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The Effect of Discovery Learning Model Based on Augmented Reality Media on Students' Critical Thinking Skills

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Abstract
This study aims to examine the effect of the DINAR (Discovery Learning based on Augmented Reality) model on the critical thinking skills of grade V *Madrasah Ibtidaiyah* students on the material of human respiratory organs. The method used was quasi-experimental with a non-equivalent control group design, involving 48 students divided into experimental (DINAR learning) and control (conventional method) groups. This research was conducted at MIS Raudlatul Mutaallimin, Pakis, Bringin District, Semarang Regency. Data were collected through critical thinking tests based on analysis, evaluation, and inference indicators, and analyzed using parametric statistical tests (Independent Sample T-Test) and N-Gain. The results showed a significant increase in the experimental group with an average posttest of 156.8 (versus 133.2 in the control). The T-Test produced a value of t(46) = -5.836 (p = 0.000), indicating a highly significant difference. N-Gain analysis reinforced these findings with an effectiveness score of 57.49% (moderately effective) in the experiment, while the control only reached 38.52% (less effective). The integration of Augmented Reality in Discovery Learning facilitates 3D visualization of respiratory organs, allowing students to explore concepts interactively and build independent understanding. This finding is in line with Bruner's theory of constructivism, asserting that a combination of immersive technology and explorative approaches effectively improves critical thinking skills. This study recommends the adoption of the DINAR model in science learning, particularly for abstract materials, as well as teacher training in AR-based media development.

Keywords: Discovery learning, Augmented Reality, Critical Thinking, Quantitative, Madrasah Ibtidaiyah

Pengaruh Model *Discovery Learning* Berbasis Media *Augmented Reality* Terhadap Kemampuan Berpikir Kritis Siswa

Abstrak
Penelitian ini bertujuan menguji pengaruh model DINAR (Discovery Learning berbasis Augmented Reality) terhadap kemampuan berpikir kritis siswa kelas V Madrasah Ibtidaiyah pada materi organ pernapasan manusia. Metode yang digunakan adalah quasi-experimental design dengan desain non-equivalent control group, melibatkan 48 siswa yang terbagi menjadi kelompok eksperimen (pembelajaran DINAR) dan kontrol (metode konvensional). Penelitian ini dilaksanakan di MIS Raudlatul Mutaallimin, Pakis, Kecamatan Bringin, Kabupaten Semarang. Data dikumpulkan melalui tes berpikir kritis berbasis indikator analisis, evaluasi, dan inferensi, serta dianalisis menggunakan uji statistik parametrik (Independent Sample T-Test) dan N-Gain. Hasil penelitian menunjukkan peningkatan signifikan pada kelompok eksperimen dengan rata-rata posttest 156,8 (berbanding 133,2 pada kontrol). Uji T-Test menghasilkan nilai t(46) = -5,836 (p = 0,000), mengindikasikan perbedaan sangat signifikan. Analisis N-Gain memperkuat temuan ini dengan skor efektivitas 57,49% (cukup efektif) pada eksperimen, sementara kontrol hanya mencapai 38,52% (kurang efektif). Integrasi Augmented Reality dalam Discovery Learning memfasilitasi visualisasi 3D organ pernapasan, memungkinkan siswa mengeksplorasi konsep secara interaktif dan membangun pemahaman mandiri. Temuan ini sejalan dengan teori konstruktivisme Bruner, menegaskan bahwa kombinasi teknologi imersif dan pendekatan eksploratif efektif meningkatkan keterampilan berpikir kritis. Penelitian ini merekomendasikan adopsi model DINAR dalam pembelajaran sains, khususnya untuk materi abstrak, serta pelatihan guru dalam pengembangan media berbasis AR.

Kata kunci: *Discovery learning, Augmented Reality,* Berpikir Kritis, Kuantitatif, Madrasah Ibtidaiyah

INTRODUCTION

In the world of 21st-century education, critical thinking skills are one of the main pillars in shaping learners who are adaptive, reflective, and ready to face global complexity (Hikmah, Chudzaifah, & Rohman, 2024). This ability is relevant in the academic realm and an important provision in social and professional life (Ngatminiati, Hidayah, & Suhono, 2024). Critical thinking involves analyzing, evaluating, and interpreting information to make rational decisions (Raj, Chauhan, Mehrotra, & Sharma, 2022). Meaningful education no longer focuses on mastering details alone, but emphasizes how learners can interpret, analyze, and evaluate information independently and systematically (Seibert, 2021).

