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School Mathematics amid the Attention Crisis: Learning Challenges in a Fast Digital Culture

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ABSTRACT

The rapid digital transformation of education has fundamentally reshaped mathematics learning worldwide, particularly in the post-pandemic era. While digital technologies offer powerful opportunities to enhance learning outcomes, motivation, and accessibility, they simultaneously generate complex challenges related to students' attention, emotional wellbeing, digital inequality, and the sustainability of pedagogical practice. This study aims to critically examine the opportunities and challenges of digital integration in school mathematics learning by synthesizing recent international research published between 2020 and 2025. Employing a qualitative systematic literature review with thematic analysis, this study analyzed twenty peer-reviewed journal articles focusing on digital mathematics instruction across primary and secondary education contexts. The findings reveal that well-designed digital tools significantly improve academic achievement, student engagement, and recovery from post-pandemic learning loss, while also transforming students' mathematical identity and learning environments. However, excessive digital exposure contributes to attention crises, psychosocial tension, and persistent structural inequalities. The study concludes that sustainable digital mathematics education requires an integrated framework that aligns technological innovation with pedagogical quality, responsive teacher education, equitable infrastructure development, and systematic support for students' cognitive and emotional wellbeing.

INTRODUCTION

The digital transformation of education has fundamentally altered the landscape of school mathematics learning worldwide. Large-scale studies conducted since 2020 indicate that digital tools, learning management systems, online platforms, and interactive media have become integral components of mathematics instruction at primary and secondary school levels (Hillmayr et al., 2020; Topping et al., 2022; Wijaya et al., 2022). Meta-analytic evidence demonstrates that technology-supported mathematics instruction yields moderate to high positive effects on students' achievement, with effect sizes ranging from 0.65 to 0.82 compared to traditional classroom approaches, particularly when digital tools complement direct teacher instruction (Hillmayr et al., 2020; Topping et al., 2022). These findings confirm that technology offers substantial pedagogical benefits by expanding access to learning resources, enhancing visualization of abstract concepts, and enabling personalized learning experiences.

Despite these documented benefits, recent international research reveals a growing crisis of attention among school students within fast-paced digital culture. Teachers across diverse educational contexts report that students increasingly struggle to maintain focus during mathematics instruction due to constant exposure to social media, entertainment platforms, and non-academic digital content (Fjærestad & Xenofontos, 2025). The 2022 PISA dataset further strengthens this concern, indicating that intensive engagement with digital resources combined with health-related issues such as anxiety and sleep disturbance is significantly associated with lower mathematics achievement, while mathematical self-confidence acts as a protective factor (Joshi & Khanal, 2025). These findings illustrate that technology simultaneously serves as both a learning facilitator and a disruptive force that threatens students' cognitive endurance and emotional regulation.

Empirical studies consistently demonstrate that mathematics is particularly vulnerable to the negative consequences of digital distraction. Research conducted in early childhood, elementary, and secondary education shows that abstract mathematical topics, including geometry, fractions, and spatial reasoning, become significantly more difficult for students to comprehend in online or hybrid environments when interactive instructional support is insufficient (Lavidas et al., 2022; Ramdhani et al., 2025). The absence of structured scaffolding and reduced teacher student interaction further amplifies cognitive overload and weakens students' conceptual understanding, thereby undermining the long-term quality of mathematical learning outcomes.

Simultaneously, innovative digital interventions continue to display strong potential for enhancing mathematics learning. Digital game-based learning, animated instructional media, and adaptive platforms consistently improve student motivation, engagement, and anxiety management, including among learners with special educational needs such as ASD and ADHD (Dan et al., 2024; Ng et al., 2022; Herrerías, 2025; Umar et al., 2025). Instructional models integrating digital literacy and collaborative strategies, such as the RMS teaching model with brainstorming techniques, have also been shown to significantly improve mathematical literacy and digital competence (Komarudin et al., 2024). These developments suggest that the central challenge is not the presence of technology itself, but rather the manner in which it is pedagogically designed and socially regulated within classroom environments.

