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Implementation of Interactive Media-Based Deep Learning in Elementary School Students' Science Learning

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Abstract: The development of educational technology has encouraged the need for learning innovations that can improve conceptual understanding and student engagement, especially in science subjects in elementary schools. This study aims to analyze the effect of the implementation of interactive media-based deep learning on learning outcomes and student engagement in Grade IV students. The study used a quantitative approach with a one-group pretest–posttest design involving 30 students at MI Muhammadiyah Tahfidzul Qur'an. The instruments consisted of a learning outcome test and an activity observation sheet. Data analysis was carried out using a paired sample t-test and effect size calculation. The results showed a significant increase in learning outcomes, from 64.40 to 77.20 ($t = -22.06$; $p = 0.000$), and an increase in student activeness from 60.40 to 78.77 ($t = -24.252$; $p = 0.000$). The very large effect size values ($d = 4.02$ for learning outcomes and $d = 4.24$ for student activeness) indicate that the learning influence is very strong and practically meaningful. These findings confirm that interactive media-based deep learning is effective in improving academic achievement and active student participation, making it suitable for implementation as a learning strategy in the science subject in elementary schools.

Keywords: Deep learning; Interactive media; Learning outcomes; Science and technology; Student activity

Introduction

Basic education is the primary foundation for student development, in line with the National Education System Law No. 20 of 2003. At this level, science and natural sciences learning play a crucial role because the material is closely related to human life (Lestari et al., 2025) and aims to develop critical thinking, observation, and problem-solving skills (Wahyuni et al., 2024). Entering the 21st century, technological developments demand a transformation in education, encouraging teachers to integrate technology and improve digital literacy (Rahayuningsih & Muhtar, 2022; Murtiyasa & Anisyawati, 2022). Innovation in learning media is urgently needed to make the science and natural science learning process more effective, efficient, and relevant (Arni et al., 2025; Adu-Gyamfi et al., 2024). However, practices in elementary schools often remain classical, emphasizing memorization and relying solely on blackboards and textbooks, resulting in students lacking active engagement and struggling to grasp abstract concepts (Tony et al., 2025). This situation makes interactive learning media crucial, especially since elementary school students rely heavily on visual stimuli (Sutama et al., 2020). Empirical research shows that interactive media effectively improves learning outcomes and active participation (Saputri et al., 2025), supported by features such as quizzes, animations, and automated feedback that foster systematic understanding (Hayati et al., 2025; Sulistyanto et al., 2023; Li et al., 2025).

The shift from teacher-centered to student-centered learning demands an appropriate approach, namely interactive media-based deep learning. This approach emphasizes student engagement in deep thinking, understanding concepts, and linking knowledge to real-life experiences (meaningful, mindful, joyful). Deep learning (DL) is seen as an approach that encourages

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students to build meaningful knowledge (Putra et al., 2025), enhances critical thinking skills and creativity, and supports scientific literacy. DL, supported by AI technology, enables adaptive and personalized learning, increases active participation, and minimizes conceptual gaps (Naseer & Khawaja, 2025). Although infrastructure and digital literacy challenges persist, policy and academic support emphasize the importance of integrating digital learning (DL) to improve learning quality and develop character (Muhibbin et al., 2020).

Theoretically, deep learning (DL) has been shown to help students retain long-term conceptual understanding (Heffernan & Heffernan, 2014) and strengthen cognitive competencies. The use of interactive media, including AI-based media, has been shown to automatically develop assessments and provide digital literacy training to teachers (Hanis & Wahyudin, 2024; Sadikin et al., 2025). Through the exploration, visualization, and active problem-solving enabled by interactive media, the implementation of interactive media-based DL is believed to improve learning outcomes and student engagement (Fuad et al., 2025; Santoso et al., 2024). The purpose of this study is to analyze the effect of implementing interactive media-based deep learning on learning outcomes and student activity in elementary school science subjects, with the hypothesis that there is a significant influence on both variables.