The Discovery Learning model, introduced by Jerome Bruner, answers this need. The Discovery Learning model allows learners to discover concepts through direct experience, experimentation, and active interaction with their learning environment (Marougkas, Troussas, Krouska, & Sgouropoulou, 2023). The main syntax in Discovery Learning includes five stages: stimulation, problem statement, data collection, data processing, verification, and generalization (Rahman, 2023). The advantages of this model include encouraging independent learning, improving long-term memory, and fostering higher-order thinking skills. Students are not only recipients of information, but also discoverers of the meaning of each concept they learn (Khuriyathusyfah & Muslim, 2024).

However, in many basic education institutions, learning is still dominated by conventional teacher-centered approaches. Muzdalifah & Saputri (2025) stated that conventional models have the potential to curb students' critical thinking skills due to the lack of space for exploration, questioning, and drawing conclusions based on personal understanding. This condition becomes a crucial problem in the context of 21st-century education, where analysis, evaluation, and creativity skills are the main prerequisites for competing in the era of technological disruption (Fadila et al., 2024). An education system that relies on memorization and one-way instruction risks producing graduates who are not prepared to face the complexity of global problems, such as climate change or digital inequality (Hidayat & Sukari, 2025).

Based on observations and interviews on January 13th to 16th, 2025, students' critical thinking skills are still relatively low, mainly due to learning patterns that are too focused on memorization and passive acceptance of information in IPAS subjects, the material of recognizing human respiratory organs. To overcome this, interactive learning strategies that can trigger optimal cognitive engagement are needed. One learning innovation is the utilization of Augmented Reality (AR) technology as a learning medium (Arifuddin, Wahyudin, Prabawanto, Yasin, & Elizanti, 2022).

AR allows integration between digital objects and the real environment in real time, thus providing a more immersive and contextual learning experience (Arena, Collotta, Pau, & Termine, 2022). With 3D visualization and high interactivity in Augmented Reality (AR) media, students can explore concepts more deeply and flexibly (Putra et al., 2021). The use of AR media in science learning, especially in human respiratory organ material, has proven to facilitate student understanding of abstract concepts (Riduan, Suryani, & Lubis, 2024). In addition, AR technology can also encourage students to make observations, formulate hypotheses, and verify independently. The combination of AR with the Discovery Learning approach has great potential in forming a constructive critical mindset in students.

Various studies show that the Discovery Learning model consistently improves students' critical thinking skills. Rahayuningsih, Asrowi, Gunarhadi, & Ramli (2024) in a meta-analysis study found that the effectiveness of this model reached a value ≥ 0.8, categorized as a large effect and superior to conventional methods. Similar results were shown by Solissa, Haetami, Yustita, Santosa, & Syafruddin (2023) with an effect size of 0.90 and an N-gain value of 0.52, signifying significant improvement in the experimental class. Gunawan, Soekamto, Sahrina, & Suharto (2023) also noted the significant effect of the video-assisted discovery model ($p < 0.05$), with the data collection syntax as the stage most contributing to critical thinking. In addition, it was found that female students showed higher achievement, which was attributed to learning style differences. These findings strengthen the theoretical basis that Discovery Learning, whether in its pure form or media-assisted, is effective in developing students' critical thinking skills.

Research related to the use of Augmented Reality (AR) in learning shows positive results on increasing students' critical thinking. Azrai, Rini, Kurnianto, & Ampang (2023) found that AR SINAPS media was significantly more effective than traditional image media, with the experimental class posttest score reaching 48.70 and a gain of 17.86, higher than the control class which only obtained a score of 44.16 and a gain of 7.79 higher posttest scores and gains and shifts in student performance to higher categories. Damopolii, Paiki, & Nunaki (2022) also stated an increase in critical thinking through AR-marked comic books, with an n-gain of 0.38 and a significant difference between pretest and posttest ($p < 0.05$). Both

studies show that AR not only improves learning outcomes but also supports cognitive development in a more meaningful way.

