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AI-Science Learning with a Deep Learning Approach to Improve Inclusive Student Learning Outcomes

Siti Mayang Sari[1], Fidawati[2], Zahraini[3], Akmaluddin[4]

[1,2,3,4]Bina Bangsa Getsempena University, Banda Aceh, Indonesia
*Email: mayang@bbg.ac.id

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ABSTRACT

Purpose - This study aimed to investigate the effectiveness of implementing AI-based science learning integrated with a deep learning approach in improving the academic achievement of inclusive students. This study also evaluated the impact of deep learning strategies on inclusive students' conceptual understanding, engagement, and critical thinking skills in science learning.

Methodology – This study uses a quantitative approach with 25 elementary school students, including inclusive students who have adopted or tried AI-based or deep learning-based educational tools in science lessons.

Findings – The results of this study indicate that the implementation of AI-based science learning and deep learning positively impacted the academic achievement of elementary school students, including those with special needs. The average post-test score for students increased by 21%, comparable to their peers. Observational data show that inclusive students are more actively engaged during learning. AI features such as voice support, visual simulations, and interactive tasks helped reduce learning barriers, boost their confidence, and increase their participation in science learning activities. Student feedback collected during the learning sessions indicated that most students found the AI-based learning tools enjoyable and easy to use. Paired-sample t-test results showed a statistically significant difference between pre- and post-test scores ($p < 0.05$), confirming the effectiveness of AI-based learning and deep learning in improving students' science learning outcomes.

Contribution – The results of this study demonstrate that AI-based learning tools, integrated with deep learning strategies, are highly effective in supporting inclusive education. AI adapts to diverse learning needs and can reduce barriers for students with special needs in the classroom, benefiting learning for diverse students.

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INTRODUCTION

Technology integrated into learning has transformed conventional teaching methods and created new opportunities for inclusive and diverse learning. Artificial Intelligence (AI) has emerged and is helping some teachers as a powerful tool in differentiated learning by providing adaptive content, feedback, and intelligent tutoring systems. AI offers a variety of accessibility technologies, such as screen readers, speech recognition, and sign language translation tools, which make it easier for students with visual, auditory, or cognitive disabilities to learn. For example, AI-powered text-reading software can assist students who struggle to read due to dyslexia. Meanwhile, speech recognition allows students with motor disabilities to interact with digital devices using their voice. This facility is invaluable in inclusive classrooms, where students with diverse learning needs require tailored support to access and understand lessons. AI has great potential to support inclusive education by providing more tailored learning and improved accessibility. However, this technology is not the sole answer to the challenges of inclusive education. Science learning at the elementary level plays a crucial role in developing students' curiosity, problem-solving skills, and conceptual understanding. However, many inclusive students often face challenges in understanding scientific concepts due to attention, language, or cognitive processing limitations. Traditional teaching methods do not fully address these differences, leading to gaps in learning outcomes and student engagement (Bhardwaj et al., 2021). Deep learning approaches in education focus on knowledge retention and developing higher-order thinking, analysis, synthesis, and reflection. When combined with AI technology, deep learning can foster meaningful, student-centered learning experiences. This synergy holds great promise for inclusive education, where students benefit from meaningful learning.

Despite growing interest in AI and deep learning in education, their application in inclusive science classrooms at the elementary level remains limited. Therefore, this study aims to examine the implementation of AI-based science learning integrated with deep learning strategies to improve inclusive student learning outcomes. It aims to evaluate this approach's effectiveness, challenges, and potential in supporting high-quality education for all learners. (Ahmad & Seandy, 2024). There is a lack of empirical studies focusing on how deep learning technologies support inclusive students in educational settings (Korhonen et al., 2019). Therefore, this study aims to analyze the implementation of deep learning as a technical guide in inclusive classrooms. This research investigates how deep learning-based tools are implemented and evaluates their impact on inclusive teaching and learning practices.

