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THE EFFECT OF DISCOVERY LEARNING ASSISTED BY AUGMENTED REALITY ON FOURTH GRADE ELEMENTARY STUDENTS' SCIENCE LEARNING OUTCOMES

Syilla Fhadlilla Fharhah¹⁾, Aan Widiyono²⁾

^{1,2)} Elementary School Teacher Education, Nahdlatul Ulama Islamic University of Jepara

*Corresponding author email: 221330000964@unisnu.ac.id

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Abstract

Prompted by the unsatisfactory academic performance of students regarding the abstract principles of force, this research aimed to evaluate the shifts in learning mastery following the integration of Augmented Reality-enhanced Discovery Learning. A quantitative methodology was adopted, utilizing a pre-experimental one-group pretest-posttest framework centered on 32 fourth-grade pupils. The primary data, derived from pre- and post-intervention evaluations, underwent rigorous analysis through a Paired Sample t-Test to determine the efficacy of the instructional tool. The results showed a significant difference between pretest and posttest scores with $t(31) = -14.3$, $p < 0.001$, as well as a Cohen's d effect size of -2.53, indicating a large effect size. The students' average scores increased from 63.7 to 87.0. These findings indicate an improvement in learning outcomes following the intervention. The implications of this study point to the need for further research using a design that includes a control group to strengthen the validity of the findings.

Keywords : Discovery Learning, Augmented Reality, Science Learning Outcomes

Abstrak. Didasari oleh capaian akademik siswa yang kurang memuaskan pada prinsip-prinsip abstrak mengenai gaya, penelitian ini bertujuan untuk mengevaluasi perubahan penguasaan pembelajaran setelah integrasi model *Discovery Learning* berbasis *Augmented Reality*. Metodologi kuantitatif diterapkan dengan menggunakan kerangka pra-eksperimental *one-group pretest-posttest* yang terfokus pada 32 murid kelas empat. Data primer, yang diperoleh dari evaluasi sebelum dan sesudah intervensi, menjalani analisis mendalam melalui *Paired Sample t-Test* untuk menentukan efektivitas perangkat instruksional tersebut. Hasil penelitian menunjukkan adanya perbedaan yang signifikan antara nilai pretest dan posttest dengan $t(31) = -14.3$, $p < 0,001$, serta nilai effect size Cohen's $d = -2.53$ yang mengindikasikan kekuatan pengaruh yang besar. Rata-rata nilai siswa meningkat dari 63.7 menjadi 87.0. Temuan ini menunjukkan adanya peningkatan hasil belajar setelah perlakuan. Implikasi penelitian mengarah pada perlunya penelitian lanjutan dengan menggunakan desain yang melibatkan kelompok kontrol guna memperkuat validitas temuan.

Kata Kunci : Discovery Learning, Augmented Reality, Hasil Belajar IPAS

Background

Enhancing the quality of student engagement through meaningful learning necessitates a thorough review of the current pedagogical strategies applied to Natural and Social Sciences (IPAS) in elementary education. IPAS instruction aims to develop students' ability to understand knowledge about the universe, foster an appreciation for the beauty and fascinating phenomena around them, and cultivate a scientific mindset (Widiyono, 2021). In elementary education, IPAS learning plays a crucial role in developing students' skills and understanding of various natural phenomena, including fundamental concepts such as types of forces, which help students recognize the influence of forces in daily life. However, the topic of forces is often considered abstract and uninteresting, which can lower students' learning outcomes. Therefore, the application of innovative and engaging teaching methods is necessary to improve the quality of the IPAS learning process at the elementary education level (Nurhayati et al., 2025).

Research on learning outcomes is becoming increasingly important because this aspect significantly influences student engagement in the learning process. Learning outcomes serve as a key benchmark for improving a teacher's performance in the learning process (Musyaffa & Isdaryanti, 2024). Learning outcomes can be defined as changes that occur in students after undergoing the learning process (Abduloh et al., 2022). Learning outcomes refer to changes in student behavior resulting from experiences gained through interaction with the learning environment (Marlita et al., 2023). According to Benjamin S. Bloom's taxonomy of educational objectives, educational goals are divided into three domains: cognitive, affective, and psychomotor (Masitoh, 2023). Consequently, adopting a suitable pedagogical strategy is vital for bolstering academic performance among students.