Research integrating Discovery Learning and AR media in one whole learning model is minimal, especially in the context of IPAS learning at the Madrasah Ibtidaiyah level. Theoretically, the combination of exploration-based learning strategies (Discovery Learning) and immersive visualization (AR) can strengthen each other in stimulating students' analysis, evaluation, and inference. Therefore, this research is essential to fill the gap by developing and testing the effectiveness of the DINAR (Discovery Learning based on Augmented Reality) model as an integrated approach in improving students' critical thinking skills on the human respiratory system material.

Based on the above background, this article aims to examine the effect of the DINAR model: Discovery Learning model assisted by Augmented Reality on students' critical thinking skills in IPAS subjects, especially on the material of recognizing human respiratory organs. Through this research, theoretical contributions are expected to be obtained in developing technology-based innovative learning models, as well as practical benefits for teachers, schools, and education policy makers in designing teaching strategies that are adaptive to the needs of the times. The findings are expected to not only strengthen existing theories but also expand the scope of Discovery Learning implementation in an increasingly dynamic digital era.

METHODS

This study uses a quantitative approach with a quasi-experimental design (Sugiyono, 2019). The design used is a non-equivalent control group design, which involves two groups, namely the experimental group that gets learning using the DINAR model (Discovery Learning assisted by Augmented Reality media) and the control group that uses conventional methods, namely one-way lectures, questions and answers, and the use of static images from package books without interactive media. The purpose of this design is to determine the effect of treatment on students' critical thinking skills in a measurable and objective way.

Table 1. Quasi-Experimental Model

Group	*Pretest*	*Treatment*	*Posttest*
Experiment	O_1	X	O_2
Control	O_1	-	O_2

Keterangan:
O_1 : pretest score before treatment
O_2 : posttest value after treatment
X : treatment in experimental classes with Augmented Reality (AR) media

The research was conducted at MIS Raudlatul Mutaallimin Pakis, Bringin District, Semarang Regency, from January 21 to February 3, 2025. This location was chosen because it has supporting infrastructure, such as multimedia devices and stable internet access, as well as the support of educators ready to implement technology in learning. The population in this study was all fifth-grade students, totaling 49 students. Sampling was conducted using a purposive sampling technique, which is the selection of samples based on specific criteria relevant to the research objectives (Arikunto, 2013). The sample consisted of two classes; an experimental class of 24 students and a control class of 24 students, with an equal number to avoid bias.

The variables in this study consisted of two types, namely independent and dependent variables. The independent variable is the DINAR (Discovery Learning based on Augmented Reality) model, which is given the symbol X. The dependent variable is the critical thinking skills of students. While the dependent variable is the critical thinking skills of students, which is given the symbol Y. These two variables are measured to determine the extent of the influence of the learning model used on critical thinking skills.

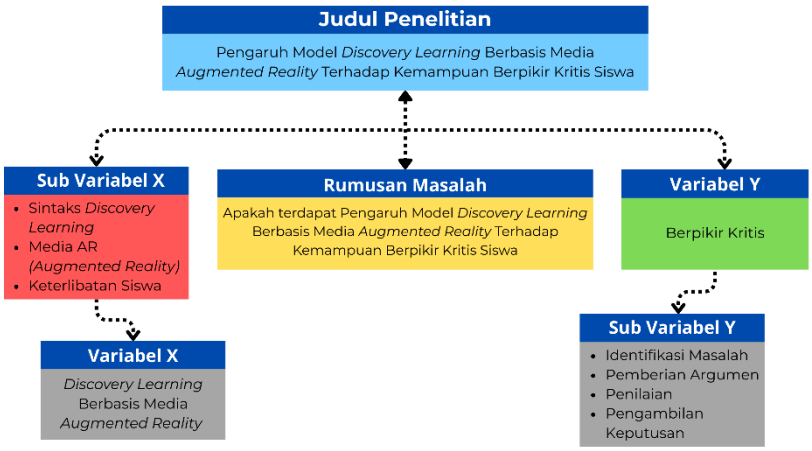

Figure 1. Research Framework (Source: Processed by the author, 2025)

