

The Integration of Deep Learning and Digital Interactive Boards in Elementary School Learning

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ABSTRACT

Background: The increasing use of digital technology in elementary education encourages schools to adopt learning approaches that promote active and meaningful student engagement. In boarding school settings, digital interactive boards combined with deep learning offer new opportunities to support students' cognitive, emotional, and behavioral development.

Aims: This study aims to analyze the implementation of the integration between deep learning and digital interactive boards in elementary school learning and to examine its impact on student engagement within a boarding school environment.

Methods: This study employed a qualitative approach using an intrinsic descriptive case study design. Data were collected through classroom observations, semi-structured interviews with teachers and school administrators, focus group discussions with students, and document analysis. The data were analyzed using the interactive model of Miles, Huberman, and Saldaña.

Result: The findings reveal that digital interactive boards function as cognitive enablers and collaborative learning media that support conceptual understanding, critical thinking, and problem-solving skills. Their integration with deep learning encourages active participation, positive emotional responses, and stronger behavioral engagement among students. Nevertheless, challenges related to teachers' technical workload, screen-time management, and the development of digital learning content remain.

Conclusion: The integration of deep learning and digital interactive boards contributes to the development of meaningful and student-centered learning environments in elementary schools, provided that adequate pedagogical and institutional support is available.

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Introduction

The digital transformation taking place in education has changed not only the tools used in classrooms but also the way students construct knowledge and interact with learning materials (Olivares et al., 2021; Timotheou et al., 2023). Elementary schools are increasingly encouraged to adopt educational practices that promote critical thinking, creativity, communication, and collaboration as essential competencies for the twenty-first century (Kennedy & Sundberg, 2025; Z. ur Rehman, 2023). In recent years, schools have invested in various digital technologies to create more engaging learning environments and to respond to the needs of students growing up in a technology-rich society (Johler & Krumsvik, 2024; Navas-Bonilla et al., 2025). However, the successful integration of technology depends on pedagogical strategies that enable students to actively participate in the learning process rather than merely consume information (Marougkas et al., 2023; Wekerle et al., 2022). Consequently, educational institutions must reconsider how digital resources can be employed to support meaningful learning experiences.

One of the technologies that has attracted considerable attention is the digital interactive board (Mhlongo et al., 2023; A. Rehman et al., 2024). Unlike traditional whiteboards, interactive boards provide opportunities for teachers and students to manipulate multimedia content, access online resources, and collaborate in real time (Chan et al., 2024). Their interactive features allow abstract concepts to be represented visually and dynamically, which is particularly important for elementary school learners

whose cognitive development still relies heavily on concrete experiences (Kallia & Cutts, 2023; Tsai et al., 2026). Previous studies have reported that interactive technologies can enhance classroom participation and facilitate collaborative learning activities (Wen, 2021). Nevertheless, technological devices alone cannot guarantee improvements in educational quality if they are not accompanied by appropriate instructional approaches.

The widespread use of educational technology has also revealed several challenges. In many schools, digital tools are still employed primarily as presentation media, resulting in passive learning experiences that emphasize information delivery rather than knowledge construction (Abedi, 2024; Colasante, 2022). Researchers have expressed concerns about excessive screen exposure, limited student autonomy, and the risk of reducing classroom interaction to one-way communication (Durgungoz & Durgungoz, 2025). Such conditions indicate that technological innovation should be supported by pedagogical models capable of encouraging inquiry, reflection, and higher-order thinking (Vendrell & Johnston, 2026). Without a solid pedagogical foundation, sophisticated technologies may fail to generate meaningful educational outcomes.

These challenges become even more relevant in boarding school settings, where students spend most of their daily lives within a structured educational environment (Darwanto et al., 2024). Boarding schools provide opportunities for learning activities to extend beyond formal classroom sessions and continue through interactions in residential settings. As a result, the integration of technology in this context should not only improve academic performance but also contribute to students' cognitive, emotional, and behavioral development (Kosmas & Zaphiris, 2023; Shahzad et al., 2024). Understanding how digital tools can support these dimensions is therefore essential for designing effective learning environments in elementary education.

