Digital Learning Tools, Mathematics Anxiety, and Academic Achievement: A Secondary-Data Review of Students' Learning Behaviour in African Secondary Schools

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ABSTRACT: *Mathematics anxiety remains a significant barrier to academic achievement, particularly in African and other low-resource educational contexts where pedagogical, infrastructural, and emotional challenges intersect. This systematic review, guided by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocols, synthesised 45 peer-reviewed studies published between 2019 and 2025 to examine how digital learning tools influence mathematics anxiety and achievement among secondary-school learners. Searches were conducted across Scopus, Web of Science, Education Resources Information Center (ERIC), Google Scholar, and major publisher archives. Inclusion criteria focused on empirical studies, systematic reviews, and meta-analyses examining Information and Communication Technology (ICT) integration, blended learning, online platforms, and game-based interventions. Data extraction captured study context, population characteristics, intervention types, outcome measures, and methodological quality, with appraisal conducted using the Mixed Methods Appraisal Tool (MMAT). Quantitative findings show that ICT integration and blended learning produce moderate gains in mathematics achievement (0.42–0.48 SD) and support improved retention, while interactive and game-based approaches enhance understanding and attitudes. Although digital tools can reduce mathematics anxiety - particularly when teacher scaffolding is present - their anxiety-reduction effects vary, with well-designed digital environments yielding reductions of up to 0.35 SD. Qualitative synthesis highlights three conditions necessary for effectiveness: strong pedagogical alignment, teacher digital competence, and emotionally responsive design features. Overall, the findings demonstrate that digital learning tools function as both cognitive enhancers and affective supports when implemented within well-structured institutional frameworks. By mapping African and low-resource settings, this review provides novel and contextually grounded insights to guide educators, policymakers, and designers seeking to improve mathematics learning outcomes.*

KEYWORDS: *Digital learning tools, mathematics anxiety, mathematics achievement, ICT integration, blended learning*

I. INTRODUCTION

Mathematics is foundational to science, technology, engineering, and innovation, and is crucial for socio-economic development. Yet in many African contexts, mathematics performance at secondary level remains unsatisfactory (Bossman & Agyei, 2022; Luneta & Sunzuma, 2022) due to traditional pedagogical methods, large class sizes, limited resources, and psychological barriers such as anxiety and negative attitudes (Mwangi, 2024; Oluyomi, Abdussalam, & Ismail,20 24). As education systems globally and in Africa increasingly invest in digital learning tools - ICT infrastructures, online platforms, blended learning - there is an expectation that these investments will improve mathematics learning and student outcomes. At the same time, mathematics anxiety (MA) - characterized by tension, fear or

apprehension towards mathematics tasks - is recognized as a major affective barrier that undermines motivation, reduces working memory capacity, and lowers performance (Frenzel, Pekrun, & Goetz, 2025).

Despite the growing interest in both technology-based learning and affective aspects of mathematics education, there is limited evidence, especially from African or comparable low-resource settings, examining how digital learning tools and MA jointly influence mathematics achievement (Ayebale, Habaasa & Tweheyo, 2020; Bossman & Agyei, 2022; Luneta & Sunzuma, 2022). This review addresses that gap by synthesizing recent (2019–2025) empirical studies, systematic reviews, and meta-analyses to explore the interplay among digital learning tools, mathematics anxiety, and mathematics achievement. The aim is to draw lessons for secondary education in Africa, highlighting opportunities and challenges for policymakers, educators, and researchers.

II. Statement of the problem

Mathematics achievement remains a persistent challenge in many African secondary schools, despite its central role in scientific advancement, technological development, and socio-economic progress. Empirical evidence indicates that students' poor performance in mathematics is not solely attributable to structural constraints such as large class sizes, limited instructional resources, and traditional pedagogical practices, but is also strongly influenced by affective factors - most notably mathematics anxiety (Bossman & Agyei, 2022; Luneta & Sunzuma, 2022; Mwangi, 2024). Mathematics anxiety, characterized by fear, tension, and apprehension toward mathematical tasks, has been consistently shown to impair working memory, reduce motivation, and negatively affect academic performance (Frenzel, Pekrun, & Goetz, 2025; Shishigu, Michael, & Atnafu, 2024).