Data collection techniques were carried out through tests and documentation. The test was given in the form of multiple-choice questions prepared based on critical thinking indicators, and provided at the pretest and posttest stages (Creswell, 2018). In addition, documentation was used to collect supporting data in the form of administrative records and documentation of the learning process. The test instrument was first tested through validity and reliability tests. The validity test was conducted using Pearson Product-Moment correlation at 5% significance level, with an r-table of 0.361. Of the 26 items tested, 20 were declared valid because they had an r-calculated value > r-table. In comparison, six other items were declared invalid and eliminated from the main instrument. Furthermore, the reliability test was carried out using Cronbach's Alpha with the help of the SPSS 26 program, and obtained a value of a = 0.813, which is in the highly reliable category. This means that the instrument has high internal consistency and is suitable for use in collecting research data.

Table 2. Answer Score

Answer	Score
Correct	1
Incorrect	0

The data analysis uses parametric statistical tests. Before hypothesis testing, the data was first tested to meet the assumptions of normality (Shapiro-Wilk test) and homogeneity of variance (Levene Test Statistics test) (Ghozali, 2018). The normality test results show that all pretest and posttest data in both groups have a Sig. Value between 0.081 and 0.409, which means the data is normally distributed. The results of the homogeneity test also showed a value of Sig. = 0.654, indicating that the variance of the two groups is homogeneous. Thus, the data meet the basic assumptions for the use of the Independent Sample T-Test. After fulfilling, the data were analyzed using the t-test (Independent Sample T-Test) to determine the significant difference between the experimental and control groups. In addition, N-Gain analysis was used to measure the effectiveness of the treatment based on the increase in student learning outcomes. The N-Gain formula is as follows:

$$N - Gain = \frac{Skor\ PostTest - Skor\ PreTest}{Skor\ Ideal - Skor\ PreTest}$$

Table 3. N-Gain Interpretation Criteria

N-Gain Percent	Interpretation
> 76%	Effective
56-75%	Moderately Effective
40-55%	Less Effective
< 40%	Not Effective

RESULTS AND DISCUSSION

This study analyzes the effect of the Discovery Learning model based on Augmented Reality media (DINAR) on the critical thinking skills of fifth-grade students at MI Raudlatul Mutaallimin. The analysis was conducted based on the pretest and posttest results of two groups, namely the experimental group consisting of 24 students who took part in learning with Augmented Reality (AR) media, and the control group consisting of 24 students who took part in learning with conventional methods. The analysis results show that there is a significant difference between the two groups, both in terms of score improvement and learning effectiveness. Details of the test results from both groups are presented in the following section.

Control Class Pretest-Posttest Results

The control class is a group that does not receive treatment, or the variable being tested in this study is the use of conventional methods. In the control class, there were 24 fifth-grade students. The following is a diagram of the results of the implementation of the pretest and posttest conducted by students in the control class:

