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Augmented Reality-based Discovery Learning: an Effective Strategy to Improve Critical Thinking in Sciences for Grade IV

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Abstract
This study examines the effectiveness of the Discovery Learning model supported by Augmented Reality (AR) media in enhancing critical thinking skills among Grade IV students at SDN 02 Kuto on the topic of plants as a source of life. It also explores how this method compares to the Problem-Based Learning model using PowerPoint media. The research aimed to determine whether Discovery Learning with AR can improve students' critical thinking skills and engagement. The study also seeks to identify differences in critical thinking outcomes between the experimental and control groups. A quantitative approach was applied with a quasi-experimental design. The study involved 40 students, divided into an experimental group (20 students) using Discovery Learning with AR and a control group (20 students) using Problem-Based Learning with PowerPoint. Data collection utilized validated and reliable multiple-choice and essay tests, analyzed through N-Gain and independent t-tests. The findings showed a significant improvement in critical thinking skills in the experimental group compared to the control group. The N-Gain analysis indicated 66% effectiveness in the experimental group, categorized as moderately effective. The independent t-test revealed a significant difference in critical thinking aspects between the two groups. This study concludes that the Discovery Learning model supported by AR media effectively fosters critical thinking skills and engagement in learning. By integrating innovative teaching strategies with digital technologies, this approach addresses the challenges of 21st-century education and creates an interactive and enjoyable learning environment.

Keywords: Discovery learning, augmented reality, critical thinking, elementary school

INTRODUCTION

When students lack enthusiasm for learning, teachers can make changes to improve the situation. Motivating students to participate more actively in class is very important (Tanjung & Louise, 2024). Participation in class discussions, completing assignments, asking peers or teachers for help when struggling to understand the material, and submitting final reports are indicators of student engagement in the learning process and active learning (Prasetyo, 2021). To achieve this, teachers need a guide for teaching. One such guide is a learning model, which can serve as a reference for teachers in conducting instruction (Saragih et al., 2021). Discovery Learning is one of the learning models that provide opportunities for students to explore and learn independently. This model plays an important role in encouraging students to become more enthusiastic about learning, discover problems on their own, and generate new ideas (Dea & Rahmawati, 2021). By implementing Discovery Learning, it is expected that a passive learning atmosphere can transform into one that is more active and creative (Utami & Giarti, 2020).

Media can make lessons more enjoyable and engaging for students. Augmented Reality (AR) can be utilized in education and has become an active area of research in educational settings as a technology to support teaching and learning processes (Rodzi et al, 2022). AR has garnered significant interest within the research community because it provides a unique learning experience that cannot be achieved with other technologies or approaches (Avila-Garzon et al., 2021). AR have an important role in designing contextual learning processes. The use of Augmented Reality (AR) in the classroom has the potential to capture students' interest and maintain their attention during lessons. The implementation of this technology will become increasingly relevant in the future, in line with technological advancements and the growing demands of digital-based education.

In the *Merdeka Curriculum* learning approach, developing critical thinking skills is a crucial aspect where students are expected to actively participate in the learning process, while teachers act as facilitators (Safitri & Mediatati, 2021). Today's students must be able to think critically to address various challenges that may arise due to rapid technological advancements. This skill is an essential element that students need to build their knowledge (Amalia et al., 2021). Critical thinking helps students become smarter, more independent learners, and better prepared to face challenges, both in academic contexts and in daily life. Critical thinking is one of the characteristics that can be developed through learning of Natural Sciences (*Ilmu Pengetahuan Alam/IPA*). Science is a scientific discipline that studies all aspects of natural objects and their contents (Khomairroh et al., 2024). Through Natural Sciences, students not only gain a deeper understanding of the subject matter but also cultivate qualities such as patience, awareness, accuracy, critical thinking skills, and a strong sense of curiosity or interest (Wati et al., 2022). Encouraging students' curiosity, fostering care and responsibility for the environment, and improve their thinking and learning abilities are the primary goals of Natural Sciences Learning (Thalib et al., 2020). In Natural Sciences subject, students are also expected to develop the skills to address and solve problems encountered in everyday life.