Method

This study employed a quantitative approach with a one-group pretest/posttest design. This design was chosen because the study involved only one class without a comparison group. The study was conducted at MI Muhammadiyah Tahfidzul Qur'an, with 30 fourth-grade students as subjects. The research topic was the Social Sciences (IPAS) chapter on Force and Motion. Prior to the lesson, students were given a pretest to assess their initial abilities in the aspects of IPS learning outcomes and activeness. After the interactive media-based deep learning was implemented, students were given another posttest and observations of their activeness were conducted.

The research data consisted of pretest and posttest scores on learning outcomes, as well as observation scores on activeness before and after the treatment. The test instruments and observation sheets were designed based on IPS indicators and were validated for their feasibility through expert validation. Data analysis was conducted using a paired sample t-test to determine differences in results before and after the treatment.

Result and Discussion

The research results show that the use of interactive media-based deep learning can produce significant changes in student learning outcomes, both in terms of conceptual understanding and their engagement in the learning process. The improvement between pretest and posttest scores for the learning outcome variables indicates that the media used not only serve as a supplement but actually helps students understand the material more comprehensively. The average score, which was initially 64.40, increased to 77.20 after the treatment. This nearly 13-point increase demonstrates that the more visual, interactive, and systematic learning approach allows students to learn at their own pace. This improvement aligns with the results of the statistical analysis. The very large t-value ($t = -22.064$) and a significance level of 0.000 indicate that the changes were not coincidental but a direct impact of the implemented learning strategies. The same trend was observed for the activeness variable. Student activeness scores increased from 60.40 to 78.77 after the use of interactive media. This increase demonstrates that students not only understood the material better but also demonstrated greater interest and engagement during the learning activities.

The relationship between measurement periods is also evident in the significant correlation values. For learning outcomes, a correlation of 0.649 indicates that students with better initial understanding maintained their performance after the lesson, demonstrating that improvements occurred consistently across all students. For engagement, a correlation of 0.519 suggests that the pattern of change also occurred across most students, although the variation was slightly greater than for the learning outcomes. A stronger impact was evident from the effect size calculations. Cohen's d for learning outcomes reached 4.02, while for engagement, it was 4.24. Both values are well above the "large" category, confirming that interactive media significantly contributed to achieving learning objectives. The strength of this effect indicates that learning not only improved scores but also influenced how students interacted with the material and constructed their own understanding.

When linked to the characteristics of science subjects, which require exploration, observation, and conceptual reinforcement activities, these findings become relevant. Interactive media allows students to engage more actively through visual displays, instant quizzes, simulations, and feedback features that help them check their understanding directly. Students become more than just recipients of information, but also engage in deeper thinking processes, in line with the

concept of deep learning itself: meaningful, playful, and joyful. Overall, this study reinforces the view that integrating interactive media into learning can enhance the effectiveness of learning activities. These findings align with various previous studies, but demonstrate a much greater impact. This can serve as a foundation for teachers and schools to develop more innovative learning patterns and expand the use of digital media that supports meaningful learning in science subjects.

Table 1. Descriptive Statistics of Learning Outcomes

Variables	N	Mean	SD	difference	T	p	Cohen's d
Pretest Learning Outcomes	30	64.40	3.93	-	-	-	-
Posttest Learning Outcomes	30	77.20	3.62	12.80	-22.06	0.00	4.02

Table 2. Descriptive Statistics of Activity

Variables	N	Mean	SD	difference	T	p	Cohen's d
Pretest Learning Outcomes	30	60.40	3.927	-	-	-	-
Posttest Learning Outcomes	30	78.77	4.477	18.37	-24.25	0.00	4.24

Table 3. Pretest–Posttest Correlation

Variable		
Learning Outcomes	0.64	0.00
Activity	0.51	0.00

Research findings confirm that the implementation of interactive media-based deep learning significantly impacted learning outcomes and student engagement in fourth-grade science subjects at MI Muhammadiyah Tahfidzul Qur'an. Deep learning, which emphasizes concepts, analysis, and connections to student experiences, is more optimal when supported by animations, videos, simulations, and digital quizzes (Diab et al., 2024; Alnasyan et al., 2024). Interactive media is considered capable of helping to concretely understand abstract science concepts, enabling students to not simply memorize but truly understand the material in depth. In addition to improving conceptual understanding, interactive media also encourages student engagement during learning. These findings align with previous research that confirms interactive media improves learning outcomes and student engagement (Natharani et al., 2024; Agustin et al., 2025).