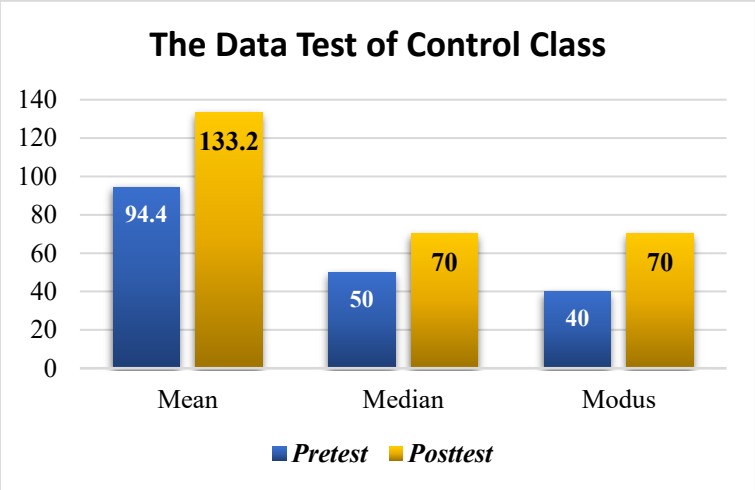

Figure 2. Diagram of Control Class Test Results

Based on the data presented in Figure 2, the control class, consisting of 24 students, showed an increase in critical thinking skills with the application of conventional methods. At the pretest stage, the average value (mean) of students was recorded at 94.4, with a median value of 50, and the most frequently occurring value (mode) was 40. Based on these data, it indicates that before the study, the majority of students had critical thinking skills of around 40. After undergoing a conventional learning process (without using Augmented Reality media), the posttest results showed a significant increase. The mean value increased to 133.2, the median was 70, and the mode was 70. The increase indicates that conventional learning methods are still effective in improving students' critical thinking skills, although not as optimal as the use of innovative media.

The study by Hartanti, Hasiana, & Mufidah (2024) states that the limited improvement in the control class reflects the weakness of conventional learning that focuses on memorization and one-way delivery. The lack of use of interactive media and independent exploration makes it difficult for students to visualize abstract concepts, such as the structure of respiratory organs (Wulan, Afnani, & Anam, 2025). These findings are in line with research by Istiqomah, Ayuningrum, Supriyanti, & Yuhana (2024) which states that passive learning is not sufficient to develop students' analysis and evaluation skills, especially on complex science materials. Thus, although conventional methods remain relevant, the integration of interactive technology and constructivist approaches such as Discovery Learning is a must to optimize the development of students' critical thinking in the modern education era.

Experimental Class Pretest-Posttest Results

The experimental class is a group used in experimental research and receives treatment or variables that are being tested; in this study, the use of Augmented Reality (AR) media is used. This research was conducted in an experimental class consisting of 24 students. The following is a diagram of the results of the pretest-posttest conducted by students in the experimental class:

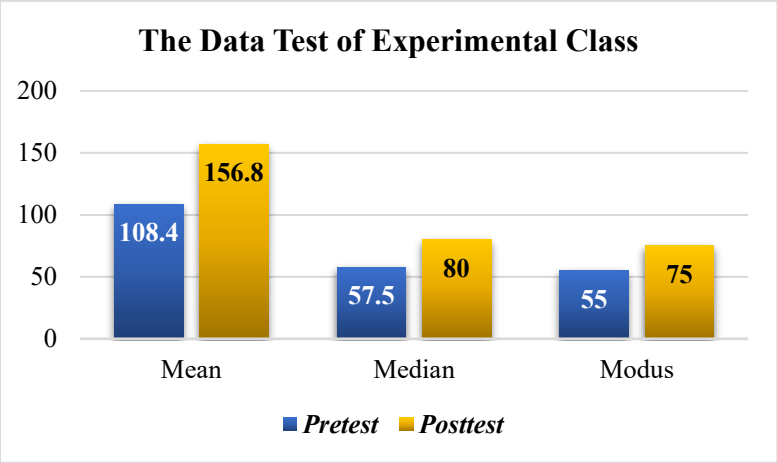

Figure 3. Diagram of Experimental Class Test Results

Based on the diagram data in Figure 3, the experimental class that applied Augmented Reality media showed a very significant increase in counting ability. In the pretest, the average value (mean) of students was recorded at 108.4, with a median value of 57.5 and the most frequently occurring value (mode) 55. The distribution of these scores illustrates that before the intervention, the majority of students had critical thinking skills around 55 (mode). After the intervention using Augmented Reality media, the posttest results showed a significant increase. The mean value increased dramatically to 156.8 with a median of 80 and a mode of 75. The increase was not only quantitatively significant, but also showed a high level of consistency. The symmetrical distribution of scores indicates that the improvement occurred evenly across the class, with most students achieving a relatively uniform level of understanding.

The increase in posttest scores in the experimental class reflects the positive impact of Augmented Reality integration in Discovery Learning (Yuswantina, Dyahariesti, & Lestari, 2022). In line with this Iqbal, Purbiyanto, & Hamid (2024) states that 3D visualization of respiratory organs through AR allows students to explore the structure and function of organs interactively, thus strengthening analysis and inference skills. Students can observe a simulation of the gas exchange process in the alveoli, which encourages deeper conceptual understanding. These findings are in line with research by Aswan (2024) which states that visual elements in Augmented Reality increase information retention compared to conventional methods.