Several learning challenges were identified through interviews and classroom observations of Grade IV at SDN 02 Kuto. Students showed a lack of enthusiasm, interest, and readiness to learn. Moreover, the less-than-ideal classroom environment hindered effective two-way communication between educators and their students. The root cause of these issues lies in the use of teaching models that are not well-suited to the subject matter. The prevailing approach to education remains predominantly one-way or teacher-centered. Students are not able to participate in solving the problem, so the critical thinking process cannot run well (Latifah & Suprihatiningrum, 2024). During the learning process, the teacher utilized PowerPoint media; however, students still struggled with the topic of plants. PowerPoint media was also considered less relevant to the learning material. Although PowerPoint is classified as digital media, it still feels conventional.

A considerable number of students are still unable to understand concepts related to plants. This is reflected in the low test scores, where only 15 students (62.5%) managed to achieve the Minimum Competency Standard (*Kriteria Ketuntasan Minimal*/*KKM*), while 9 students (37.5%) did not meet the standard. The test results indicate that nearly half of the total students have not reached the Minimum Competency Standard.

Educators in Indonesia often rely on outdated practices when designing learning activities (Hasriadi, 2022). These methods are no longer relevant to the current learning needs. In the 21st century, learning models should be digital-based (Rahma et al., 2023). In determining the appropriate learning model, it is essential to address the issues of student boredom and distraction caused by monotonous teaching patterns (Musyawir, 2022). The learning media commonly used, such as PowerPoint, typically presents the material in text format. Although these teaching materials utilize digital technology, their implementation remains less than optimal as their presentation tends to feel conventional (Rahma et al., 2023).

Discovery Learning is a learning model that emphasizes active student participation in observing, investigating, and solving problems to improve their understanding (Hanifah & Indarini, 2021). Students are given the opportunity to learn through practice using this technique, which allows them to acquire information and understanding independently (Azizah & Winarti, 2016). In Discovery Learning, teachers do not provide all the information directly but guide students in organizing and developing their knowledge and skills to solve problems (Marta et al., 2022). According to Sukri et al., (2022) the steps of Discovery Learning include stimulation, problem formulation, data collection, data processing, verification, and generalization. Ibanez et al., (2015) divide Discovery Learning into planning, monitoring, and structuring the discovery process. Meanwhile, according to Setiadi & Elmawati (2019), this process includes orientation, hypothesis formulation, hypothesis testing, conclusion drawing, and regulation. The regulation stage involves planning, monitoring, and evaluating the learning process to ensure students' success in understanding the material being studied.

Augmented Reality (AR) is a technology that combines 2D or 3D virtual objects with the real world in real time to enhance students' learning experiences (Sari et al.,2022). This technology allows students to more easily understand abstract concepts that are difficult to explain with words, such as geometry, natural phenomena, and evolution (Chen et al., 2017). AR-based learning media have been proven to capture students' attention, make learning more interactive, and improve learning effectiveness

(Shaumiwaty et al., 2022). According to Syazwani et al., (2022), AR has three main characteristics: the integration of the real and virtual worlds, real-time interaction, and the presentation of objects in 3D. Yusup et al., (2023) added that AR is interactive, motivates learning, and enhances the clarity of information between teachers and students. Dewi, as cited in Yusup et al., (2023), although AR offers many advantages, such as improving accuracy, efficiency, and innovation in learning, it also has several drawbacks, including high implementation costs, limited device availability, and data security concerns. To overcome these challenges, teachers need to receive training in AR technology, prioritize student privacy, and establish clear usage guidelines.