However, existing studies largely examine either the benefits of technology for learning outcomes or the risks associated with digital distraction as separate phenomena. Few studies systematically integrate these two dimensions to explain how digital innovation simultaneously strengthens and destabilizes mathematics learning through its impact on students' attention, emotional wellbeing, and cognitive processes. Moreover, much of the current literature focuses on isolated interventions or single educational levels, leaving limited understanding of how attention crises develop across educational stages and how they interact with teachers' pedagogical practices and institutional conditions (Viberg et al., 2020; Li et al., 2025; Fitrah et al., 2024; Fjærestad & Xenofontos, 2025).

This study addresses these gaps by synthesizing recent international research (2020–2025) to construct an integrated analytical framework that explains the dual role of digital technology in mathematics education: as a catalyst for academic improvement and as a source of attention-related risk. The novelty of this research lies in its focus on attention crisis as a central explanatory mechanism linking digital culture, pedagogical practice, and students' mathematical performance. By positioning attention management and emotional regulation as core mediating variables, this study extends existing models of technology-enhanced learning beyond technical effectiveness toward a more holistic understanding of learning sustainability in digital environments.

Accordingly, the objective of this study is to critically analyze the opportunities and challenges of digital technology in school mathematics learning within the context of emerging attention crises, and to formulate pedagogical implications for designing balanced, effective, and psychologically sustainable mathematics instruction in the digital era.

METHODOLOGY

Research Design

This study employed a qualitative systematic literature review design with a thematic synthesis approach. The research focused on examining recent empirical findings related to the impact of digital technology on school mathematics learning and its relationship with student attention, motivation, emotional regulation, and conceptual understanding. The review protocol followed structured stages consisting of identification, screening, eligibility assessment, and thematic synthesis of relevant studies published between 2020 and 2025.

Population and Sample

The population of this study comprised international peer-reviewed journal articles discussing digital technology integration in mathematics education at the preschool, primary, and secondary school levels. A purposive sampling strategy was applied to select high-quality studies indexed in reputable academic databases. Based on predefined inclusion criteria, 20 journal articles published within the last five years were selected as the primary data sources. These articles represented diverse educational contexts, research methodologies, and technological interventions relevant to the research objectives.

Data Collection Techniques

Data were collected through systematic document analysis. The researchers conducted comprehensive searches using academic databases and manually screened articles based on the following criteria: relevance to mathematics education, focus on digital technology integration, empirical data reporting, and discussion of learning outcomes or attention-related variables. Each selected article was carefully reviewed, and key information regarding research context, methodology, findings, and implications was extracted using a structured data extraction form.

Data Analysis Techniques

The extracted data were analyzed using thematic content analysis. The analysis process involved open coding to identify recurring concepts, axial coding to establish relationships among categories, and selective coding to integrate major themes. This procedure enabled the identification of dominant patterns concerning technological benefits, attention-related challenges, pedagogical practices, and systemic constraints influencing mathematics learning in digital environments.

Below is the research procedure diagram that you can insert into the methodology section.

Figure 1. Research Procedure Flowchart

RESULTS AND DISCUSSION

Effectiveness of Digital Technology in Mathematics Learning

The findings indicate that digital technology consistently improves students' mathematics achievement, motivation, and engagement when pedagogically integrated with direct instruction. Meta-analytic evidence shows medium to high effect sizes ($g \approx 0.65$–0.82), confirming strong learning benefits across educational levels (Hillmayr et al., 2020; Topping et al., 2022; Wijaya et al., 2022). Digital game-based learning further reduces mathematics anxiety and supports students with special needs (Dan et al., 2024; Herrerías, 2025).

Table 1. Effects of Digital Technology on Mathematics Learning

Indicator	Observed Impact	Educational Implication	Sources
Achievement	Significant improvement ($g \approx 0.65$–0.82)	Strong learning gains	Hillmayr et al., 2020; Topping et al., 2022
Motivation	Increased engagement	Higher participation	Dan et al., 2024
Math anxiety	Substantial reduction	Improved confidence	Ng et al., 2022; Herrerías, 2025

The empirical evidence summarized in Table 1 confirms that digital technology exerts a substantial positive influence on mathematics achievement when it is embedded within sound pedagogical structures. Meta-analytic results consistently report moderate to high effect sizes ranging from 0.65 to 0.82, indicating that digital instruction significantly outperforms traditional approaches in fostering conceptual understanding and procedural fluency (Hillmayr et al., 2020; Topping et al., 2022; Wijaya et al., 2022). These outcomes demonstrate that technology enhances not only content delivery but also the cognitive processes underlying mathematical reasoning.