Among the pedagogical approaches currently receiving increasing attention, deep learning offers a promising framework for creating meaningful learning experiences (Kong & Yang, 2024). Deep learning emphasizes conceptual understanding, critical reflection, knowledge transfer, and students' active engagement with authentic problems (Shen & Chang, 2023). Rather than focusing on memorization, this approach encourages learners to connect new information with prior knowledge and apply it in different contexts (Nilimaa, 2023). For elementary students, deep learning is particularly important because it supports the development of reasoning skills and independent learning habits from an early age. Furthermore, the integration of deep learning with digital technologies may help students develop the competencies required to navigate increasingly complex educational environments. The integration of deep learning with digital interactive boards can be explained through several theoretical perspectives. Constructivist theory argues that knowledge is actively constructed through social interaction and meaningful experiences (Wibowo et al., 2025). Similarly, Dual-Coding Theory suggests that students learn more effectively when verbal explanations are combined with visual representations (Kalender, 2026). In addition, the Technological Pedagogical Content Knowledge framework emphasizes the need to balance technological competence, pedagogical expertise, and subject knowledge in classroom practice. These perspectives collectively suggest that digital interactive boards may become powerful learning tools when integrated with pedagogical strategies that prioritize active participation and conceptual understanding.

Research on interactive technologies in education has expanded considerably over the past two decades. Early studies conducted by Bourbour (2023) demonstrated that interactive whiteboards could facilitate classroom dialogue and encourage student participation. More recent investigations have shown that digital learning media contribute positively to students' motivation, collaboration, and academic engagement (Ateş & Köroğlu, 2024). Several scholars have also highlighted the role of educational technologies in supporting student-centered learning and improving the visualization of complex concepts in primary education (Wang & Huang, 2025). At the same time, researchers have emphasized that technological innovation is most effective when accompanied by pedagogical transformation and adequate teacher preparation (Ong & Annamalai, 2024). Studies focusing specifically

on deep learning have similarly reported positive outcomes in terms of critical thinking, problem-solving skills, and learner autonomy (Achuthan, 2025). Contemporary educational research increasingly recognizes that meaningful learning requires students to engage cognitively, emotionally, and behaviorally with instructional activities (Pradeep et al., 2024). Nevertheless, much of the existing literature examines educational technology and deep learning as separate phenomena. Comparatively few studies have explored how interactive technologies and deep learning approaches can be integrated within a single instructional framework, particularly at the elementary-school level.

Although previous studies have provided valuable insights into technology-enhanced learning, several important gaps remain. First, empirical evidence regarding the implementation of digital interactive boards in elementary boarding schools remains limited, as most studies have been conducted in conventional school settings. Second, earlier research has primarily focused on technological adoption and academic outcomes while paying less attention to the pedagogical mechanisms that support meaningful learning. Third, there is still insufficient understanding of how cognitive, emotional, and behavioral engagement develops when deep learning principles are combined with interactive digital technologies. These limitations reveal the need for a more comprehensive investigation into the integration of deep learning and digital interactive boards in elementary education.

Based on these considerations, this study aims to analyze the integration of deep learning and digital interactive boards in elementary school learning at SD Al-Falah Boarding School. Specifically, the study explores how this integration shapes students' cognitive, emotional, and behavioral engagement and identifies the challenges encountered during its implementation. The findings are expected to contribute theoretically to discussions on technology-enhanced learning and deep learning pedagogy in elementary education. Practically, the study may provide recommendations for teachers, school administrators, and policymakers seeking to design effective and sustainable digital learning environments in the era of educational transformation.

Method

Research Design

This study employed a qualitative approach using an intrinsic descriptive case study design to examine the integration of deep learning and digital interactive boards in elementary school learning at SD Al-Falah Boarding School. A case study design was considered appropriate because the phenomenon under investigation is embedded within a specific educational context characterized by the interaction between technology, pedagogy, and the boarding-school environment. Rather than measuring causal relationships statistically, the study sought to develop a comprehensive understanding of how teachers and students experience technology-supported learning in everyday classroom practices. Particular attention was given to the ways in which digital interactive boards facilitate cognitive, emotional, and behavioral engagement among elementary school students. The research was conducted at SD Al-Falah Boarding School during one academic semester, from January to June 2026. As a boarding institution, the school offers a distinctive learning environment in which classroom activities are closely connected with students' residential experiences. This setting enabled the researchers to investigate not only the instructional use of digital technologies but also the continuity of learning beyond regular classroom sessions.