The Role of Interactive Media in Reducing Cognitive Load

The significant improvement in learning outcomes (mean increase from 64.40 to 77.20; t=−22.06) can be explained through cognitive theory, particularly in the context of multimedia learning.

Utilization of Visualization

Science subjects often contain abstract concepts (e.g., force and motion) that are difficult for elementary school students to visualize. Interactive media provides dynamic visualizations (animations, simulations) that help transform abstract concepts into more concrete representations (Oktariani et al., 2024).

Reducing Extraneous Cognitive Load

When information is presented through a balance of visual (media) and auditory (teacher explanation) channels, it reduces unnecessary cognitive load (extraneous cognitive load) and optimizes students' working memory. Students can focus on processing essential information (germane cognitive load) (Howie et al., 2023; Paas & Van Merriënboer, 2020).

Self-Directed Learning

Automatic feedback and instant quizzes allow students to control their own learning pace. This mechanism aligns with the concept of "self-regulated learning," where students actively monitor and adjust their understanding without waiting for correction from the teacher (Ponomariovienė et al., 2025; Langelaan et al., 2024; Amerstorfer et al., 2021).

Deep Learning and Student Intrinsic Motivation

The increase in student engagement (scores rose from 60.40 to 78.77; t=−24.252) indicates success in increasing engagement and motivation. This increase is closely related to the deep learning approach, which is described as meaningful, mindful, and joyful (Sudarmono et al., 2025; Feriyanto & Anjariyah, 2024).

Joyful Learning

Interactive media, often packaged as games (gamification), directly trigger intrinsic motivation. When students enjoy the learning process, they naturally become more active in asking questions, discussing, and exploring (Koć-Januchta et al., 2020; Salmon & Barrera, 2021; Dahl et al., 2025).

Mindful and Meaningful Learning

In the context of science, interactive media can create structured challenges (problem-solving activities) (Nisa' & Yulianto, 2025; Manurung & Pangabean, 2017). This active engagement (such as through practical

simulations) encourages students to engage in deeper information processing. They do not just memorize facts but connect new concepts to their existing knowledge and experience, which is the essence of the deep learning approach.

Consistency of Improvement and Implications of Correlations

The significant positive correlation between pretest and posttest (r=0.64 for learning outcomes and r=0.51 for engagement) provides additional perspective.

Learning Outcome Correlation

This relatively high correlation implies that the intervention successfully improved overall scores without eliminating initial differences between students. Students who were already performing well at the start (with better initial understanding) continued to benefit, and weaker students also improved. This suggests that the interactive media are adaptable enough to accommodate different levels of understanding (Mani et al., 2025).

Activity Correlation

The lower correlation indicates that although engagement increased on average, there was greater variation in individual patterns of change. This means that not all students responded to the intervention with the same level of engagement, suggesting that personal factors (e.g., personality, home environment) may play a larger role in engagement than purely cognitive outcomes. Overall, these findings support the literature that technology integration, particularly interactive media, acts as a bridge between abstract concepts and elementary school students' understanding, as well as a motivational trigger that shifts the focus of learning from passive to active and exploratory (Garcia I Grau et al., 2021; Yue et al., 2025).

Conclusion

This study demonstrates that the implementation of interactive media-based deep learning has a strong impact on improving student learning outcomes and engagement in elementary school science subjects. The increase in mean pretest and posttest scores for both variables, along with statistically significant results, demonstrates that interactive media can strengthen conceptual understanding and increase student engagement during the learning process. The very large effect size also confirms that the learning impact is not only statistically significant but also practically meaningful in the context of science learning. Interactive media-based deep learning can be an effective alternative strategy to support a more meaningful and active learning process, aligned with the demands of current educational technology developments.

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Author Contributions

Conceptualization, H.F.; methodology, H.F.; validation, H.F.; formal analysis, H.F.; investigation, H.F.; data curation, H.F.; writing—original draft preparation, H.F., N.S., F.S.U., T.E., B.M.; writing—review and editing, H. F., N. S., F. S. U., T. E., B. M.; All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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