Beyond achievement, Table 1 reveals meaningful gains in student motivation and engagement. Digital environments provide immediate feedback, multimodal representations, and interactive problem-solving experiences that promote active learning and sustained participation (Dan et al., 2024). Such features foster students' intrinsic motivation by transforming mathematics from a passive subject into an exploratory and interactive learning experience, which aligns with self-determination theory emphasizing autonomy and competence as drivers of engagement.

Another critical finding reflected in Table 1 concerns the reduction of mathematics anxiety. Digital game-based learning and adaptive instructional tools have been shown to significantly lower anxiety levels, particularly among early-grade learners and students with learning difficulties such as ASD and ADHD (Ng et al., 2022; Herrerías, 2025). This affective improvement is pedagogically significant, as anxiety has long been recognized as a major barrier to mathematical performance and persistence.

However, Table 1 also implies that technological effectiveness is contingent upon instructional quality. Studies emphasize that learning gains are maximized when technology supplements direct instruction rather than replacing teacher-guided learning

entirely (Hillmayr et al., 2020; Viberg et al., 2020). This supports constructivist learning theory, which views teachers as essential mediators who guide meaning-making and scaffold conceptual development.
Taken together, the evidence in Table 1 suggests that digital technology functions as a powerful pedagogical amplifier. When aligned with coherent instructional design and professional teaching practice, it enhances cognitive outcomes, emotional engagement, and learner confidence in mathematics, reinforcing the central thesis that technological innovation must be anchored in pedagogical excellence (Topping et al., 2022; Fitrah et al., 2025).

Transformation of Learning Environments and Mathematical Identity

Digital environments reshape students' mathematical identity from performance-based to participation-based, fostering ownership, confidence, and meaning (Darragh, 2021; Chan et al., 2021).

Table 2. Digital Learning Environment and Mathematical Identity

Dimension	Transformation Observed	Learning Impact	Sources
Learning space	Flexible, collaborative	Higher engagement	Darragh, 2021
Student identity	From procedural to meaningful	Sustained interest	Chan et al., 2021
Participation	Active & social	Stronger self-efficacy	Darragh, 2021

Table 2 demonstrates that digital learning environments profoundly reshape students' mathematical identity by altering how learners perceive themselves in relation to mathematics. Darragh (2021) shows that flexible digital spaces and collaborative technologies foster students' sense of ownership and agency, enabling them to construct positive mathematical self-concepts that extend beyond examination performance. This shift reflects a broader sociocultural transformation in learning, where identity is co-constructed through participation and social interaction.

The pandemic context further accelerated this transformation. Chan et al. (2021) report that COVID-19 forced educators and learners to reconceptualize mathematics as a tool for critical thinking, problem solving, and adaptation in real-life contexts. This reframing strengthened the relevance of mathematics for students and supported deeper engagement, moving mathematical identity away from rote procedural mastery toward meaningful intellectual practice.

Moreover, Table 2 suggests that participation-oriented learning environments increase long-term persistence in mathematics. When students experience mathematics as socially meaningful and personally valuable, their commitment to learning becomes more resilient to academic challenges (Darragh, 2021). This finding aligns with identity-based motivation theory, which posits that individuals are more motivated when learning activities are congruent with their self-concept.

However, the development of positive mathematical identity is not automatic. Chan et al. (2021) caution that without intentional pedagogical design, digital environments can reproduce existing inequities and marginalize less confident learners.

Thus, identity transformation requires structured support, inclusive practices, and continuous feedback.

Ultimately, Table 2 reinforces the notion that mathematical identity is a central determinant of learning sustainability in digital contexts. By cultivating confidence, belonging, and personal meaning, digital learning environments create the psychological foundations necessary for long-term success in mathematics education (Darragh, 2021; Chan et al., 2021).

Digital Technology for Post-Pandemic Learning Loss Recovery

Technology-driven accelerated learning models significantly improved numeracy and conceptual understanding after COVID-19 disruptions (Asogwa et al., 2023; Alabdulaziz, 2021).