Figure 1. Research Procedure Flowchart

The research procedure began with identifying the educational issues related to the integration of digital technologies in elementary classrooms. Subsequently, an extensive review of the literature on deep learning and digital interactive boards was conducted to establish the conceptual framework of the study. After determining the research design, participants were selected purposively based on their involvement in the implementation of technology-assisted instruction. The researchers then developed and validated the research instruments before carrying out classroom observations, interviews, focus group discussions, and document analysis. The collected data were coded, categorized, and analyzed through an interactive process involving data condensation, data display, and conclusion drawing. Finally, triangulation and member-checking procedures were conducted to strengthen the credibility of the findings before formulating the conclusions and implications of the study.

Participant

Participants were selected using purposive sampling to ensure that those involved possessed direct experience with the implementation of deep learning and digital interactive boards. The study involved two classroom teachers representing lower and upper grades, one curriculum coordinator, and students from Grades IV and V who actively participated in digital learning activities. The inclusion criteria required participants to have been involved in the use of interactive boards for at least one semester and to be willing to participate voluntarily in the research process. Grade IV and V students were chosen because they had sufficient communication skills and learning experience to articulate their perceptions during interviews and focus group discussions. In contrast, students with limited exposure to digital learning activities were excluded from participation. The purposive sampling strategy allowed the researchers to obtain rich and contextually meaningful data regarding the phenomenon under investigation.

Instrument

To ensure a comprehensive understanding of the research context, data were collected through multiple instruments and sources. Classroom observations were conducted using structured observation sheets designed to document interactions among teachers, students, and digital interactive boards. The observation indicators included instructional strategies, collaborative learning activities, students' participation, and manifestations of cognitive, emotional, and behavioral engagement. Semi-structured interview protocols were developed for teachers and school administrators to explore their experiences, perceptions, and challenges associated with implementing deep-learning practices. In addition, focus group discussions were organized with groups of students to capture their reflections on technology-supported learning. Documentary materials, including lesson plans, digital instructional resources, students' assignments, and classroom recordings, were collected to complement the primary data. The trustworthiness of the instruments was established through expert judgment involving specialists in

educational technology and qualitative research. The instruments were reviewed in terms of relevance, clarity, and alignment with the theoretical constructs of deep learning and student engagement. Following the review process, several revisions were made to improve the wording and structure of the instruments. Pilot observations and interviews were also conducted before the main data collection phase to ensure consistency and feasibility.

Data Analysis

Data collection was conducted in several stages. First, the researchers obtained formal permission from the school administration and informed all participants about the objectives and procedures of the study. Classroom observations were then carried out periodically throughout the semester to capture instructional practices and students’ interactions with digital technologies. Interviews and focus group discussions were conducted after observation sessions to allow participants to reflect on their experiences in greater depth. All interviews were audio-recorded with participants’ consent and transcribed verbatim for further analysis. The data were analyzed using the interactive model proposed by Miles, Huberman, and Saldaña (2014), which consists of data condensation, data display, and conclusion drawing and verification. During the first stage, field notes, interview transcripts, and documentary evidence were coded systematically to identify recurring patterns and meaningful statements. The resulting codes were grouped into broader categories associated with technology integration, deep-learning practices, student engagement, and implementation challenges. These categories were subsequently synthesized into overarching themes that represented participants’ experiences and perspectives. To enhance the credibility and dependability of the findings, several validation strategies were employed. Source triangulation and methodological triangulation were used to compare information obtained from different participants and data collection techniques. Member checking was conducted by allowing participants to review selected summaries of the interview findings, while peer debriefing sessions among the researchers were organized to minimize subjective interpretations and improve analytical rigor.

Results and Discussion

Results

Based on the results of the investigation at SD Al-Falah Boarding School, each experimental classroom has been equipped with a high-spec 86-inch digital interactive board, supports 4K resolution, and is equipped with dual OS Android and Windows operating systems. This hardware integrates seamlessly with the school's Local Learning Management System (Local LMS). However, the true advantage of this model does not lie in its hardware, but rather in the design of instructional scenarios that are strictly compiled by the school's curriculum team. Teachers are required to develop a digital learning plan that allocates the role of interactive boards not as visual lecture tools, but as workstation hubs for student groups.