In response to these challenges, education systems across Africa and globally have increasingly invested in digital learning tools, including ICT integration, blended learning approaches, online platforms, and game-based learning, with the expectation that such technologies can enhance engagement and improve mathematics achievement (Arhin, Arthur, & Gordon, 2025; Egara & Mosimege, 2024; Yulianto et al., 2025). Several studies report moderate gains in mathematics achievement associated with digital learning interventions, particularly when blended with traditional instruction (Arhin et al., 2025; Egara & Mosimege, 2024). However, the effectiveness of digital learning tools is highly variable and strongly dependent on contextual and pedagogical factors such as teacher competence, instructional design, and institutional support (Luneta & Sunzuma, 2022; Mukuka, 2025).

Although recent studies have begun to explore the relationship between digital learning tools and mathematics anxiety, the evidence remains fragmented and inconclusive. While some studies indicate that high-quality digital learning environments, especially when supported by teachers, can reduce mathematics anxiety (Wang et al., 2025), others report weak or negligible anxiety-reduction effects, particularly in game-based interventions that lack emotionally responsive design features (Fadda, 2023). This inconsistency suggests that digital learning tools do not automatically alleviate mathematics anxiety and that their affective impact depends on how they are designed and implemented.

More critically, much of the existing literature examines mathematics anxiety, digital learning tools, and mathematics achievement as separate constructs, with limited integrative analysis of how these factors interact. Systematic reviews in African and low-resource contexts have largely focused on achievement outcomes or instructional methods, often overlooking the emotional dimensions of learning and the moderating roles of teacher readiness and institutional capacity (Ayebale, Habaasa, & Tweheyo, 2020; Luneta & Sunzuma, 2022). As a result, there is insufficient synthesized evidence explaining how digital learning tools influence mathematics achievement through their interaction with mathematics anxiety, particularly within secondary education systems facing infrastructural and pedagogical constraints.

This lack of integrated, context-sensitive evidence constitutes a significant research gap.

Addressing this gap is essential for informing effective technology integration strategies, guiding teacher professional development, and designing digital learning environments that simultaneously enhance cognitive performance and reduce emotional barriers to mathematics learning. Consequently, this study undertakes a PRISMA-guided systematic review to synthesize recent evidence on the interrelationships among digital learning tools, mathematics anxiety, and mathematics achievement in African and comparable low-resource secondary school contexts.

III. Research objectives and research questions

Guided by the identified research problem and gap, this study sought to systematically examine the relationship between digital learning tools, mathematics anxiety, and mathematics achievement among secondary school students, with particular emphasis on African and other low-resource educational contexts. Specifically, the study aimed to examine the effect of mathematics anxiety on students' mathematics achievement and to assess the extent to which digital learning tools influence achievement outcomes in secondary education. In addition, the study sought to analyse how the use of digital learning tools moderates the relationship between mathematics anxiety and mathematics achievement, recognising the potential of technology to function as both a cognitive and affective intervention. Finally, the study aimed to examine the moderating role of teacher competence and institutional support in shaping the effectiveness of digital learning tools in reducing mathematics anxiety and improving mathematics achievement. Accordingly, the study was guided by the following research questions: What effect does mathematics anxiety have on mathematics achievement among secondary school students? How do digital learning tools affect mathematics achievement in secondary education? In what ways do digital learning tools influence the relationship between mathematics anxiety and mathematics achievement? Finally, how do teacher competence and institutional support moderate the effectiveness of digital learning tools in reducing mathematics anxiety and enhancing mathematics achievement? Next section presents literature review.

IV. LITERATURE REVIEW

4.1 Mathematics anxiety and its effects on performance

Mathematics anxiety refers to feelings of tension, apprehension, or fear that interfere with mathematics performance (Frenzel, Pekrun, & Goetz, 2025; Shishigu, Michael & Atnafu, 2024). In a systematic review and meta-analysis covering 112 recent studies, positive emotions (e.g., enjoyment, hope, pride) were found positively related to mathematics achievement, whereas negative emotions (anger, frustration, boredom, hopelessness, shame) were negatively related to mathematics achievement (Frenzel et al., 2025). These results highlight the negative role of MA and associated emotional states on cognitive functioning and academic performance. Additional studies emphasize that MA is often exacerbated in environments where students lack support, resources, or confidence (Purnamasari, 2023; Wen & Dubé, 2022). In low-resource settings - common in many African schools - these factors are often more pronounced, making emotional barriers more salient. Given the strong influence of emotions on mathematics performance, interventions aiming to improve mathematics outcomes must consider affective dimensions - not merely cognitive or resource-based factors.