The ability to observe, analyze, and evaluate information logically before making decisions is known as critical thinking skills (Safitri & Mediatati, 2021). Suratmi & Sopandi (2022) explain that critical thinking is not an innate ability but a skill that must be cultivated through learning. Students' problem-solving and decision-making abilities can greatly benefit from the development of this skill (Sarwanto et al., 2021). In addition, Firdausi et al., (2021) further add that critical thinking trains students to carefully consider all evidence before deciding whether to accept or reject it. According to Putri et al., (2020) several indicators of good critical thinking include the ability to explain something simply, study the fundamentals, draw conclusions, provide detailed explanations, and develop plans and strategies. In assessing students' critical thinking skills, Rahayu & Alyani (2020) emphasize the importance of markers such as interpretation, analysis, evaluation, and inference. Similarly, Hidayanti et al., (2016) measuring critical thinking through interpretation, analysis, evaluation, and inference. Ramdani et al., (2020) add indicators such as explanation, data analysis, and solution identification.

The objectives of science education in elementary schools include encouraging students to think critically, sparking their interest, and fostering a sense of care and responsibility toward the environment (Thalib et al., 2020). According to Winangsih & Harahap (2023), science subjects prioritize hands-on learning experiences through the "learning by doing" method, enabling students to understand concepts concretely. The science learning process also involves the development of cognitive, affective, and psychomotor aspects to ensure that students can comprehensively master the material (Azizah & Winarti, 2016). Consequently, the goal of science education is to help students develop not only factual knowledge but also the mindset and skills necessary for academic success and life.

The study conducted by Hanifah & Indarini (2021) demonstrated that fifth-grade students learn science more effectively through Discovery Learning compared to Inquiry-Based Learning. However, the learning process did not utilize interactive media, resulting in a monotonous or less engaging experience for students. Similarly, research by Dari & Ahmad (2020), found that Discovery Learning can improve elementary school students' critical thinking skills through active engagement, although the learning media used were still conventional. Prasetyo (2021), highlighted an improvement in students' learning activeness at a class-wide level through Discovery Learning, yet the study did not examine its impact on critical thinking skills or the use of technology-based media such as Augmented Reality (AR).

In a study conducted by Octavia (2021) it was stated that AR can train students' critical thinking skills through imagination and visual literacy, although it has not yet

been applied within the Discovery Learning model. Amalia et al., (2023) concluded that AR, which combines holograms and instructional videos, improves students' focus and critical thinking skills, but it has not yet been integrated with Discovery Learning. Zaid et al., (2022), found that interactive multimedia based on AR is effective in improving the quality of elementary science learning; however, the study was still focused on a STEAM-based approach rather than Discovery Learning.

Research conducted by Avandra & Desyandri (2022), stated that a well-designed learning framework improves students' critical thinking skills, even though it does not integrate AR or Discovery Learning. Setyawan & Kristanti (2021), showed that Discovery Learning significantly improves students' critical thinking skills, but it has not yet utilized AR media. Sae & Radia (2023) claimed that engaging presentations using animated video media can help students develop their critical thinking skills, but the study did not employ Augmented Reality or Discovery Learning in their research.

METHOD

This study used a quantitative approach with an experimental design. The design applied was a quasi-experimental design, specifically a non-equivalent control group design. Furthermore, by utilizing the Discovery Learning approach supported by Augmented Reality media and Problem Based Learning with PowerPoint in improving students critical thinking skills. Pretest and Posttest instruments were used to assess students' critical thinking skills. The sample for this study consisted of Grade IV students from SD Negeri 02 Kuto, Kerjo District, Karanganyar Regency, Central Java. A total of 20 students from the experimental group and 20 students from the control group were included as the sample. The research data were collected using a Pretest and Posttest design. The results of the instrument testing showed that 12 multiple-choice questions were deemed valid with a significance value >0.468, while 3 questions were found to be invalid. After the validity test, the instrument was tested for reliability, as shown in Table 1 below.