Table 1. Matrix of Alignment of Interactive Board Features with Deep Learning Components at SD Al-Falah

Key Features of Interactive Boards	Instructional Activities in Al-Falah Elementary School Classroom	Cognitive Consequences of the Deep Learning Process
Kinesthetic Digital Object Manipulation	Students perform virtual dissecting of organs, constructing food chains, or manipulating 3D space structures directly through the touch of a finger.	Transforming abstract theoretical concepts into concrete digital forms; Simplify spatial visualization.

Key Features of Interactive Boards	Instructional Activities in Al-Falah Elementary School Classroom	Cognitive Consequences of the Deep Learning Process
Collaborative Multitouch Canvas	Groups of students (3-4 children) simultaneously pour out research ideas in the form of collaborative mind-mapping on a board screen.	Encourage the process of concept negotiation, peer dialogue, and social construction of common knowledge.
Real-Time Formative Feedback	Simulation-based adaptive interactive quiz integration where student responses are instantly analyzed and graphed on the board.	Provide instant evaluation information for students' metacognition processes and adjustment of teachers' teaching strategies.

Table 1 above clearly illustrates how the technical features of interactive board devices are deliberately paired with meaningful learning activities. This pattern confirms that the use of digital technology in SD Al-Falah Boarding School has managed to get out of the trap of technocentrism thanks to functional integration oriented towards meeting the basic cognitive needs of elementary school-age children.

The implementation of the deep learning approach through the integration of digital interactive boards at SD Al-Falah Boarding School empirically relies on the realization of three main components that interact dynamically with each other.

First, in-depth understanding through active and experiential learning. Inside the classroom, teachers utilize interactive science simulation software to bring micro or macro-scale natural phenomena into the sensory range of students. For example, in learning hydrological cycle material, students no longer just listen to the teacher's explanation or read static diagrams in printed books. Through the interactive board, students can control the intensity of artificial solar radiation on the screen, visually observe the evaporation process of water molecules, accelerate cloud condensation, and trigger rainfall in their chosen geographical area. This manipulative activity forces the child's brain to engage in a high-level scientific reasoning process, test hypotheses instantly, and evaluate the cause-and-effect relationship of the variables they are tinkering with.

Second, meaningful collaboration and interaction between students. The large physical structure of the digital whiteboard and supporting multi-touch inputs is changing the dynamics of social interaction within the classroom. Learning at SD Al-Falah is designed in a teamwork format, where groups of students advance together to the front of the class to solve a problematic challenge displayed on the screen, such as solving a contextual mathematical logic puzzle. In this process, interactive boards act as a medium for articulating the collective mind. When a student shifts a digital object, his or her classmates will immediately respond verbally, debate the argument, or offer an alternative solution. This rich interaction of cognitive negotiation accelerates the process of assimilation and accommodation of new knowledge in the child's memory, while also honing their interpersonal intelligence and collaborative communication skills that are essential capital in boarding life.

Third, the use of digital technology as a learning enabler that is integrated with the dormitory ecosystem. One of the cutting-edge advantages of the implementation at SD Al-Falah Boarding School is the systemic integration between activities in the formal classroom and enrichment in the dormitory environment. All digital notes, mind maps, analysis snippets, and group work that students create on an interactive board during school hours are automatically stored into the school's cloud LMS. At night in the dormitory, the dormitory coaches (tutors/musyrief) or students can independently access the

interactive digital documents through the educational tablet gadgets provided by the dormitory. This allows for cognitive continuity, where reflection and deepening of the material are not interrupted when the school bell ends, but can continue in a more relaxed but still directed atmosphere of dormitory discussions.

The synergy between advanced technology and in-depth pedagogical methods has a very real transformative impact on the three dimensions of student engagement at SD Al-Falah Boarding School.