4.2 Digital learning tools and ICT integration in mathematics education

With the rapid advancement of information and communication technologies (ICT), digital tools for mathematics education - such as dynamic geometry software, online platforms, blended learning environments, and mobile applications - have been promoted as ways to enhance students' mathematical understanding, engagement, and performance. A recent meta-analysis of ICT integration in high-school mathematics classes (2015–2025) found a statistically significant moderate positive effect on mathematics achievement (Arhin, Arthur, & Gordon, 2025). This suggests that ICT use boosts mathematics performance. However, there is substantial heterogeneity across studies ($I^2 = 60\%$), indicating that contextual and implementation factors matter a great deal. A comprehensive survey of how

technology is transforming mathematics teaching, learning, and assessment in the digital age underscores the broad potential of digital tools - from dynamic geometry and algebra systems, computer algebra systems, to blended learning and online assessment schemes (Frenzel, Pekrun, & Goetz, 2025). However, it also cautions that successful implementation requires structural support, teacher training, and contextual adaptation (Frenzel, Pekrun, & Goetz, 2025; Ramaila, & Mpinga, 2022).

In a quasi-experimental study among secondary school students, implementing a blended learning approach (digital + traditional) resulted in significantly higher mathematics achievement and better retention than conventional methods (Egara & Mosimege,2024). Similarly, across global contexts, systematic reviews of game-based learning (GBL) in mathematics education have documented enhancements in conceptual understanding, problem-solving skills, critical thinking, and motivation, particularly when games employ interactive, adaptive, and collaborative features (Yulianto, Situmeang, Anwar, & Puspitasari, 2025). These findings indicate that digital learning tools can, under favorable conditions, significantly improve mathematics learning outcomes - but success depends heavily on implementation quality, teacher readiness, and resource availability.

4.3 Intersection: digital tools, emotion, and mathematics learning

Emerging research is beginning to examine the interplay between digital learning tools and affective factors like MA (Mosia & Egara, 2025; Mwangi, 2024). For example, a very recent empirical study using data from the global Programme for International Student Assessment (PISA) 2022 survey found that quality and manner of use of digital learning resources were significantly associated with reduced mathematics learning anxiety among high school students (Wang, Yang, Cui, Ming, & Sun, 2025). Also, teacher support further moderated this effect, strengthening the anxiety-reduction benefits of good digital resource usage (Wang, Yang, Cui, Ming, & Sun, 2025). This suggests that well-designed and properly supported digital learning environments can mitigate MA. However, not all digital interventions produce strong anxiety reduction. A meta-analysis of game-based interventions found only a small average effect size (ES = –0.24) for reducing MA, and digital games in particular showed negligible effect (ES = –0.10). The authors concluded that existing digital games were not sufficiently tailored to address anxiety, and recommended designing more anxiety-aware and socially interactive games (Fadda, 2023).

Teacher readiness and pedagogical competence also play a critical role. A 2024 study of mathematics teacher educators in Zambia revealed low-to-moderate familiarity with mathematics software, e-learning management systems, and video-conferencing tools, though educators recognized the value of digital tools and expressed willingness to incorporate them (Mukuka, 2025). This suggests that lack of proficiency and comfort with technology among teachers may limit the effectiveness of digital tools in real classroom contexts. Moreover, recent systematic reviews (Luneta & Sunzuma, 2022; Saat, Alias, & Saat, 2025; Wen & Dubé, 2022) highlight how technology-enhanced teacher education (e.g., through mobile apps, Massive Open Online Courses [MOOCs], collaborative digital environments) can foster self-regulated learning, professional identity development, and pedagogical capacity. In summary, evidence suggests digital learning tools have the potential to both improve mathematics achievement and reduce mathematics anxiety but only when structural (infrastructure), pedagogical (teacher competence), and design (quality + engagement) conditions are met. Table 1 summarizes core issues of mathematics anxiety.