This research aims to provide practical insights and theoretical contributions to inclusive education and educational technology. This research benefits schools implementing AI as a recommended technology-based immersive learning tool. Thus, this research contributes to the growing understanding of the relationship between technology and inclusive education, through the role of AI not only as an efficiency driver but also as a potential equalizer in diverse learning environments. In this era of rapid technological advancement, education is shifting toward more personalized, data-driven, and adaptive learning environments. While few studies have explored the effectiveness of AI in general and inclusive education contexts, this study combines the use of AI and immersive learning approaches in science classes with inclusive elementary school students. There is a critical need to examine how such integrated approaches impact inclusive students' learning outcomes, engagement, and critical thinking skills, and how educators can adopt these methods in practice. This study aims to fill this gap by investigating the implementation of AI-based science learning integrated with immersive learning strategies in inclusive elementary school settings. The objectives of this study include assessing the effectiveness of science learning implementation in improving learning outcomes, evaluating student engagement, especially among inclusive learners, and identifying opportunities and challenges in implementing this approach in real classrooms and designing more equitable, adaptive, and inclusive learning environments in science education (Mbua, n.d.). One of the most transformative technologies shaping this change is artificial intelligence (AI), intense learning, which has been widely applied across various fields and is increasingly used in education (Bengio, Lecun, and

Hinton 2021). Deep learning can simulate cognitive functions for humans, managing everyday thoughts and behaviors, even habits (Giovannini, 2019).

Immersive approaches to education offer significant opportunities for automated assessment, real-time feedback, personalized instruction, and student analytics. Inclusive education has received significant attention in the education sector due to the limitations experienced by special needs students, but the adaptability of its capabilities to those of regular students. Schools already provide learning media for inclusive students, with various teacher creativity and meaningful teaching techniques, despite limitations in teacher capacity, learning facilities, a lack of individual teaching tools, and inadequate support systems. Traditional teaching methods are often not flexible or responsive enough to meet the needs of students with special needs. Students require differentiated strategies, visual technology, and engaging learning. Recent advances in deep learning offer a variety of new tools that have the potential to transform inclusive education. For example, adaptive learning platforms powered by deep learning can analyze student performance and adjust learning paths accordingly (Susilawati et al., 2021). Speech-to-text and text-to-speech tools can help students who struggle with speaking or writing. At the same time, emotion recognition and behavior analysis can provide teachers with insights into student engagement, stress, or confusion (Korhonen et al., 2019). Through these tools, students are more engaged in learning and engage in meaningful learning.

Educational technology offers innovation, with promising pilot programs emerging in developed and developing countries. The application of immersive learning in inclusive education remains underexplored in the educational world. Most current research on AI in education focuses on efficiency, on the learning of students with special needs and those with disabilities in mainstream classroom settings, with little emphasis on equity, inclusion, or accessibility *(*Gabriel, 2024*).* Critical evaluation of student learning outcomes through technology-enabled testing is needed (Shaxnoza Akbarovna, 2022*).* This study provides empirical evidence on the usefulness and effectiveness of immersive learning in inclusive environments, a topic that remains underexplored in current research issues. In line with current developments, this study is related to the empowerment of human resources integrated with the globalization of technology taught to inclusive learners. In line with this, this study identifies key features and design principles that make AI devices inclusive, responsive, and adaptive. Learning related to AI, teachers should contribute more to the achievements designed in learning so that they can improve learning outcomes and obtain meaningful knowledge in depth that is significant to learning objectives.

METHODOLOGY

This study used an experimental approach with a single-group pre-test and post-test design. This model was used due to the limited number of participants and the inclusive classroom environment.

Subjects

The subjects of this study were 25 fourth-grade students at Banda Aceh 1 Public Elementary School, including several inclusive students. The sample was randomly selected and given the same treatment for in-depth science learning using AI implemented by the teacher in the lesson. The sample consisted of: (1) students in an inclusive classroom with diverse learning characteristics, (2) students have different learning needs, including students with mild disabilities, (3) students have access to simple technology devices (computers/tablets/smartphones), and (4) students were accompanied by a classroom teacher who understood the characteristics of inclusive students.