Based on the findings from interviews and observations of the fourth-grade class at SD Negeri 6 Tahunan, it was found that the implementation of IPAS instruction specifically the "Force" unit within Topic 2 of Module 2, Reaching the Learning Objective Achievement Criterion (LOAC) of 75 proved to be a significant hurdle, as student performance consistently

fell short of these expectations. Assessment of student performance reveals that just 37.5% of the class specifically 12 out of 32 individuals attained the KKTP, leaving the remaining 62.5% below the required threshold. These figures highlight a widespread difficulty in grasping the curriculum, signaling an urgent need for pedagogical refinement. Despite the intermittent use of basic technological tools like projectors, current instructional strategies appear insufficient in maintaining consistent student engagement across the cohort. This situation indicates that student learning outcomes in IPAS instruction still need to be improved, particularly regarding abstract concepts such as force.

To address these learning challenges, the Discovery Learning model can serve as a relevant alternative approach to implement. This model emphasizes students' active engagement in discovering learning concepts, resulting in deeper understanding that lasts over the long term (Marinda & Aditya Rakhmawan, 2025). However, according to Westwood, implementing Discovery Learning requires relatively more time and adequate learning resources, and its effectiveness heavily depends on students' abilities. Students often struggle to form opinions and draw conclusions, while some teachers have not yet fully mastered the management of this model (Pranoto, 2023). Therefore, Discovery Learning can be integrated with Augmented Reality technology, which can blend the real environment with virtual objects, allowing students to observe and practice learning objects in a more concrete manner (Carolina, 2022).

Based on these preliminary observations, this study explores the integration of a Discovery Learning framework enhanced by Augmented Reality tools. The focus is specifically directed toward instructing the concept of diverse forces within the elementary science curriculum, aiming to bridge the gap in student understanding. The Discovery Learning model encourages students to deepen their conceptual understanding through the use of various learning resources and independent discovery processes, thereby making learning more meaningful and concrete (Pujiati et al., 2021). The use of Augmented Reality supports this process by presenting visualizations and explanations of force concepts in a clearer and more interactive manner, making it easy for students to use (Setiawan, 2021). The integration of Discovery Learning with Augmented Reality allows students to observe force phenomena directly and discover concepts independently, thereby potentially improving student learning outcomes (Zahro et al., 2024).

The proposition that merging Discovery Learning with Augmented Reality enhances educational efficacy is firmly rooted in existing empirical literature. Notably, Fujiyati (2024) demonstrated that this specific instructional combination not only boosts academic performance but also significantly elevates student motivation and focus during the learning process. Furthermore, a second study by Telaumbanua & Wulandari (2023) found that the use

of the Discovery Learning model with AR media is effective in improving student mastery and learning activities regarding Newton's Law of Gravity. A third study by Firdausa & Darmawan (2024) also concluded that the use of AR media has a positive effect on the learning motivation of elementary school students. Ultimately, the synergy between Discovery Learning and Augmented Reality proves to be a powerful driver for enhancing not only academic achievement but also student involvement and drive. This evidence serves as a foundational pillar for the current inquiry, which investigates performance shifts regarding force concepts in primary education. By doing so, the study seeks to offer fresh perspectives on how AR-backed Discovery Learning can be effectively operationalized in a classroom setting.

Practical learning requirements for students within the concrete operational period serve as the primary catalyst for this study. The research is structured to bridge the gap between curriculum demands and the developmental realities of elementary aged pupils, making them highly dependent on tangible visualizations through Augmented Reality technology. Unlike previous studies that applied this approach to other topics such as the solar system and gravity, this study focuses specifically on the topic of force in fourth grade elementary school within the context of Integrated Science Education (IPAS). Thus, this study also contributes novelty through empirical evidence in improving student learning outcomes on abstract scientific concepts.

The main goal of this project is to see if there is a real difference in how fourth-grade students at SD Negeri 6 Tahunan understand the topic of forces after trying a new way of learning. This method uses Discovery Learning and Augmented Reality. Beyond just analyzing scores, the study wants to help elementary teachers improve their teaching methods and offer fresh insights into how modern technology like AR can support students.

