

INTERACTIVE DIGITAL BOARD IN EARLY CHILDHOOD: ENHANCING NUMERACY, GRAPHOMOTOR SKILLS, COLLABORATION, AND CHARACTER

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ABSTRACT

This study examines how the pedagogical implementation of an Interactive Digital Board (IDB) enhances the integrated development of numeracy, graphomotor skills, collaboration, and character in early childhood education. Graphomotor skills in this study refer to fine motor abilities related to early writing activities, including tracing, drawing, and symbol formation. Employing a qualitative descriptive case study design, the research was conducted in a natural classroom setting at PAUD At-Taqwa, Bojonegoro, involving 15 children aged 4–6 years and two teachers. Data were collected through non-participant observation and documentation of IDB-integrated thematic learning activities. The findings reveal four key outcomes: (1) IDB-mediated activities effectively bridge concrete and abstract numerical understanding; (2) stylus-based interaction supports the development of graphomotor control through repetitive and error-tolerant practice; (3) multi-touch features facilitate peer interaction, negotiation, and collaborative problem-solving; and (4) the implementation of the “queue technique” (Teknik Antre) promotes patience, discipline, and honesty. This study contributes to the literature by providing empirical evidence of a holistic pedagogical approach that integrates multiple developmental domains through a single digital learning medium. In practice, the findings highlight the importance of context-sensitive and teacher-designed strategies for optimising the use of digital technology, particularly in resource-limited early childhood classrooms.

Keywords: interactive digital, early numeracy, skills, collaborative, character education

INTRODUCTION

The global landscape of early childhood education (ECE) is undergoing a profound digital transformation, compelling educators and policymakers to reconsider traditional pedagogical paradigms. The integration of technology has shifted from a peripheral supplement to a central component of instructional design, driven by the promise of enhanced engagement and personalised learning (Baharudin, 2021). This transformation is particularly evident in the adoption of Interactive Digital Boards (IDB), which are increasingly replacing conventional whiteboards in preschool classrooms worldwide. These tools are valued not only for their novelty but also for their capacity to create dynamic, multi-sensory learning environments that align with the developmental characteristics of young children, who are

inherently active and sensory-oriented learners (Baikulova et al., 2024). However, the rapid expansion of such technology is not always accompanied by equally robust pedagogical frameworks to guide its effective use.

A central issue motivating this research is the persistent reductionist perspective on IDB's role in early learning. In many classroom implementations, the IDB is treated merely as a projection device, a one-way medium for delivering content, with children remaining passive recipients. This perspective overlooks the interactive potential of IDB, including its multi-touch functionality, stylus-based input, and capacity for immersive, game-based learning (Alotaibi, 2024). More importantly, it reflects a methodological concern: existing discussions tend to emphasise technological benefits in general terms, with insufficient attention to how teachers pedagogically use specific features to support holistic developmental processes.

A review of current scholarship indicates a disconnected body of research, with studies typically focusing on a single developmental outcome. Prior research, such as Alotaibi (2024) and Syarfina et al. (2023) primarily examines cognitive development or numeracy, while Mohamed et al. (2023) Concentrates on touchscreen use in relation to graphomotor skills. This segmented approach does not adequately reflect the holistic nature of early childhood development, where cognitive, motor, and socio-emotional domains are inherently interconnected. Consequently, there remains a scarcity of integrative models demonstrating how a single IDB-based learning activity can simultaneously support multiple developmental domains. This gap results in limited practical guidance for educators seeking holistic instructional strategies (Burns et al., 2024).

In addition, a theoretical gap emerges from the limited consideration of how contextual factors, particularly resource constraints in developing countries, influence the implementation of IDB. Much of the existing research is situated in well-resourced educational environments, offering limited insight into adaptive pedagogical practices in settings with restricted technological access. As a result, there is insufficient understanding of how teachers creatively use limited resources, such as a single IDB unit, to support meaningful and inclusive learning experiences. The exploration of context-specific strategies, including classroom management approaches and locally relevant thematic design, remains underrepresented in the literature (Masoumi et al., 2023).