Table 1. Reliability Test of Critical Thinking Instrument

Learning Achievement Instrument	
Multiple-choice questions	
Cronbach's Alpha	N Item
.810	12
Essay questions	
Cronbach's Alpha	N Item
.705	3

The critical thinking skill instrument had an r-table value of 0.468, and the reliability results indicated that the test instrument was valid and reliable, with a Cronbach's Alpha value of 0.810 for multiple-choice questions and 0.705 for essay questions (Table 1). The collected data were analyzed using statistical tests, including normality and homogeneity tests, independent and dependent t-tests, and N-Gain analysis, conducted via SPSS version 23 to measure the effectiveness of the learning models.

Table 2. Categories of N-Gain Effectiveness Interpretation

Percentage	Interpretation
< 40	Not Effective
40 - 56	Marginally Effective
56 - 75	Moderately Effective
> 76	Effective

FINDINGS AND DISCUSSION

Findings

The Discovery Learning model with Augmented Reality media was implemented through well-planned learning steps. The first stage involved stimulation, where a problem-based video was presented before the class session began. This provided students with an opportunity to understand the basic concepts of the material to be studied by formulating a preliminary hypothesis. During the class session, students were grouped to discuss and solve problems related to the material, utilizing Augmented Reality media containing the learning content. This interactive activity encouraged students to actively participate while also providing feedback to the teacher, which was beneficial for planning subsequent lessons

After the class session was completed, students were given assignments to work on independently at home. They were also provided with an Augmented Reality media barcode containing the learning material to assist them in completing the assignments. These tasks not only deepened the students' understanding of the material but also helped improve their digital literacy skills through the use of technology

This study began with the validation of research instruments and reliability testing. Data were collected before and after the tests. Subsequently, a comparison between the experimental and control groups was conducted using normality and homogeneity tests. Below are the findings from the SPSS data analysis.

Table 3. Normality Test

Test Name	Group	Significance Value	α
Pretest	Experimental	0.910	0.05
	Control	0.457	
Posttest	Experimental	0.673	0.05
	Control	0.510	

In Table 3, before testing, the experimental group had a significance value of 0.910, while the control group had a value of 0.457. After testing, the significance value for the experimental group was 0.673, and for the control group, it was 0.510. Since these values are greater than 0.05, it can be concluded that the data are normally distributed.

Table 4. Homogeneity Test

Data 1	Data 2	Significance Value	A
Experimental Class Pretest	Control Class Pretest	0.584	0.05
Experimental Class Posttest	Control Class Posttest	0.550	0.05
Experimental Class Pretest	Experimental Class Posttest	0.094	0.05

Significance values higher than 0.05 are shown in the calculations in Table 4. As seen in Table 5, the data were subjected to an independent t-test because they are normally distributed and homogeneous.

Table 5. Independent T-test for Pretest Data

Sig. (2-tailed)	Significance Level (α)	t-value	Status
0.550	0.05	-0.048	H_0 accepted

The Sig. (2-tailed) value of 0.550, as shown in Table 5, is higher than the significance level of 0.05. If this is the case, we can accept H_0 as the null hypothesis and reject H_1. Therefore, it can be concluded that the critical thinking skills of Grade IV students were similar before using the Problem-Based Learning model with PowerPoint media or the Discovery Learning model with Augmented Reality media for the topic of plants in class. The results of the posttest were also subjected to an independent t-test.

Table 6. Independent T-test for Posttest Data

Sig. (2-tailed)	Significance Level (α)	t-value	Status
<0.001	0.05	-6.038	H_0 rejected

The two-tailed significance value is less than 0.001, which is smaller than the conventional threshold of 0.05, as shown in Table 6. Therefore, we can conclude that H_1 is accepted, and the null hypothesis (H_0) is rejected. These findings indicate that, unlike the Problem-Based Learning model using PowerPoint, the utilization of the Discovery Learning model with Augmented Reality media has a substantial or significant impact on students' critical thinking skills. This discovery is particularly relevant for fourth-grade elementary school students, especially for material related to plants.