Instruments

The test instruments used in this study are science learning outcomes test, student response questionnaire, and teacher response questionnaire. Science learning outcomes test consisting of multiple-choice and essay questions aligned with core competency indicators. This test was administered as both a pre-test and post-test. Student response questionnaire during the learning implementation for various students to measure motivation, attention, participation, and learning Independence during the learning process. Teacher response questionnaire to observe the implementation of the immersive learning process and the use of AI features with students.

Research Procedure

The steps for implementing the research are as follows:

1. Pre-Test: Measures students' prior knowledge of the science material to be taught.
2. Learning Implementation: Students participate in science learning using an AI-based platform designed with a deep learning approach.
3. Post-Test: Conducted after the entire learning process is completed to assess learning outcomes.
4. Observation and Engagement Scale: Completed during and after learning to assess the extent to which students are engaged in the learning process.

The research flow is explained as follows:

Table 1. Research Flow

Group Pre-test	Treatment Post-test
Experiment	Control
O_1 X O_2	O_3 – O_4

Data Analysis

Data analysis was conducted through the following stages: Normality and homogeneity tests for pre-test and post-test scores. Paired-sample t-tests were used to determine significant differences between pre-test and post-test scores. Calculate Gain Score and Effect Size (Cohen's d) to assess learning effectiveness—descriptive analysis of the results of the engagement scale and observation sheets.

FINDINGS

The findings revealed that the tools used by teachers were AI applications that support a more meaningful student learning process. Deep learning-based learning provides a new atmosphere in learning with collaboration and elaboration of diverse students by eliminating the learning gap between inclusive and non-inclusive students. Thus, it can be explained that the lessons carried out by teachers have significantly impacted learning outcomes in accordance with the objectives. The effectiveness of student learning engagement is described in the following table:

Table 2. Pre-test and Post-test Results

Measure	Pre-Test Mean (M)	Post-Test Mean (M)	Standard Deviation (SD)	t-value	p-value	Effect Size (Cohen's d)
Academic Performance Score	65.24	78.56	10.12	5.43	< .001*	1.21 (Large)
Engagement Rating	3.42	4.15	0.85	4.21	.002*	0.95 (Large)

The average learning outcome score increased from 65.24 (SD = 10.12) in the pre-test to 78.56 in the post-test. A paired sample t-test showed this increase was statistically significant, $t = 5.43$, $p < 0.001$. This shows student learning outcomes in the learning evaluation process. To determine the effect of the application of in-depth learning, a retest was conducted on 25 students with diverse backgrounds who had participated in learning with AI technology through the implementation of science learning.

Table 3. Assessment indicators for Data Practicality

No	Assessed Aspect	Mean (M)	Standard Deviation (SD)	Maximum Score
1	Concept Understanding	82.4	6.8	100
2	Active Participation	78.6	7.3	100
3	Learning Independence	80.1	5.9	100
4	Communication Skills	76.5	8.1	100
5	Overall Achievement Score	79.4	6.7	100

Table 3 presents the results of practicality data through flashbacks on the inclusive students' in-depth learning process based on the five assessed aspects. The highest mean score was found in Conceptual Understanding (M = 82.4, SD = 6.8), indicating a strong understanding of the science material presented to students. Learning Independence (M = 80.1, SD = 5.9), indicating that students could manage their learning process facilitated by AI. Students' Active Participation showed a high average score (M = 78.6, SD = 7.3), namely student involvement during learning activities. Communication Skills had the lowest average score (M = 76.5, SD = 8.1), thus requiring further guidance from teachers to students. The total achievement score was M = 79.4 (SD = 6.7) out of a maximum score of 100, indicating that the diversity of learning outcomes levels is deep among students. These results reflect the positive impact of the applied learning approach and its specific approach in enhancing student understanding, Independence, and engagement in the learning process.