1. **Cognitive Engagement:** The results of observations show a very significant increase in terms of the depth of self-regulation strategies and students' mental investment in the subject matter. With interactive boards, teachers can present real-world problems in the form of rich and challenging multimedia (ill-structured problems). These visual challenges spark children's epistemic curiosity, encourage them to exert their critical thinking skills to the fullest, relate science theories to everyday applications in dormitories, and dare to take intellectual risks to try a variety of problem-solving solutions without fear of making physical mistakes.
2. **Emotional Engagement:** In-depth interview sessions with students reveal a very positive affective perception of their new classroom environment. Students report feelings of joy, enthusiasm, and a high level of intrinsic motivation during the teaching and learning process. Digital interactive boards have succeeded in eliminating the boredom and monotonous boredom that elementary school students usually experience in conventional text-based learning models. In addition, elements of instant visual appreciation and recognition of the group's digital work in front of the class foster a sense of achievement and drastically increase children's confidence.
3. **Behavioral Engagement:** Quantitatively and qualitatively, classroom observation data confirmed a drastic decrease in off-task behaviors such as daydreaming, undirected chatting, or disturbing friends. The natural nature of digital interactive boards that require active physical responses such as writing in digital stylus, touching answer indicators, or participating in competitive educational games makes students' motor and visual attention fully tied to instructional activities. Students exhibit high levels of task compliance, strong persistence when faced with difficult problems, and much more active verbal participation during class discussion sessions.

Although the model of integration of digital interactive board technology and a deep learning approach at SD Al-Falah Boarding School has been very impressive, an objective qualitative analysis still identifies a number of structural and operational challenges that should not be overlooked. The first challenge is closely related to the workload, curation and digital pedagogical readiness of educators. Preparing interactive, multimedia-based deep learning materials requires a much greater allocation of time and technical expertise from teachers than just reading standard textbooks. Some senior teachers initially experienced technological anxiety and difficulty in aligning whiteboard interaction scenarios with limited classroom timeline management.

The second challenge is the risk of digital fatigue and visual over-stimulation in elementary school children. Given that students in boarding schools interact with structured environments throughout the day, exposure to high-resolution digital screens for too long periods of time in the classroom is feared to trigger eye strain, short-term decreased focus, and erode children's ability to focus on non-digital verbal instruction or offline social interactions naturally. The third challenge stems from the technical aspects of infrastructure, such as fluctuations in the stability of local internet connections, the need for periodic maintenance of the board operating system, and the scarcity of educational software content that is specifically designed in accordance with the religious curriculum and the typical character of the Al-Falah dormitory.

In order to anticipate and mitigate these challenges, the management of SD Al-Falah Boarding School has formulated and implemented three long-term systemic mitigation strategies. First, the school established a Digital Educational Technology Support Unit (DETSU) which is tasked with providing one-on-one technical assistance (one-on-one coaching) for teachers, performing hardware maintenance every weekend, and providing ready-to-use standard template digital teaching modules to reduce the

administrative burden of educators. Second, schools enforce strict screen-time rationing rules with a 60:40 formula; Where in one hour of lessons, the maximum interactive board is operated actively for 60% of the total time, while the remaining 40% must be allocated for offline physical activities, reflection of physical journals, and circular discussions (halaqah) between students without the intervention of digital screens. Third, the school establishes a strategic partnership with the faculty of educational technology of a leading public university to conduct joint research and produce special interactive learning content software that harmoniously integrates the noble character values of the dormitory with high-level science competencies.

Discussion

The findings indicate that the educational value of digital interactive boards extends far beyond their role as classroom display devices. In the context of SD Al-Falah Boarding School, these technologies served as mediating tools that enabled students to visualize abstract ideas, manipulate learning objects, and participate in collaborative activities. This pattern suggests that the effectiveness of educational technology is determined less by its technical sophistication than by the pedagogical practices that accompany its use. Such evidence is consistent with Dual-Coding Theory, which posits that combining verbal explanations with visual representations strengthens cognitive processing and facilitates knowledge retention (Gayathri & Vijayalakshmi, 2025; Kalender, 2026). Earlier studies have similarly reported that interactive whiteboards can improve classroom interaction and support conceptual understanding (Su & Zou, 2026). However, the present study broadens this perspective by demonstrating that the pedagogical potential of interactive technologies becomes more apparent when they are embedded within a structured learning ecosystem.