The novelty of this study lies in its simultaneous focus on four interconnected developmental domains: numeracy, graphomotor skills, collaboration, and character education

within a single, naturally occurring IDB-integrated learning context. Furthermore, this study introduces the “Teknik Antre” (Queue Technique) as a context-driven pedagogical innovation. Rather than functioning solely as a logistical solution, this strategy demonstrates how resource limitations can be transformed into opportunities for fostering character values such as patience, honesty, and discipline, thereby extending the discourse on character education in technology-mediated learning environments (Behnamnia et al., 2022). This study is among the few that empirically demonstrate how a single digital tool can simultaneously support cognitive, motor, social, and character development in early childhood settings.

This study is grounded in a theoretical framework that integrates Piaget’s theory of preoperational cognitive development, Vygotsky’s concept of the Zone of Proximal Development, and Dewey’s philosophy of learning by doing, alongside contemporary findings in digital game-based learning. Accordingly, the primary objective of this research is to conduct an in-depth qualitative exploration of pedagogical practices at PAUD At-Taqwa in Mojokampung, Bojonegoro. The study aims to analyse how the strategic use of IDB within a thematic learning unit supports the integrated development of early numeracy, graphomotor coordination, collaborative learning, and foundational character values.

LITERATURE REVIEW

Digital learning in early childhood education has evolved from simple computer-assisted instruction to complex, interactive ecosystems that promise to revolutionise how young children engage with knowledge. Alotaibi (2024) A systematic review and meta-analysis provide robust evidence that game-based learning significantly enhances cognitive outcomes in preschool children by fostering intrinsic motivation and sustained attention. This aligns with the constructivist assertion by Behnamnia et al. (2022) Well-designed digital games provide an optimal environment for active, experiential learning through exploration and immediate feedback. Baharudin et al. (2021) Further specify the pedagogical advantages of interactive whiteboard technology, noting its unique ability to present dynamic, multisensory content that combines visual, auditory, and kinesthetic elements. However, Baikulova et al. (2024) caution that the cognitive benefits of digital didactic games are contingent on systematic design aligned with specific learning objectives and warn against unguided use, which may lead to distraction rather than cognitive enrichment.

The role of the teacher within this digital ecosystem emerges as the decisive factor in translating technological potential into pedagogical reality. Alsaeed & Aladil (2024) explored

early childhood mathematics teachers' beliefs about technology through reflective writing and found a significant tension between theoretical appreciation and practical pedagogical uncertainty; many teachers acknowledged the potential of interactive environments but lacked confidence in integrating them effectively. Fajardo (2025) empirically demonstrates that the influence of technology on early numeracy skills is heavily mediated by the quality of the teacher's integration strategy. In essence, the IDB is not a pedagogical panacea; its effectiveness depends on the teacher's capacity to embed it in structured, developmentally appropriate, and meaningful learning sequences.

The specific domain of early numeracy development has been a fertile ground for examining how digital tools can facilitate the transition from concrete to abstract thinking. Hyde (2021) Through an experimental computer-based intervention, it was confirmed that digital environments can effectively train the link between non-symbolic quantities and abstract numerical symbols, thereby accelerating the foundational understanding of number concepts. This resonates with Azahra et al. (2024), who argue that the importance of mathematics learning in early childhood lies in developing numeracy skills through a structured progression from concrete manipulation to abstract reasoning. Empirical investigations into digital board media have yielded promising results: Yuniria, Atikah, and Asmawati (2025) found that multimedia approaches significantly boosted numeracy skills in children aged 4–5 years, while Makulua et al., (2024) and Menge et al. (2025) reported significant gains in accuracy and speed of counting using smart board media.