Table 3. Post-Test on The Five Assessed Aspects

No	Assessed Aspect	Mean (M)	SD	Max Score	t-value	df	p-value	Effect Size (Cohen's d)
1	Concept Understanding	82.4	6.8	100	-12.61	29	< .001*	2.59 (Very Large)
2	Active Participation	78.6	7.3	100	-14.65	29	< .001*	2.77 (Very Large)
3	Learning Independence	80.1	5.9	100	-16.87	29	< .001*	3.08 (Very Large)
4	Communication Skills	76.5	8.1	100	-14.57	29	< .001*	2.63 (Very Large)
5	Overall Achievement Score	79.4	6.7	100	-15.37	29	< .001*	2.83 (Very Large)

The data in Table 3 explain that the highest average score was found for students' Conceptual Understanding, with a score (M = 82.4, SD = 6.8), indicating strong content mastery and student engagement. Learning Independence also showed solid results (M = 80.1, SD = 5.9), indicating that students could manage their learning effectively and collaborate with diverse students. Meanwhile, the implemented science learning had the lowest average score (M = 76.5, SD = 8.1), indicating a relatively weaker area that may require targeted support, as the initial learning techniques with AI can be further improved. These findings indicate enhanced immersive learning significantly improves students' conceptual understanding and active engagement. The visual and interactive nature of the learning tools contributes to increased focus, motivation, and self-regulation among students with special needs. Students' need for technology significantly contributes to strong learning, so the immersive impact of AI-based lessons involving visualization provides new experiences for diverse students.

Integrating deep learning technology as a deep learning technique for inclusive students has shown measurable benefits across several core competencies. Based on assessment data, students showed significant performance improvements in various aspects of learning. Through conceptual understanding, the highest mean score was found in conceptual understanding, indicating that systems supporting deep learning (e.g., personalized content delivery, intelligent tutoring) effectively support students in understanding and remembering new material. Visual recognition, natural language processing, and adaptive feedback mechanisms likely contribute to reinforcing key concepts in a way accessible to students with different needs. Students' Learning Independence scored relatively high, indicating that AI-powered devices empower students to engage with content independently. This is important in inclusive environments, where students may struggle in traditional, one-size-fits-all instruction models. Active participation is caused by interactive features in deep learning-based applications, such as real-time feedback, speech recognition, or gamification elements. Communication Skills received the lowest average score, which still reflects a positive result. Overall achievement shows that implementing deep learning in inclusive education supports cognitive development and creates a more inclusive and student-centered learning environment. Moderate standard deviations across aspects indicate consistency.

DISCUSSION

The one-sample t-test results in Table 3 provide meaningful insights into inclusive students' deep learning gains following the instructional intervention. Although no mean scores reached the theoretical maximum of 100, all assessed domains—including conceptual understanding, active participation, learning Independence, communication skills, and overall achievement, showed statistically significant differences from the maximum scores ($p < .001$). The effect sizes were consistently large to very large (Cohen's $d > 2.5$), indicating that these deviations were statistically significant and practically meaningful. These findings suggest that although inclusive students have not achieved complete mastery, they have made significant progress in key learning domains (Gabriel, 2024). The highest mean score in conceptual understanding ($M = 82.4$) indicates that students could effectively understand and internalize academic content. This may reflect the strength of the instructional strategy that emphasized clarity, scaffolding, and visual support based on elements known to benefit inclusive learners (Fitas, 2025). Strong performance in learning Independence ($M = 80.1$) speaks to students' ability to manage tasks and make decisions about learning independently. This is encouraging, as Independence is an important goal in inclusive education and a key indicator of student agency and self-regulation. Students' communication skills achieved ($M = 76.5$) recorded the lowest mean score, indicating that although students can engage cognitively and behaviorally, expressing ideas and interacting with others remains a challenge. This is due to barriers such as language processing difficulties or limited socio-pragmatic support during learning (Mardhatillah et al., 2023). According to Vygotsky's sociocultural theory, interaction plays a crucial role in constructing knowledge, and therefore, improving communicative competence should be prioritized (Alkalah, 2022). The findings of this study indicate that inclusive students benefit from well-structured and differentiated learning environments. AI in education enables the delivery of personalized learning trajectories by continuously assessing student progress and adjusting content, feedback, and pace (Bengio et al., 2021), Flexible learning environments accommodate diverse learners' abilities, interests, and backgrounds AI provides varying levels of support based on each student's performance and interaction patterns (Yang & Taele, 2025). For example, students with reading difficulties receive additional voice-over guidance and sectioned materials, while students with visual impairments access text-to-speech tools and tactile learning elements (Arends & Kilcher, 2010).