Table 7. Dependent T-test for Pretest and Posttest Data

Sig. (2-tailed)	Significance Level (α)	t-value	Status
<0.001	0.05	-20.044	H_0 rejected

The results of the dependent t-test in Table 7 show a two-tailed significance value of less than 0.001, which is below the threshold of 0.05. This evidence supports H_1 and rejects H_0. When fourth-grade students learned about plants using the Discovery Learning model and Augmented Reality media, their critical thinking skills improved. The N-Gain formula was used to compare the improvement in critical thinking skills before and after applying the learning model. The results of the N-Gain are presented below.

Table 8. N-Gain Test (Posttest for Experimental and Control Groups)

Number of Students	Average Posttest Score (Experimental)	Average Posttest Score (Control)	Highest Score	N-Gain	Category
20	60	74	87	0.34	Moderately Effective

Table 9. N-Gain Table (Pretest and Posttest for Experimental Group)

Number of Students	Average Posttest Score (Experimental)	Average Posttest Score (Control)	Highest Score	N-Gain	Category
20	60	86	100	0.66	Moderately Effective

In Table 8, the calculated N-Gain score indicates that the posttest data for both the experimental and control groups is 0.34, which falls into the moderate category (see Table 2). Comparatively, the Discovery Learning Model demonstrates superior results compared to the Problem-Based Learning Model that utilizes visual aids. Additionally, as shown in Table 9, the N-Gain score for the experimental group's pretest and posttest data is 0.66, which also falls into the moderate category. An improvement of 66% (ranging from 56% to 75%) in students' critical thinking skills provides evidence that this learning paradigm is effective.

According to the statistical analysis using SPSS version 23, students' critical thinking skills were similar before and after using the Augmented Reality-based Discovery Learning model and the PowerPoint-based Problem-Based Learning model. After using the Discovery Learning model, students' critical thinking skills significantly increased by 0.000, which is smaller than 0.05. The N-Gain test was also used to assess the effectiveness of this learning model. After implementing the Augmented Reality-based Discovery Learning model, students' critical thinking skills improved by 66% (ranging from 57% to 75%), with an average posttest score of 86, in contrast to the average posttest score of 73 for the Problem-Based Learning model. Students' critical thinking skills were substantially improved by applying the Augmented Reality-based Discovery Learning model compared to the PowerPoint-based Problem-Based Learning model. During each experimental class session, students followed a predetermined procedure outlined as follows. The initial step involved pre-class activities where students watched a video presentation of a problem (as shown in Figure 1). At this stage, students viewed a video of a problem related to the material and were asked to form a preliminary hypothesis about the issue. The first session focused on understanding the parts of a plant, the next session covered the process of photosynthesis, and the final session addressed plant reproduction.

Figure 1. Problem Statement

The second phase of classroom learning includes the delivery of learning objectives, participation in group discussions to address the problem, task presentations, drawing conclusions from the learning experience, providing feedback, and monitoring learning progress (as shown in Figures 2 to 5). In this second phase, classroom learning used Augmented Reality media to improve understanding of plant concepts. In the control class, the learning process followed the same structure as the second phase, with the exception that the material explanation was delivered using the Problem-Based Learning model with PowerPoint media, which resulted in decreased student engagement in the learning process.