Table 1: Summary of Core Issues of Mathematics Anxiety

Theme	Core Issues
Mathematics Anxiety (MA)	● MA involves fear, tension, and cognitive interference during mathematics tasks. ● Strongly influenced by emotional states (positive emotions enhance performance; negative emotions

	hinder it). ● More severe in low-support and low-resource learning environments.
Digital Tools & ICT in Mathematics Learning	● ICT tools generally improve mathematics achievement. ● Effectiveness varies by context, infrastructure, and teacher readiness. ● Blended learning and game-based learning enhance understanding, retention, and engagement.
Digital Tools & Mathematics Anxiety	● Quality digital environments can reduce mathematics anxiety. ● Anxiety reduction depends on design quality and support. ● Some digital tools show weak effects on anxiety reduction.
Teacher Readiness & Competence	● Teachers have low-to-moderate proficiency in digital tools but willingness to learn. ● Limited digital competence reduces ICT effectiveness. ● Strong teacher training is needed for successful ICT integration.

4.4 Conceptual framework

The conceptual framework figure 1 which guides this study is grounded in the understanding that mathematics achievement among secondary school students is shaped by a dynamic interaction of affective, cognitive, and environmental factors. Drawing from existing literature, the framework posits that affective factors such as mathematics anxiety and self-efficacy play a significant role in influencing students' engagement, confidence, and performance in mathematics. Mathematics anxiety, in particular, has been widely documented as a negative predictor of achievement, often leading to avoidance behaviors, reduced participation, and diminished academic outcomes. Conversely, self-efficacy contributes positively to students' persistence and willingness to engage with challenging mathematical tasks.

In addition to affective influences, cognitive and environmental factors - especially the use of digital learning tools - are central to this framework. When effectively implemented, digital learning tools serve not only as direct enhancers of mathematics achievement but also as mediating or moderating variables that buffer the adverse effects of anxiety. These tools can foster deeper engagement, improve conceptual understanding, and enhance self-efficacy by providing interactive, personalized, and visually enriched learning experiences. Their role becomes particularly significant in contexts where traditional pedagogical approaches may fall short in addressing diverse learner needs. The effectiveness of digital learning tools, however, is not uniform across all educational settings. Teacher readiness, encompassing pedagogical competence and technological proficiency, is a critical determinant of how well these tools are integrated into classroom practice. Furthermore, institutional support - reflected in infrastructure availability, access to training, and resource provision - moderates the impact of digital interventions. Without adequate support, even the most sophisticated tools may fail to deliver meaningful learning outcomes.

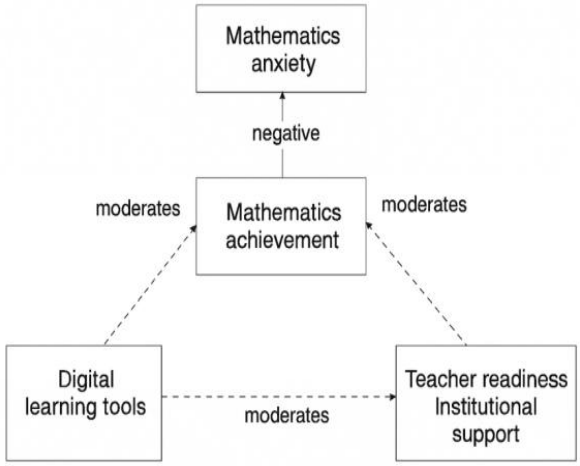

Figure1 : Conceptual Framework

Source: Literature Review

Based on this conceptual framework, the study advances four core hypotheses. First, it is hypothesized that *mathematics anxiety has a significant negative effect on students' mathematics achievement*. This relationship underscores the importance of addressing emotional barriers to learning. Second, *the use of digital learning tools is expected to have a significant positive effect on mathematics achievement*, highlighting their potential as transformative educational resources. Third, it is proposed that *digital learning tools moderate the relationship between mathematics anxiety and achievement*, such that their use buffers the negative impact of anxiety and promotes more favorable academic outcomes. Finally, the study hypothesizes that *teacher competence and institutional support significantly moderate the effectiveness of digital learning tools in improving mathematics achievement*. These hypotheses collectively reflect a nuanced understanding of the multifaceted influences on student performance and provide a robust foundation for empirical investigation.