Normality Test

Furthermore, researchers conducted normality testing on pretest and posttest scores. This test was carried out using the IBM SPSS Statistics 25 application with the Shapiro-Wilk method. The purpose of the normality test is to verify that the research data has a normal distribution, which is an important prerequisite for the application of parametric statistical tests, namely the independent sample t-test. The decision making is as follows:

1. If the Sig. value> 0.05, then the data is normally distributed
2. If the Sig. value <0.05, then the data is not normally distributed

The following are the results of the Shapiro-Wilk normality test calculation obtained using IBM SPSS Statistic 25:

Table 4. Normality Test Results

Tests of Normality			
Kelas	Shapiro-Wilk		
	Statistic	df	Sig.
Pretest Control	.954	24	.329
Posttest Control	.952	24	.292
Pretest Eksperimen	.958	24	.409
Posttest Eksperimen	.926	24	.081
a. Lilliefors Significance Correction			

Table 4 shows the results of the Shapiro-Wilk normality test for pretest and posttest scores in the control and experimental groups. The statistical values range from 0.926 to 0.958, with degrees of freedom (df) 24 for all groups. The significance values (Sig.) were all above 0.05 (control pretest: 0.329; control posttest: 0.292; experimental pretest: 0.409; experimental posttest: 0.081), which indicates that the data is normally distributed. This fulfills the basic assumptions of parametric analysis, so the research results can be considered statistically valid. Although the experimental group's posttest statistic value (W = 0.926) was lower than the control group, the significance value of 0.081 remained above the critical limit of 0.05 (0.081 > 0.05). The data confirmed that there was no significant deviation from the normal distribution, even in the experimental group after the intervention. Thus, the use of parametric statistical methods in this study is justified, and the difference in results between the control-experiment groups is not due to abnormalities in the data.

Homogeneity Test

The homogeneity test was conducted to determine whether the variances between the experimental and control groups were in equal conditions. This test uses Levene's Test for Equality of Variances, with the basis for decision making as follows:

1. H_0: The data variances of the two groups are homogeneous (there is no significant difference in variance)
2. H_1: The data variances of the two groups are not homogeneous (there is a significant difference in variance)

The following are the calculation results for the homogeneity test:

Table 5. Homogeneity Test Results

Test of Homogeneity of Variance				
	Levene Statistic	df1	df2	Sig.
Based on Mean	082	1	46	.654

Table 5 shows the results of the homogeneity of variance test using Levene's Test. Levene's statistical value is 0.082 with degrees of freedom (df1 = 1 and df2 = 46). The significance value (Sig.) obtained is 0.654, far above the critical limit of 0.05 (0.654 > 0.05). The homogeneity test results indicated that there was no significant difference in variance between the control and experimental groups (p > 0.05). Thus, the assumption of homogeneity of variance is met. The equality of variance ensures that the difference in results between the two groups is not caused by the inequality of data variation, so the research findings can be considered valid. Thus, researchers can apply the parametric independent sample t-test with the certainty that the prerequisite of homogeneity has been met.

T-Test

To determine the difference in critical thinking skills between the experimental and control groups, the Independent Sample T-Test test was conducted. This test was used to test the following research hypothesis:

1. H_0 (Null hypothesis): Discovery Learning assisted by Augmented Reality media has no effect on students' critical thinking skills in IPAS class V material on human respiratory organs at MI Raudlatul Muta'alimin Pakis, Semarang Regency in 2025.
2. H_1 (Alternative hypothesis): Discovery Learning assisted by Augmented Reality media affects students' critical thinking skills in IPAS class V material on human respiratory organs at MI Raudlatul Muta'alimin Pakis, Semarang Regency in 2025.

The decision-making criteria used are as follows:

1. If the t-count is negative: if the t-count < t-table and the P-value < 0.05, then H_0 is rejected and H_1 is accepted.
2. If the t-count is positive: if the t-count> t-table and the P-value> 0.05, then H_0 is accepted and H_1 is rejected.