Method

By employing a quantitative pre-experimental design, this research measures the impact of using Augmented Reality within a Discovery Learning model to teach elementary students about force. This methodology mirrors the objective evaluation standards found in recent literature (Maharani et al., 2025), focusing on pre- and post-intervention data to confirm the effectiveness of the chosen instructional media. This study utilizes a One-Group Pretest–Posttest framework, focusing on a consistent set of participants throughout the process. The methodology begins with an initial assessment (O_1) to establish a baseline, followed by the introduction of the experimental intervention (X). Finally, a subsequent evaluation (O_2) is conducted to identify and analyze any significant shifts in the students' educational performance resulting from the treatment (Satriadi et al., 2023). The study focused on the entire fourth-grade cohort at SD Negeri 6 Tahunan, totaling 32 students. By employing a

saturated sampling approach, every individual within this population was included in the final sample, ensuring a comprehensive representation of the group.

The data collection method involved a multiple-choice test that initially consisted of 25 questions; after undergoing a validity test, 20 questions were deemed valid. The cognitive levels of the questions included C4, C5, and C6. Additionally, the researcher conducted direct observations to assess student activities and responses; the researcher also interviewed classroom teachers during the initial phase of the study to identify the starting point of learning and the challenges faced; the researcher also collected photographic documentation as supporting research data. Using Jamovi for data analysis, the study first established instrument validity and reliability through Pearson's correlation and Cronbach's Alpha ($> 0,7$), respectively. With the data confirmed as normal via the Shapiro-Wilk test ($\text{sig} > 0,05$), a Paired Sample t-Test was then employed. This final step aimed to determine how effectively the Discovery Learning model, aided by Augmented Reality, influenced student learning outcomes.

During the second semester (March 2025/2026), this research was carried out at SD Negeri 6 Tahunan with fourth-grade participants across three sessions of 2 x 35 minutes each. Evaluations were conducted at the start (pretest) and end (posttest) of the period. In between, the learning activities strictly adhered to the Discovery Learning stages, which involved stimulating interest, defining problems, managing data through collection and processing, and concluding with verification and generalization. The Augmented Reality platform used in this study was based on Assmblr Edu, operated via a smartphone by scanning a code to display objects in three dimensions.

Result and Discussion

Result

Research at SD Negeri 6 Tahunan engaged 32 fourth graders using a pre-validated test instrument. Out of the 25 multiple-choice questions originally drafted, 20 items were found to be valid and suitable for data collection. The decision to utilize these 20 items followed a comparison where the calculated r -value proved higher than the table value ($r > 0,374$), adhering to the standard 0,05 significance criteria for a sample size of 32 students.

After the validity test was conducted, the next step was the reliability test, which aimed to assess the overall consistency of the instrument in measuring the research variables. Following the statistical assessment, the research tool demonstrated a Cronbach's Alpha coefficient of 0.739. This value confirms that the instrument possesses a remarkably high degree of internal consistency, making it a dependable measure for the study's objectives. This value is above the minimum reliability threshold of 0,7, so the instrument is deemed consistent and suitable for use in the data collection process. These preliminary results

establish a robust justification for advancing to the normality testing phase of the analysis. By comparing pre-intervention and post-intervention assessments, the study sought to pinpoint the impact of Augmented Reality on student performance. The data reveals a substantial shift in mean scores, reinforcing the idea that such media not only streamlines the learning process but also fosters a deeper sense of active participation during classroom sessions. This improvement indicates that students not only comprehend the material on force but also demonstrate enhanced learning outcomes.

A Table 1 illustrates the comparative data between students' initial and final assessment results:

Table 1. Descriptive Statistics of Pretest and Posttest Learning Outcomes							
	N	Mean	Median	Mode	SD	Minimum	Maximum
<i>Pretest</i>	32	63.7	65.0	55.0	17.0	25.0	90.0
<i>Posttest</i>	32	87.0	85.0	85.0	8.31	70.0	100