Table 3. Digital Strategies for Learning Loss Recovery

Strategy	Observed Outcome	Instructional Value	Sources
Accelerated learning	Improved numeracy	Learning recovery	Asogwa et al., 2023
LMS & apps	Higher engagement	Motivational support	Alabdulaziz, 2021
Digital redesign	Permanent transformation	Sustainable reform	Mulenga & Marbán, 2020

Table 3 highlights the central role of digital technology in mitigating learning loss following the COVID-19 pandemic. Asogwa et al. (2023) provide compelling evidence that technology-driven accelerated learning models significantly improve students’ numeracy and conceptual understanding through personalized instruction and rapid feedback mechanisms. These models enable learners to rebuild foundational skills efficiently and systematically.

Complementing these findings, Alabdulaziz (2021) demonstrates that the integration of learning management systems, interactive applications, and instructional videos substantially increases student motivation and engagement. These platforms allow teachers to monitor progress, differentiate instruction, and respond adaptively to individual learning needs.

Mulenga and Marbán (2020) further argue that the pandemic has produced irreversible shifts in mathematics education, compelling institutions to redesign curricula, assessment strategies, and instructional delivery modes. Table 3 reflects this transformation by showing how digital strategies now function not as emergency measures but as permanent components of instructional reform.

Nevertheless, Table 3 also indicates that technological effectiveness depends heavily on teacher readiness and infrastructure stability. Inadequate training or unreliable connectivity can significantly reduce the impact of digital interventions (Alabdulaziz, 2021; Asogwa et al., 2023).

Collectively, the evidence suggests that digital strategies represent a powerful instrument for educational recovery. When combined with pedagogical competence and institutional support, they enable mathematics education systems to not only recover from disruption but emerge more adaptive and resilient (Mulenga & Marbán, 2020).

Attention Crisis and Psychosocial Challenges

Digital expansion triggers attention loss, anxiety, digital fatigue, and declining wellbeing (Joshi & Khanal, 2025; George, 2024).

Table 4. Attention and Psychosocial Effects of Digital Learning

Challenge	Manifestation	Academic Risk	Sources
Distraction	High off-task behavior	Lower achievement	Fjærestad & Xenofontos, 2025
Anxiety & fatigue	Emotional exhaustion	Cognitive overload	George, 2024
Conceptual difficulty	Weak abstract understanding	Learning stagnation	Lavidas et al., 2022

Table 4 captures the emergence of significant attention-related and psychosocial challenges in digital mathematics learning. Fjærestad and Xenofontos (2025) document widespread student distraction and increased off-task behavior in technology-rich classrooms, which undermine sustained cognitive engagement.

Joshi and Khanal (2025) further reveal that excessive digital resource use, coupled with anxiety and sleep disorders, correlates negatively with mathematics achievement. These findings demonstrate that attention regulation is a critical mediating variable between technology use and learning outcomes.

George (2024) conceptualizes this condition as *technology tension*, describing how efficiency gains coexist with rising psychological fatigue and declining wellbeing among both students and teachers. This tension contributes to emotional exhaustion and reduced instructional effectiveness.

Additionally, Lavidas et al. (2022) and Ramdhani et al. (2025) show that abstract mathematical concepts remain particularly vulnerable to these psychosocial pressures, as online environments often lack sufficient scaffolding for deep conceptual understanding.

Therefore, Table 4 underscores that attention management and emotional wellbeing must be integrated into digital pedagogy as core design principles rather than treated as secondary concerns (George, 2024; Joshi & Khanal, 2025).

Structural Barriers: Digital Inequality and Infrastructure Gaps

Digital inequality widens learning gaps and intensifies teacher workload and stress (Bozkurt et al., 2020; Moldavan et al., 2022).

Table 5. Structural Barriers in Digital Mathematics Learning

Barrier	Observed Condition	Educational Impact	Sources
Device & access	Limited	Achievement	Bozkurt et al.,

gap	availability	inequality	2020
Infrastructure	Unstable internet	Reduced learning quality	Marbán et al., 2021
Teacher workload	Increased pressure	Professional burnout	Moldavan et al., 2022

Table 5 demonstrates that digital inequality constitutes one of the most persistent structural barriers in mathematics education. Bozkurt et al. (2020) show that limited access to devices, internet connectivity, and digital literacy disproportionately affects students from lower socioeconomic backgrounds, thereby widening achievement gaps.