A growing body of literature investigates the impact of touchscreen and stylus-based technologies on young children's fine motor development, a foundational skill for later writing competence. Mohamed et al. (2023) found that regular, guided interaction with touchscreen devices could enhance skills such as pincer grasp and hand-eye coordination, while Rosalianisa et al. (2023) Confirmed that structured digital activities provide a motivating context for repetitive motor practice. The use of a stylus pen on an IDB represents a particularly potent form of motor interaction, as it creates a direct analogue to the pencil grip requiring a higher degree of precision and pressure control. Daryati (2025) emphasises that the effectiveness of interactive learning media is maximised when it provides an "error-friendly" environment where mistakes can be corrected instantly, reducing frustration and encouraging sustained practice.

The social dimension of IDB use, particularly its multi-touch capability, is theorised as a powerful catalyst for collaborative learning. Masoumi et al. (2023) Mapped children's actions during IDB use and provided concrete evidence of the scaffolding process, showing how children spontaneously guide, gesture, and verbally mediate for one another when interacting with a shared touchscreen. Burns et al. (2024) conducted a scoping review finding that structured collaborative tasks on multi-touch devices led to increased instances of explanatory talk, joint attention, and conflict resolution—however, Misirli et al. (2025) Caution that the collaborative potential of the IDB is not an automatic result of the hardware but must be intentionally activated through the design of cooperative activities. The synthesis of these thematic areas reveals a profound fragmentation in the extant research, with studies rarely intersecting to examine how developmental domains co-occur during an IDB lesson. This study seeks to fill this integrative gap while introducing a largely absent variable, the cultivation of character through the "Teknik Antre" as a significant contribution to the pedagogical literature.

METODOLOGY

This study adopted a qualitative descriptive case study design to achieve a holistic and in-depth understanding of the pedagogical practices surrounding the Interactive Digital Board at PAUD At-Taqwa. This approach, as articulated by Creswell & Poth (2018) It is ideally suited to exploring a bounded system using rich, contextual, and multifaceted data, while prioritising participants' meaning-making. The qualitative nature of the inquiry was essential because the research objectives were not to measure discrete variables in isolation but to unravel the complex, interconnected processes through which IDB integration concurrently influences numeracy, motor skills, collaboration, and character development.

The research was conducted at PAUD At-Taqwa, a kindergarten located in Desa Mojokampung, Kabupaten Bojonegoro, East Java, Indonesia. The school operates as a typical Indonesian village preschool with limited resources, possessing only a single government-granted IDB unit to serve its entire student body of 15 children aged 4–6 years. The IDB, mounted at a child's eye level on a classroom wall, served as the focal point of group learning sessions. The classroom space was arranged with a large mat in front of the board where children sat during whole-group activities. During IDB-integrated sessions lasting approximately 40 minutes, the lead teacher and one assistant teacher co-managed the class. The IDB was used twice a week as the central tool for thematic learning. The subjects of this

study were a purposively selected group of all 15 preschool children (9 boys, 6 girls) enrolled in the school, whose ages spanned the critical preoperational stage (4–6 years), and their two lead teachers.

A critical methodological consideration was the lead author's dual role as the school principal/teacher and principal investigator. To address potential biases, several trustworthiness strategies were employed as recommended by Creswell and Poth. The assistant teacher served as a co-observer during data collection, independently recording observations that were cross-referenced with the researcher's field notes. The researcher maintained a reflexive journal throughout data collection, documenting personal reactions and interpretive decisions to promote transparency. Member-checking sessions were conducted with the assistant teacher after preliminary thematic analysis. The role adopted during formal observations was strictly non-interventionist, with the lead teacher ceding instructional duties to the assistant teacher during designated observation sessions to minimise dual-role conflict.