Data in Table 1 reflects a notable upward trend in academic achievement among the 32 fourth graders at SD Negeri 6 Tahunan after using Augmented Reality-integrated Discovery Learning. This progress is highlighted by the substantial shift in mean scores, which climbed from an initial 63.7 during the pretest to a final average of 87.0 in the posttest. This improvement indicates that, overall, students' abilities improved after receiving the intervention. Additionally, the median score increased from 65.0 to 85.0, and the mode shifted from 55.0 to 85.0, indicating that the majority of students in the class experienced improvement. The standard deviation decreased from 17.0 to 8.31, suggesting that the distribution of scores became more homogeneous following the intervention. The score range also changed, with the minimum score increasing from 25.0 to 70.0, while the maximum score increased from 90.0 to 100. This indicates that students experienced a significant improvement after the intervention. With the data meeting all necessary benchmarks, the analysis proceeds to the normality testing stage. A summary of these findings is documented in the following table.

Table 2. Results of the Normality Test

	N	<i>Shapiro-Wilk</i>	
		W	P
<i>Pretest</i>	32	0.967	0.420
<i>PostTest</i>	32	0.942	0.088

According to the data in Table 2, the assumption of normality for this study has been validated through the Shapiro–Wilk test. The pretest ($W = 0.967$, $\text{sig} = 0.420$) and posttest ($W = 0.942$, $\text{sig} = 0.088$) both yielded significance levels higher than 0.05, demonstrating that the data is normally distributed. Given that these criteria are met, the investigation proceeds to employ a Paired Sample t-Test to further examine the results, as shown below.

Table 3. Results of the Paired Sample t-Test

								95% Confidence Interval		
		statistic	df	p	Mean difference	SE difference	Lower	Upper	Effect Size	
Pretest	posttest	Student's	-14.3	31.0	<.001	-23.3	1.63	-26.6	-20.0	Cohen's d -2.53

As illustrated by the Paired Sample t-Test results in Table 3, there is a clear and statistically significant shift in academic performance after integrating AR-supported Discovery Learning. With a t-value (31) of -14.3 and $p < 0.001$, the data confirms that the observed gains in student scores are highly unlikely to be accidental. The analysis shows a mean difference of -23.3 and a standard error of 1.63 ; notably, the 95% confidence interval spans from -26.6 to -20.0 . Since this range remains entirely outside of zero, it provides definitive evidence of a substantial transformation in student competence following the intervention. Beyond the initial findings, the Cohen's d value of -2.53 signifies a remarkably large effect size resulting from the integration of Augmented Reality. This statistical evidence leads to the rejection of the null hypothesis (H_0) in favor of the alternative hypothesis (H_a). Consequently, it can be concluded that Augmented Reality media plays a transformative role in boosting student achievement in the IPAS subject, particularly for fourth graders at SD Negeri 6 Tahunan when studying the concept of force.

Discussion

The application of Discovery Learning aided by Augmented Reality has proven to be a powerful tool for enhancing student mastery of Force concepts at SD Negeri 6 Tahunan. After the treatment, the average class score jumped from 63.7 to 87.0 , a substantial increase that highlights the model's impact. Most importantly, the study achieved a high success rate, as 31 students (96.9%) were able to secure scores above the required passing mark of 75. This achievement indicates that the change in student learning outcomes was quite substantial following the intervention. Since the concept of force is difficult for students to grasp due to its abstract nature, the Augmented Reality medium allowed this concept to be visualized through interactive simulations, enabling students to observe the effects of force on the motion of objects. Additionally, the decrease in the standard deviation indicates that student learning outcomes became more homogeneous, signaling a more equitable understanding among students following the intervention.

The use of Augmented Reality technology in the learning process makes it easier for students to understand the material (Uno, 2024). Augmented Reality media helps make previously abstract concepts concrete, allowing students to observe and understand the

material more comprehensively (Harahap et al., 2023). Augmented Reality offers significant potential for enhancing the quality of the learning experience through the presentation of digital information integrated with the real environment (Liliernawati et al., 2024). As a technology based tool, Augmented Reality can visualize data in the form of videos, images, or other visualizations (Khaira et al., 2024). This effective integration of the real and virtual worlds requires advanced display technology and supportive design (Aprilia et al., 2025). In line with this, within the context of IPAS learning, Augmented Reality technology facilitates concrete visualization of force phenomena, thereby helping students analyze cause and effect relationships such as the influence of force magnitude on object motion and clarifying the interactions of non contact forces (such as magnetism and gravity) through interactive and systematic visual simulations (Sabila et al., 2026).