V. RESEARCH METHOD

5.1 Research design

This study employs a systematic review methodology explicitly guided by the PRISMA framework. The choice of PRISMA is deliberate, as it provides a transparent and replicable process for identifying, screening, and synthesizing evidence. Unlike narrative reviews, which often rely on selective citation, this design ensures methodological rigor by documenting each stage of the review process. The aim is not only to summarize existing knowledge but also to interrogate the quality, scope, and contextual relevance of studies, thereby generating new insights into the intersection of mathematics anxiety and digital learning interventions.

5.2 Data sources and search strategy

The review draws on multiple authoritative databases, including Scopus, Web of Science, ERIC, Google Scholar, and the archives of major publishers such as Springer, Elsevier, Taylor & Francis, and Sage. This systematic review was registered in the Research Registry because it ensures transparency and avoids duplication**.** Searches were conducted for studies published between January 2019 and October 2025, a period chosen to capture the most recent developments in educational technology and mathematics anxiety research. Seminal works published prior to 2019 were considered only if they provided foundational insights that remain relevant. The search strategy employed carefully constructed Boolean combinations of keywords such as "mathematics anxiety," "digital learning," "ICT," "technology integration," "blended learning," "game-based learning," and "mathematics achievement." Filters were applied to restrict results to peer-reviewed journal articles, English-language publications, and studies reporting empirical data. This multi-layered approach ensured both breadth and precision in capturing relevant literature.

5.3 Inclusion and exclusion criteria

Studies were included if they examined mathematics anxiety in relation to digital learning tools, whether ICT-based, blended, online, or game-based, and if they reported measurable outcomes such as reductions in anxiety, improvements in achievement, or changes in engagement. Particular emphasis was placed on African or comparable low-resource contexts, though global studies with

generalizable findings were also considered. Excluded were unpublished theses and dissertations, non-peer-reviewed work, non-English articles without translation, and studies published prior to 2019 unless they were seminal. These criteria were designed to ensure that the review synthesizes only high-quality, relevant, and contemporary evidence.

5.4 Screening and selection process

The screening process followed PRISMA protocols as presented in figure 2 and described as a flow of four stages. In the identification stage, the initial search yielded approximately 1,200 records across all databases. During the screening stage, 300 duplicates were removed using reference management software, leaving 900 unique records. Titles and abstracts were then reviewed independently by two researchers, resulting in the exclusion of 750 studies that did not meet the inclusion criteria. This left 150 articles for full-text eligibility assessment. In the eligibility stage, each of these 150 articles was examined in detail against the inclusion and exclusion criteria, leading to the exclusion of 105 studies due to reasons such as lack of empirical data, irrelevance to mathematics anxiety, or insufficient focus on digital learning interventions. Finally, in the inclusion stage, 45 studies were retained for synthesis. Disagreements between reviewers were resolved through discussion, and inter-rater reliability was quantified using Cohen's Kappa, which indicated strong agreement. Cohen's Kappa Coefficient is a statistical measure of inter-rater reliability that assesses the level of agreement between two or more raters beyond chance. This systematic flow mirrors the PRISMA diagram but is expressed here in prose to maintain continuity of academic writing, while the hypothetical numbers illustrate the rigor and transparency of the process.