Figure 2. Problem Statement

Figure 3. Data Collection

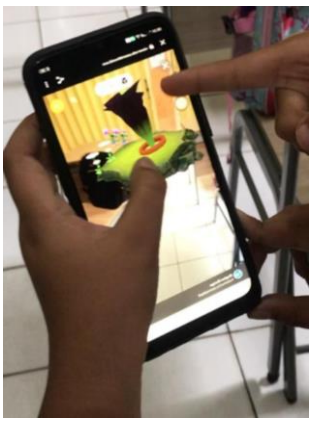

Figure 4. Data Collection

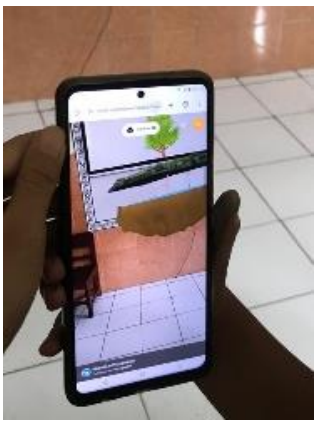

Figure 5. Data Collection

Discussion

Natural Sciences (IPA) is an effort with the primary goal of investigating the components, events occurring within it, and the relationships between various phenomena and their causes. This process uses methods carefully designed by scientists through a scientific approach (Setyawan & Kristanti, 2021). Natural Sciences focus on a systematic approach to studying nature. Thus, Natural Sciences (IPA) not only consists of a collection of knowledge such as theories, facts, concepts, and principles but also encompasses the processes of exploration and discovery (Nurhayati & , Langlang Handayani, 2020). One learning approach that aligns with this principle is the Discovery Learning model. This method encourages students to learn actively and independently through exploration and investigation, resulting in deeper and more lasting understanding (Safitri & Mediatati, 2021).

Over the course of three consecutive sessions, students followed a learning process using a model and media that were different from what they were accustomed to, in order to evaluate the improvement in their abilities. Pre- and posttests showed that the Discovery Learning model using Augmented Reality media increased students' critical thinking skills. This research is supported by a study conducted by Safitri & Mediatati, (2021) which showed that Discovery Learning can significantly improve students' critical thinking skills. This finding is further supported by Setyawan & Kristanti, (2021) The results are further reinforced by the fact that the critical thinking skills of Grade IV students at SDN Karangduren 01 were positively influenced by the Discovery Learning model.

The most common challenge faced in the Discovery Learning model is that it assumes the model presents academic barriers for students who struggle to understand, analyze, and explain the relationships between concepts, both in written and oral forms, with the mental readiness to learn, which can lead to frustration (Husniah et al., 2024). In today's digital era, teachers are required to have the skills to design interactive learning, such as on Augmented Reality platforms. The Augmented Reality model in interactive learning is able to encourage the development of teaching that is more dynamic, engaging, and relevant to the needs of students in the current digital era (Indahsari & Sumirat, 2023). In addition, the young age of students and technological limitations pose challenges and constraints in the implementation process, especially at the beginning of the learning process (R. M. Sari, et al., 2023). Therefore, in the classroom, teachers provide instruction, open question-and-answer sessions, and explain concepts that students find difficult to understand. Outside the classroom, teachers provide additional learning resources, answer students' questions, and ensure students have access to learning materials through Augmented Reality media.

The success of learning is greatly affected by the support of parents and the surrounding environment. The primary responsibility of parents as educators at home must be fulfilled (Gunawan & Amaludin, 2021). However, many parents are still not accustomed to using technology. A supportive environment, including a conducive learning atmosphere and adequate time management, plays a crucial role in improving students' active participation while reducing obstacles during the learning process.

CONCLUSION

This study demonstrates that the Discovery Learning model supported by Augmented Reality (AR) media is more effective in enhancing students' critical thinking skills compared to the Problem-Based Learning model using PowerPoint. The findings indicate that students in the experimental class, who used Discovery Learning with AR, showed significantly higher improvements in critical thinking skills than those in the control class. The post-test results revealed that the experimental group achieved an average score of 86, compared to 73 in the control group. Additionally, the N-Gain score of 0.66 in the experimental group categorized the intervention as moderately effective, while the control group achieved a lower score. These results confirm that integrating AR into Discovery Learning creates a more interactive and engaging learning environment, fostering deeper comprehension and analytical skills among students.

Despite its effectiveness, this study also identified challenges, including students' varying levels of technological readiness and the availability of AR-compatible devices. To overcome these limitations, educators should receive training on implementing AR in teaching, and schools should invest in supporting infrastructure to maximize the benefits of digital learning tools.

For future researchers, it is recommended to explore the long-term effects of AR-based Discovery Learning on other cognitive skills, such as problem-solving and creativity. Further studies could also examine its application in different subject areas and grade levels to assess its broader impact. Additionally, investigating the combination of AR with other pedagogical approaches may provide deeper insights into optimizing technology-driven learning environments.

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