The implementation of deep learning was found to encourage students to engage with knowledge in more meaningful ways. Rather than focusing on memorization, students were encouraged to investigate problems, test ideas, and connect classroom content with real-life situations. This tendency reflects the central premise of deep learning, which emphasizes conceptual understanding, critical reflection, and knowledge transfer (Pan et al., 2023). From a constructivist perspective, the opportunity to interact with digital resources and peers allows learners to construct knowledge actively through experience and dialogue (Reid-Martinez & Grooms, 2021). Similar conclusions have been reached by recent studies showing that technology-supported learning environments promote higher-order thinking and independent learning habits (Hu & Hwang, 2024). Therefore, the integration examined in this study does not simply represent the adoption of new technology but rather illustrates a shift toward a more inquiry-oriented model of elementary education.

One of the most prominent outcomes observed in this research concerns students' cognitive engagement. The use of digital simulations, interactive exercises, and collaborative tasks encouraged learners to devote greater intellectual effort to understanding the material. Students were not passive recipients of information; instead, they became active participants who explored relationships between concepts and experimented with different solutions. These findings reinforce the multidimensional framework proposed by (Goldberg et al., 2021), which recognizes cognitive engagement as a key predictor of meaningful learning. Recent investigations have likewise highlighted that interactive technologies can stimulate curiosity and support deeper information processing when integrated with student-centered instruction (Meng et al., 2025). Nevertheless, the present findings suggest that cognitive engagement emerges from the alignment between technological affordances and instructional objectives rather than from technology alone.

The analysis also reveals important implications for students' emotional and behavioral engagement. Interviews and classroom observations consistently showed that students experienced greater enthusiasm, confidence, and enjoyment during learning activities involving digital interactive boards. At the same time, instances of off-task behavior became less frequent, indicating that students maintained higher levels of concentration and participation. These results support previous research demonstrating that interactive technologies can foster positive attitudes toward learning and strengthen

classroom involvement (Pandita & Kiran, 2023). The positive emotional responses identified in this study appear to stem from the collaborative and participatory nature of classroom activities, which allowed students to express ideas and receive immediate feedback. Consequently, the integration of deep learning and digital technologies contributes not only to academic development but also to the creation of learning environments that are emotionally supportive and socially engaging.

An aspect that distinguishes this study from much of the existing literature is its focus on the boarding-school context. Unlike conventional schools, boarding institutions provide an educational environment in which learning extends beyond formal instructional hours. The findings demonstrate that digital materials produced during classroom activities remained accessible to students in the dormitory, enabling them to revisit concepts and continue discussions with peers and mentors. This continuity of learning offers an expanded interpretation of constructivist theory by showing that knowledge construction can occur across interconnected social spaces rather than within the classroom alone. Previous studies have generally examined interactive technologies in mainstream educational settings (Hew et al., 2023), whereas evidence from boarding schools remains limited. The present research therefore contributes a contextual perspective that enriches global discussions on technology-enhanced learning in elementary education.

Despite these positive outcomes, the study also identified several challenges that warrant critical consideration. Teachers reported that preparing interactive learning materials required substantial time, technical expertise, and continuous adaptation of instructional strategies. This finding resonates with the Technological Pedagogical Content Knowledge framework, which emphasizes that effective technology integration depends on the intersection of pedagogical, technological, and disciplinary competencies (Akram et al., 2021; Bitar & Davidovich, 2024). In addition, concerns related to screen fatigue and the sustainability of intensive technology use suggest that digital innovation may generate unintended consequences if not managed carefully. Similar issues have been noted in recent research, which stresses the importance of balancing technological advancement with students' well-being and teachers' professional capacities. These challenges highlight that educational transformation requires institutional support systems rather than technological investment alone.

From a broader perspective, this study contributes to contemporary debates on the relationship between pedagogy and technology in elementary education. Existing research has often examined interactive technologies and deep learning as separate domains, focusing either on the adoption of digital tools or on instructional strategies in isolation. By investigating the intersection of these two dimensions within a boarding-school setting, this study provides evidence that meaningful learning emerges from the interaction among technological resources, pedagogical design, and social context. The findings suggest that cognitive, emotional, and behavioral engagement are interconnected processes shaped by both instructional practices and institutional culture. In this respect, the study not only addresses a gap in previous research but also offers a conceptual foundation for future investigations into technology-supported learning environments. More importantly, it underscores the need to view educational technology as a catalyst for pedagogical innovation rather than as an end in itself.