The following is the output of the t-test analysis results:

Table 6. Independent Sample T-Test Results

Independent Samples Test					
	Levene's Test for Equality of Variances				
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	.544	.464	-5.836	46	.000

Based on the data in Table 6, an Independent Samples T-Test was conducted to compare significant differences between the posttest scores of the experimental and control groups. The result of Levene's Test for Equality of Variances shows the value of F = 0.544 with significance (0.464> 0.05), which indicates that the assumption of homogeneity of variance is met. Furthermore, the t-test results produced a value of t(46) = -5.836 with (Sig. 2-tailed) (0.000 < 0.001). The very small p-value indicates a very significant difference between the two groups, where the experimental group's posttest score is statistically higher than the control group. The negative sign on the t-value (-5.836) reflects the direction of the difference; the average of the experimental group is above that of the control group. Thus, the null hypothesis (Ho) is rejected, and the alternative hypothesis (Ha) is accepted, which means that Augmented Reality media effectively improve students' critical thinking skills.

N-Gain Test

Table 7. N-Gain Test Results

Descriptives						
	Class	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain_Percent	Control	24	25.00	58.33	38.5155	8.40283
	Experiment	24	28.57	88.89	57.4883	14.39026

Based on Table 7 above, the N-Gain test results show a clear difference between the effectiveness of learning using Augmented Reality media (experimental class) and conventional methods (control class). In the control group (conventional method), the N-Gain value ranges from 25.00% to 58.33% with an average of 38.52% (standard deviation 8.40), which is included in the less effective category. Meanwhile, the experimental group showed a wider range of values (28.57% - 88.89%), an average of 57.49% (Std. deviation 14.39), and was categorized as moderately effective. The difference confirms that the integration of Augmented Reality (AR) in discovery-based learning is significantly superior in encouraging the development of students' critical thinking skills. The higher data variability in the experimental group (Std. deviation 14.39) indicates the diversity of student responses to AR media, where some achieved very high improvements (maximum 88.89%), while others still needed technical assistance or adjustments to the duration of the intervention. Thus, the N-Gain test proves that Augmented Reality (AR) based media is significantly superior in improving students' critical thinking skills compared to conventional methods.

Based on data analysis regarding the results of this study, it indicates that the application of Augmented Reality-based Discovery Learning has a significant effect on improving students' critical thinking skills. This is indicated by the results of the Independent Samples T-Test test which produces a value of t (46) = -5.836 t (46) = -5.836 with p=0.000 p = 0.000 (p < 0.05), as well as the N-Gain score analysis which shows that the experimental class has an average value of 57.49% (quite effective), while the control class only reaches 38.52% (less effective). The data indicates that augmented reality media not only increases the average score but also reduces the ability gap between students. This shows that the increase in the ability value of student learning outcomes in the group that received learning with augmented reality media was higher than in the group that did not use the media. Thus, it can be concluded that learning using augmented reality media is quite effective and significantly improves the critical thinking skills of grade V students in the IPAS subject of recognizing human respiratory organs at MIS Raudlatul Mutaalimin.

The findings reveal a significant improvement in critical thinking skills in the experimental group compared to the control group, as confirmed by the *Independent Sample T-Test* (t(46) = -5.836; p = 0.000) and N-Gain analysis. The experimental group achieved an average N-Gain of 57.49% (moderately effective), while the control group scored 38.52% (less effective). Although specific N-Gain values for each indicator were not calculated, qualitative analysis of students' answers suggests that the greatest

improvement occurred in the analysis indicator. Students demonstrated stronger abilities to break down the components of the respiratory system and explain structure–function relationships after using AR media. The 3D visualization allowed them to zoom, rotate, and examine alveolar details, deepening their conceptual understanding.

The integration of Discovery Learning with AR strengthened the *data collection* and *generalization* stages. AR provided a multimodal learning experience (visual, verbal, kinesthetic) that reinforced memory encoding in line with *dual coding theory*. It also reduced cognitive load when dealing with abstract topics, enabling deeper conceptual understanding. The largest gap was observed in the evaluation indicator, with an 18-point difference in average posttest scores. Students in the experimental group had more opportunities for independent exploration, while those in the control group relied heavily on teacher-led verbal explanations.