From a theoretical standpoint, the synergy between Discovery Learning and Augmented Reality finds its roots in Jean Piaget's principles of cognitive development. This alignment is particularly relevant given Piaget's assertion that primary school-aged children are situated within a specific developmental phase that requires tangible interaction to build understanding (ages 7–11) are in the concrete operational stage. At this stage, students tend to understand concepts more easily through direct experience and visual representations (Wibowo, 2016). Through these visualizations, abstract ideas are converted into more tangible forms, which perfectly matches the cognitive profile of learners in the concrete operational phase. By bridging the gap between theory and reality, this approach caters directly to how students at this developmental level process information. This integration enables students to actively construct their knowledge through immersive and contextual learning experiences (Muspiroh et al., 2025). In accordance with the principles of Discovery Learning, learning is no longer passive but positions students as the primary agents actively engaged in the process of independently discovering concepts (Putri et al., 2025).

The use of augmented reality media fosters students' cognitive engagement through activities involving the analysis, interpretation, and evaluation of the displayed force phenomena. Students can visually observe simulations, understand cause and effect relationships, and draw conclusions based on the empirical experiences they gain (Maulyda et al., 2025). This makes the learning process more interactive and meaningful, which in turn enhances student motivation and active participation. The Discovery Learning model plays a crucial role in facilitating students to develop analytical and practical thinking skills through an innovative learning environment (Aqiela et al., 2026). Thus, the use of Augmented Reality technology supports students in understanding concepts in a more concrete and systematic manner (Finata & Risdalina, 2024).

The primary merit of this technology is found in its power to establish a vibrant learning setting that effectively secures student focus. This capability is essential for maintaining a high level of involvement and interest during complex instructional activities. This medium places students at the center of the learning process, where they play an active role in independently constructing their understanding (Maziyah & Zumrotun, 2025). Students are encouraged to take the initiative to explore knowledge related to the topic of forces by utilizing the various features available within the medium. Additionally, the interactive and visual elements presented enhance students' motivation to actively participate in the learning process (Melati et al., 2023). The use of Augmented Reality based media makes the learning process more engaging while providing optimal benefits (Nikou, 2024). Furthermore, this media encourages students to collaborate with their classmates through activities that involve sharing the knowledge and experiences gained while using the media.

In line with the research by Mufarrikhah & Nuruddin (2026), Augmented Reality media provides clear and realistic visualizations, thereby helping students make concrete connections between concepts and facilitating their understanding of previously abstract material. Research by Putra et al (2026) indicates that Augmented Reality media has a positive and significant impact on increasing students' motivation to learn about three-dimensional shapes. Research by Masayu & Fransyaigu (2026) concluded that Augmented Reality media has proven to be highly effective in increasing students' interest in learning about the provinces of Indonesia. The work of Sari et al. (2026) further supports the notion that Augmented Reality media enhances student enthusiasm for learning three-dimensional geometry. By visualizing mathematical shapes through AR, students demonstrate a much stronger inclination toward mastering 3D construction concepts.

Unlike previous studies, which focused more on engagement and motivation, the findings of this research provide clear evidence that the advancements made play a transformative role in elevating student performance within the science curriculum. This effect is particularly pronounced when examining the mastery of concepts related to the topic of forces. These findings indicate that the effectiveness of Augmented Reality media will be further optimized when integrated with concept-oriented learning models such as Discovery Learning. This study is not without its drawbacks, particularly regarding its experimental design. Conducted within just one class and without the inclusion of a control group, the findings should be interpreted with these structural limitations in mind, so the improvement in learning outcomes cannot yet be comprehensively compared with other learning methods through a more rigorous experimental design.

Conclusion

This study was born from a desire to see if technology could make the invisible laws of force feel real for young learners. The results were deeply encouraging, showing a meaningful difference in how the children performed after experiencing the AR-assisted model. Seeing the average scores climb so significantly gave us the confirmation we needed that our objectives were met with sincerity and success. Looking ahead, we envision even more robust research that includes a control group. Doing so would help us protect and refine these teaching methods, ensuring they provide a holistic and comprehensive benefit to classrooms everywhere.

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