis, Resources, Writing – review & editing, Supervision, Project administration.

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