These capabilities reflect a shift toward equity-focused digital education, where technology is a tool for efficiency and a driver of inclusive pedagogy (Sumarni et al., 2024). From a cognitive development perspective, integrating deep learning strategies significantly enhances students' knowledge (Harrington et al., 2019). According to (Bengio et al., 2021), deep learning involves meaningful engagement with science learning materials to understand fundamental science principles and connect them to prior knowledge (Bhardwaj et al., 2021). AI-based platforms foster this depth of learning by: Presenting real-world problem scenarios to contextualize science content; Facilitating interactive simulations where students can manipulate variables and observe outcomes; and providing formative feedback that immediately adapts to student errors, encouraging metacognitive reflection (Ahmad & Seandy, 2024). These features align with constructivist learning theory (Alkalah, 2022), particularly the Zone of Proximal Development (ZPD) notion. AI effectively acts as a "more knowledgeable other" by guiding students through tasks they cannot complete independently but can accomplish with digital scaffolding (Fathoni et al., 2023; Gilbert, 2015). Adaptive learning is crucial in maintaining student motivation and engagement, especially among those who struggle with self-efficacy (Rochim & Nurhayati, 2023). This confirms the findings of (Yang & Taele, 2025), who argued that AI-based learning platforms offer dynamic scaffolding that evolves based on ongoing interactions between learners. Such platforms simulate face-to-face tutoring, which is rarely possible in crowded or under-resourced classrooms (Sa'adah et al., 2018). Emotionally and behaviorally, many inclusive students in this study demonstrated increased persistence in completing tasks and self-regulated learning behaviors, such as revisiting content or using embedded hints when encountering difficulties (Filina & Sari, 2024).

This reflects the characteristics of deep learning, which views learning as an active process driven by intrinsic goals and curiosity. From an inclusive education perspective, this finding is highly significant. Conventional teaching methods often fail to meet the needs of students with disabilities. Technology, such as AI, is crucial for inclusive learning and impacts the achievement of Sustainable Development Goal 4 (SDG 4): Quality Education for All, and the role of teachers in providing meaningful learning in the era of AI-based learning (Mahbub, 2024).

Learning is now based on content delivery, with teachers increasingly acting as learning facilitators and data interpreters, using AI-generated analytics to identify learning gaps, adjust instruction, and provide social-emotional support. AI collaboration in pedagogical decision making, especially in environments that demand sensitivity to diverse learners' backgrounds. The synergy between AI-based adaptive learning and immersive learning strategies improves academic outcomes and strengthens students' personal agency, especially those often marginalized in traditional classrooms. These findings support calls for scalable, inclusive, AI-based education models grounded in evidence, equity, and empathy.

CONCLUSION

This study shows that deep learning-based educational tools can be functional in learning and effective for inclusive students, significantly enhancing artificial intelligence (AI) in a mild inclusive classroom proven to improve conceptual understanding, encourage active participation, promote self-directed learning, and develop communication skills among students with various needs. Statistical analysis confirmed the significant positive impact of the intervention, with large effect sizes indicating substantial learning gains. The results suggest that deep learning can support personalized instruction for inclusive and normal students at their own pace and according to their needs. The inclusive educational environment is highly supportive, and AI applications provide complex insights and understanding for students. The findings underscore the importance of teacher readiness, infrastructure support, and accessibility in maximizing the benefits of AI integration. While deep learning tools have strong potential, they must be complemented with inclusive teaching strategies and human-centered support systems. Inclusive education is a promising approach to bridge the learning gap and promote equitable learning opportunities for all students, regardless of their abilities or backgrounds.

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