The T-test results showing a significant increase in critical thinking skills in the experimental group are in line with Bruner's constructivism theory (1961), which emphasizes that effective learning occurs when students actively build knowledge through independent exploration. The study by Afnan & Puspitawati (2024) states that AR technology facilitates a constructivist learning environment by providing interactive simulations, allowing students to discover concepts through direct experience. The 3D visualization of respiratory organs in this study allows students to observe the relationship between the structure and function of the alveoli directly. In line with the findings of Faridi, Tuli, Mantri, Singh, & Gargrish (2021) that AR significantly increases critical thinking and learning gains among students allowing visualization and interaction with complex physics concepts. Thus, the integration of AR and Discovery Learning not only adopts Bruner's theory, but also extends it through immersive technology in the context of modern science learning.

Tusino, Dewi, & Sukarni (2024) in their research stated that improving critical thinking skills through the Discovery Learning model is in line with the development of student skills in the digital era. Critical thinking involves not only the analysis of information, but also the ability to reconstruct knowledge through active reflection (Rahmatika, 2022). The study by Sari, Abidin, Kusumadewi, Ismiyanti, & Ulia (2024) showed that Augmented Reality media significantly improved critical thinking skills in elementary school students, with an average pretest score of 33.5 and an average posttest score of 82.92, indicating effective learning outcomes in natural and social sciences. In line with this Amalia, Sihotang, Nurhayani, & Sam (2023) confirmed that the use of Augmented Reality media positively affects the critical thinking skills of elementary school students by providing an interesting interactive learning experience. Thus, this study proves that the application of Discovery Learning based on Augmented Reality (AR) significantly improves the critical thinking skills of grade V students on the material of human respiratory organs.

The evaluation indicator also showed substantial improvement, supported by the *verification* stage in Discovery Learning. At this stage, students compared their AR-based observations with initial hypotheses and refined their conclusions based on collected evidence.

The inference indicator improved as well, though to a lesser extent. This was likely due to time constraints limiting exploration of multiple scenarios and the formation of complex generalizations. Nevertheless, the posttest results still favored the experimental group, indicating the superiority of AR-supported learning over conventional methods. The largest performance gap between the two groups was observed in evaluation skills. Students in the experimental group benefited from broader opportunities for independent exploration, whereas the control group relied more heavily on teacher explanations and static images.

The theoretical contribution of this study lies in extending Bruner's constructivist theory to the context of immersive technology-based learning. AR serves as a "visual representation enhancer" that minimizes cognitive load and supports the discovery of concepts. The practical contribution includes guidance for teachers to integrate AR, particularly during the verification and generalization stages of Discovery Learning, without major curriculum changes. For policymakers, the findings provide a rationale for investing in teacher training and AR infrastructure in elementary schools.

CONCLUSION

This study proves that the application of the DINAR (Discovery Learning based on Augmented Reality) model significantly affects the improvement of critical thinking skills of grade V students on the material of human respiratory organs. The results of statistical analysis showed a very significant difference between the experimental and control groups, with the average posttest value of the experimental group (156.8) higher than that of the control group (133.2). Independent Sample T-Test (t(46) = - 5.836; p =

0.000) and N-Gain analysis (57.49% in the experimental class vs. 38.52% in the control class) confirmed the effectiveness of this model. The integration of Augmented Reality in Discovery Learning facilitates interactive visualization and self-exploration, thus strengthening students' conceptual understanding as well as analysis and evaluation skills.

Suggestions for teachers and educational institutions begin to integrate Augmented Reality in learning, especially in abstract materials such as human organs. Technical training for teachers needs to be organized to improve competence in designing and implementing AR media. Further research can test the DINAR model on different materials and education levels, as well as explore supporting factors such as the duration of intervention and variations in AR content. In addition, it is necessary to develop supporting infrastructure, such as stable internet access and multimedia devices at schools, to ensure optimal implementation. Collaboration between academics, technology developers, and policymakers is also needed to create a sustainable innovation-based learning ecosystem.

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