Implications

This study offers several implications for both educational theory and classroom practice. Conceptually, the findings reinforce the view that technology contributes to meaningful learning only when it is integrated with pedagogical approaches that encourage inquiry, collaboration, and active participation. The interaction between deep learning principles and digital interactive boards observed in this study demonstrates that students' cognitive, emotional, and behavioral engagement develops through a combination of technological support and well-designed instructional experiences. In this respect, the study enriches existing discussions on constructivist learning, Dual-Coding Theory, and the TPACK framework by situating them within the context of elementary boarding education. From a practical perspective, the findings suggest that schools should regard digital technologies as tools for facilitating learning rather than as objectives in themselves. Successful implementation requires

continuous teacher development, institutional support, and thoughtful instructional planning. Schools seeking to adopt interactive technologies need to invest not only in digital infrastructure but also in professional training and pedagogical innovation. Furthermore, the experience of SD Al-Falah Boarding School illustrates that technology-supported learning can extend beyond classroom walls and create opportunities for more continuous and interconnected educational experiences.

Limitations

Several limitations should be taken into account when interpreting the results of this research. First, the study was conducted in a single boarding elementary school, which means that the findings reflect a particular educational setting and may not fully represent conditions in other schools with different institutional characteristics. The social environment, organizational culture, and technological resources available at SD Al-Falah Boarding School may have influenced the implementation process and the experiences reported by participants. Second, the study relied primarily on qualitative evidence derived from observations, interviews, focus group discussions, and document analysis. Although these methods provided rich insights into classroom practices, they also depended heavily on participants' perceptions and the researchers' interpretations. In addition, the research covered only one academic semester, limiting the possibility of examining how the integration of deep learning and digital interactive boards influences students' development over a longer period. Variables such as family support, individual learning preferences, and differences in teachers' instructional styles were not explored in depth and may warrant further investigation.

Suggestions

Drawing on the findings of this study, several recommendations can be proposed for educational practice and future research. Schools intending to implement digital interactive boards should prioritize the development of learning activities that encourage exploration, discussion, and problem solving. Technology will be most beneficial when it is embedded within pedagogical strategies that place students at the center of the learning process. In addition, schools need to establish support mechanisms that assist teachers in designing digital materials and managing classroom technology effectively. Future studies may broaden the scope of investigation by involving schools with different educational models and levels of technological readiness. Comparative research could provide a more comprehensive understanding of how contextual factors shape the effectiveness of technology-supported learning. Moreover, quantitative or mixed-methods designs would be valuable for examining the long-term effects of integrating deep learning and digital interactive boards on students' academic achievement, critical thinking skills, and self-regulated learning. Particular attention should also be given to issues related to digital well-being and the balance between technological engagement and students' social and emotional development.

Conclusion

The integration of deep learning and digital interactive boards at SD Al-Falah Boarding School has shown that technology can enrich elementary learning when it is supported by appropriate pedagogical practices. The findings suggest that interactive digital tools are most effective not because of their technological features alone, but because they create opportunities for students to explore ideas, collaborate with peers, and engage more actively in the learning process. Through the implementation of deep-learning principles, students were encouraged to develop a deeper understanding of concepts and to participate in classroom activities in more meaningful ways. This study further highlights the importance of viewing educational technology as part of a broader learning ecosystem. In the boarding-school context, the continuity between classroom instruction and residential activities enabled students to extend their learning experiences beyond formal lessons. Such conditions contributed not only to students' cognitive development but also to their emotional involvement and behavioral participation. These findings reinforce the notion that meaningful learning emerges from the interaction between technology, pedagogy, and the social environment in which learning takes place. At the same time, the

study identified several challenges related to teacher preparedness, the development of digital learning resources, and the management of students' screen exposure. Addressing these issues requires sustained institutional support and careful instructional planning. Overall, this research provides empirical evidence that the combination of deep learning and digital interactive boards offers promising opportunities for strengthening student-centered learning in elementary education, while also opening new directions for future studies on technology-enhanced learning in diverse educational settings.

Author Contributions Statement

Risma Khoerunisa: Conceptualization, methodology, data collection, formal analysis, investigation, writing original draft preparation, and visualization.

Fajeri Arkiang: Supervision, validation, literature review, writing review and editing, and project administration. All authors have read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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