Data collection was conducted rigorously through two primary methods to ensure triangulation and depth: non-participant observation and document analysis. Non-participant observation was employed during ten dedicated IDB-integrated learning sessions centred on the thematic unit "Ayo ke Peternakan bersama Rara." The observer role was that of a passive, non-intrusive witness, positioned at the periphery of the learning mat. A structured observation protocol, developed from the merged frameworks of Masoumi et al. (2023) and Burns et al. (2024) Guided the recording of field notes with specific attention paid to children's verbal exchanges, stylus grip and movement, mathematical problem-solving strategies, teacher scaffolding language, and behaviours exhibited by children in the waiting queue. Documentation analysis provided a complementary source of data, including analysis of the teacher's comprehensive RPP for the "Ayo ke Peternakan" theme and digital artefacts from the IDB sessions, such as screen-captured images of children's completed tasks.

The data analysis followed a systematic four-stage process: data reduction, coding, categorisation, and thematic interpretation (Creswell & Poth, 2018). In the data reduction phase, voluminous raw field notes and documented artefacts were culled, selecting only segments relevant to the four core research foci. The coding phase involved a line-by-line reading of the reduced data to identify and label specific, discrete instances of meaning, producing initial codes descriptive and close to the data. In the categorisation phase, these initial codes were iteratively compared, contrasted, and synthesised into broader categories.

Finally, the thematic interpretation phase involved weaving these categories into a coherent, analytical narrative that addressed the research questions and explicitly linked back to the theoretical framework. This study adhered to ethical standards for research involving young children, including written informed consent from parents, verbal assent from children, institutional approval, and full anonymisation of all data using pseudonyms.

RESULT AND DISCUSSION

The analysis of the observational and documentary data reveals a rich tapestry of interwoven developmental processes that extend far beyond simple digital engagement. The “Ayo ke Peternakan” lesson emerged as a cohesive pedagogical experience where numeracy, graphomotor skills, collaboration, and character traits dynamically reinforced one another.

IDB-Mediated Numeracy Development: Bridging Concrete and Abstract Understanding

The IDB-integrated activities at PAUD At-Taqwa demonstrated a clear capacity to scaffold children’s numeracy development by bridging concrete and abstract numerical representations. During counting tasks involving animated farm animals on the IDB, children were observed actively pointing to each animal on the screen before verbalising the corresponding number word, a concrete-to-symbolic transition that aligns with Piaget’s account of preoperational cognitive development (Nugraha & Nuriadin, 2025). This finding is consistent with Hyde (2021), who confirmed that computer-based digital environments effectively train the link between non-symbolic quantities and abstract numerical symbols. Similarly, Yuniria et al. (2025) reported that multimedia-enriched activities significantly improved numeracy accuracy among children aged 4–5 years, while Makulua et al. (2024) documented gains in counting speed using smart board media. In the context of PAUD At-Taqwa, the locally designed thematic content, using familiar rural imagery such as chickens, goats, and cows, further enhanced children’s engagement and meaning-making, corroborating Fajardo’s (2025) assertion that contextualised, teacher-designed integration maximises the impact of digital tools on numeracy. The IDB thus functioned not merely as a display medium but as an active mediator of mathematical cognition, supporting children’s progression from perceptual counting to symbolic understanding within a single, thematically coherent lesson. This interaction is illustrated in Figure 1, where a child selects the correct answer to a simple arithmetic task on the Interactive Digital Board.

Stylus-Based Interaction and Graphomotor Skill Development

Figure 1. A child selecting the correct answer in a numeracy activity on the Interactive Digital Board

A second significant finding concerns the role of the stylus pen in supporting children's graphomotor development. Observations recorded instances of children gripping the stylus with a tripod grasp, applying controlled pressure to trace animal outlines and connect numerical symbols on the IDB surface. This form of interaction constitutes a developmentally appropriate analogue of pencil use, directly training the fine-motor coordination that underpins early writing readiness (Rosaliana et al., 2023). Mohamed et al. (2023) Similarly, it was found that guided touchscreen interaction enhanced pincer grasp and eye-hand coordination among preschool children. Critically, the IDB's "error-friendly" affordance, where incorrect strokes could be erased and repeated without penalty, was observed to reduce children's anxiety and encourage persistent, repetitive motor practice (Daryati, 2025). This finding extends the existing literature by contextualising graphomotor skill development in a resource-limited single-IDB classroom, where the stylus pen effectively compensated for the absence of individual tablet devices by rotating access via the Teknik Antre system. This process is illustrated in Figure 2, which shows a child arranging puzzle elements on the Interactive Digital Board, demonstrating visual-motor coordination and controlled hand movement.