Moldavan et al. (2022) reveal that teachers operating within such constraints face increased workloads and professional stress as they attempt to reconcile innovation demands with access realities. These pressures reduce instructional quality and teacher wellbeing.

Similar challenges are reported by Marbán et al. (2021) in conflict-affected regions, where infrastructural instability and socio-political disruption further undermine learning continuity.

The evidence indicates that technological reform without equitable access policies risks reinforcing rather than alleviating educational inequality (Bozkurt et al., 2020).

Hence, Table 5 highlights the necessity of systemic policy intervention to ensure that digital transformation in mathematics education promotes equity and social justice (Moldavan et al., 2022; Marbán et al., 2021).

Teacher Education and Policy Implications

The success of digital mathematics education depends on pedagogical competence, moral responsibility, and holistic reform (Atweh et al., 2023; Ahmad & Wahyudin, 2023).

Table 6. Teacher and Policy Directions for Digital Mathematics Education

Component	**Required Shift**	**Long-Term Outcome**	**Sources**
Teacher competence	TPACK mastery	Sustainable instruction	Viberg et al., 2020
Pedagogical paradigm	Integrate tech & character	Balanced development	Ahmad & Wahyudin, 2023
Policy orientation	Responsive & responsible	Systemic stability	Atweh et al., 2023

The evidence presented in Table 6 underscores that the sustainability of digital mathematics education is fundamentally determined by the quality of teacher preparation and the strategic direction of educational policy. Atweh et al. (2023) emphasize that post-pandemic teacher education must be grounded in the principles of *responsiveness* and *responsibility*, where educators are expected not only to adapt swiftly to technological change but also to exercise moral and professional judgment in managing its broader social and psychological consequences. This shift positions teachers as ethical agents of educational transformation rather than mere implementers of instructional technology.

In this context, teacher competence extends beyond technical proficiency with digital tools. Research demonstrates that effective digital mathematics instruction requires deep mastery of Technological Pedagogical Content Knowledge (TPACK), enabling teachers to align mathematical content, instructional strategies, and digital resources in a coherent pedagogical framework (Viberg et al., 2020; Fitrah et al., 2025). Without such integration, technology risks becoming an add-on rather than a transformative instructional medium.

Furthermore, Ahmad and Wahyudin (2023), Darmayasa et al. (2025), and Rustiyana et al. (2025) argue that the future of mathematics education demands a holistic paradigm that integrates digital technology with critical pedagogy, digital literacy, and character education. This paradigm shift reflects the growing recognition that cognitive development alone is insufficient in digital environments where students face complex ethical, emotional, and social challenges. Mathematics instruction must therefore cultivate critical reasoning, responsible technology use, and socio-emotional competence alongside procedural and conceptual mastery.

Policy frameworks play an equally decisive role in shaping the effectiveness of this transformation. Educational policies that merely mandate technology adoption without providing systematic professional development, infrastructure investment, and emotional support systems for teachers and students risk producing superficial reforms with limited pedagogical impact (Atweh et al., 2023). In contrast, responsive and responsible policies create the structural conditions necessary for teachers to innovate sustainably and ethically.

Finally, Hidayatullah (2018) reinforces the central thesis that technological success in education does not reside in the sophistication of digital tools but in the coherence of instructional design, the competence of teachers, and the strength of the learning culture within schools. When teacher education and policy reform operate in synergy, digital mathematics education evolves from a technical modernization project into a comprehensive educational transformation that supports both academic excellence and human development.

CONCLUSION

This study confirms that digital transformation has profoundly reshaped school mathematics education by improving academic performance, learning motivation, and recovery from post-pandemic learning loss, while at the same time generating complex challenges related to students' attention, emotional wellbeing, and persistent digital inequality. The findings demonstrate that the success of digital mathematics learning is not determined by the sophistication of technology but by the coherence of pedagogical design, the professional competence of teachers, and the strength of educational policy support. Sustainable digital integration therefore requires a holistic framework that unites technological innovation, responsive and ethical teacher education, equitable infrastructure development, and systematic attention to students' psychosocial needs. Without such integration, digital reform risks amplifying learning disparities and undermining long-term educational quality and social responsibility.

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