Multi-Touch Features and Collaborative Learning Dynamics

The IDB's multi-touch capability emerged as a powerful enabler of collaborative learning behaviours. During paired and small-group tasks, children were observed engaging in peer negotiation, joint problem-solving, and spontaneous scaffolding, pointing to correct answers, verbally guiding peers, and celebrating shared success. These observations align with

Masoumi et al.'s (2023) Mapping of children's scaffolding actions during IDB use, which demonstrated that shared touchscreen interaction naturally elicits Vygotskian peer mediation. Burns et al. (2024). Similarly, a scoping review found that structured collaborative tasks on multi-touch devices increased explanatory talk and conflict-resolution behaviours. In the PAUD At-Ta'qwa context, the teacher's deliberate design of dyadic drag-and-connect tasks requiring two children to manipulate different elements simultaneously was instrumental in activating these collaborative dynamics. This finding reinforces Misirli et al. (2025) and cautions that collaboration is not automatic but must be pedagogically engineered, and offers a concrete local example of how such engineering can be achieved in a resource-constrained Indonesian PAUD setting.

The Teknik Antre (Queue Technique) as Character Education

Perhaps the most distinctive finding of this study is the emergence of the Teknik Antre as a context-specific pedagogical innovation for character education. Given that only a single IDB stylus was available, the lead teacher at PAUD At-Ta'qwa designed a structured turn-taking protocol in which children queued in an orderly line while their peers completed IDB tasks. Observations revealed that children in the queue exhibited patient waiting, verbal encouragement of peers, and self-regulated adherence to the rotation order behaviours consistently associated with the character values of patience (*sabar*), honesty (*jujur*), and discipline (*disiplin*) articulated in Indonesia's national PAUD curriculum framework. This finding makes a novel empirical contribution to the literature by demonstrating that a perceived logistical constraint, limited hardware access, can be ingeniously reframed as a pedagogical asset for character formation. While existing literature on character education in digital learning contexts tends to focus on values embedded in software content (e.g., cooperative game mechanics), this study illustrates how the physical management of shared technology can itself become a site of moral and social learning, a dimension absent from the international IDB literature reviewed.

CONCLUSION

This qualitative case study conclusively demonstrates that the pedagogical power of an Interactive Digital Board in early childhood education extends far beyond its technological sophistication; it is fundamentally realised through the teacher's intentional, creative, and holistic design. The findings reveal an integrated model of development where a single thematic unit effectively served as a convergent platform for four critical domains: numeracy,

fine motor skills, collaboration, and character education. The IDB's multi-sensory features provided a crucial cognitive bridge from concrete to abstract numerical thinking, while the stylus pen offered a uniquely motivating and error-friendly medium for pre-writing motor practice; the multi-touch surface organically catalyzed peer-to-peer scaffolding; and most importantly, the study uncovered the "Teknik Antre" as a significant pedagogical innovation, converting a logistical constraint into a powerful context for cultivating patience, honesty, discipline, and respect a highly replicable model for educators, particularly in resource-limited settings, demonstrating that a single piece of technology, when used with structured pedagogical creativity, can yield rich, multi-dimensional developmental returns, though future research should employ longitudinal, mixed-methods designs across diverse socio-economic and cultural contexts to further test the generalizability and long-term impact of this holistic, teacher-centered model of digital integration.

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