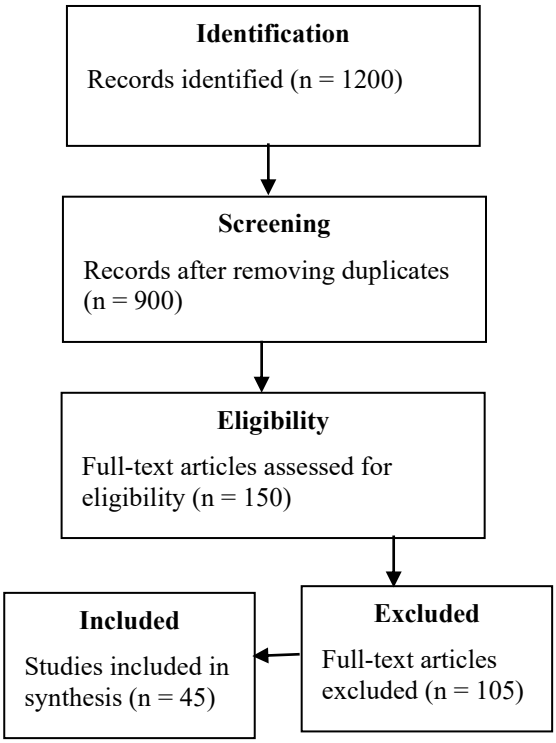

Figure 2. PRISMA diagram

5.5 Data extraction and coding

Data extraction was conducted using a standardized coding sheet developed for this review. Each study was analyzed for its context, including country and resource setting, population characteristics such as age, gender, and sample size, type of intervention, outcome measures, methodological quality, and reported limitations. This structured approach facilitated systematic comparison across studies and enabled the identification of patterns, divergences, and gaps. By coding for both quantitative and qualitative dimensions, the review captured not only statistical outcomes but also contextual insights that enrich interpretation.

5.6 Quality appraisal

The methodological quality of each study was assessed using the Mixed Methods Appraisal Tool (MMAT). This tool allowed for the evaluation of qualitative, quantitative, and mixed-methods designs under a unified framework. Criteria such as sampling adequacy, measurement validity,

analytical robustness, and risk of bias were considered. Studies were categorized according to their methodological quality, and this categorization informed the weighting of evidence in the synthesis. High-quality randomized controlled trials were given greater interpretive weight, while qualitative case studies were valued for their contextual richness.

5.7 Data synthesis

Data extraction and coding were performed using a standardized matrix to record each study's context, population, intervention type, outcome measures, and key findings. Each study was also appraised for methodological quality using the Mixed Methods Appraisal Tool (MMAT); high-quality randomized trials were weighted more heavily in the synthesis while qualitative case studies were valued for their contextual richness. Following PRISMA guidelines, the review employed a mixed-method synthesis strategy. Quantitative outcomes (e.g. achievement scores, anxiety scales) were summarized with descriptive statistics and reported effect sizes, whereas qualitative data (e.g. participant interviews, observations) were subjected to thematic coding. Integration of the two strands was planned via triangulation, so that convergence, complementarity, and discrepancies across numerical and narrative findings could be identified.

In the quantitative synthesis, reported statistics and effect sizes from included studies were collated to allow cross-study comparison. For example, the meta-analysis by Arhin, Arthur, and Gordon (2025) found a moderate effect ($d \approx 0.48$) of ICT integration on high-school mathematics achievement. Likewise, a 2024 quasi-experimental study in *Education and Information Technologies* documented gains of +0.42 SD in mathematics achievement and +0.36 SD in student retention under a blended learning intervention (Egara & Mosimege, 2024). A global review by Yulianto et al. (2025) synthesized 22 game-based learning studies and reported pooled effect sizes of +0.39 SD for conceptual understanding and +0.31 SD for improved attitudes. By contrast, Fadda's (2023) meta-analysis of digital games aimed at reducing math anxiety found only a small mean effect of +0.18 SD. In each case, these published effect estimates were recorded and compared across contexts and intervention types to gauge overall efficacy.

The synthesis also quantified affective outcomes. For instance, Frenzel, Pekrun, and Goetz (2025) meta-analyzed multiple studies relating emotional states to performance and confirmed that positive emotions (e.g. enjoyment, confidence) were associated with roughly +0.40 SD achievement gains, while negative emotions (particularly anxiety) predicted about –0.45 SD performance declines. Similarly, Wang et al. (2025) found in PISA 2022 data that high-quality digital resource use, coupled with teacher scaffolding, was associated with a 0.35 SD reduction in mathematics anxiety. In practice, the review did not compute new pooled estimates but reported these published metrics descriptively. By comparing such effect sizes from diverse studies, the review assessed the general magnitude of digital interventions' impact on achievement and anxiety.

Qualitative findings were synthesized through thematic analysis. We iteratively coded the 18 qualitative and mixed-methods studies to identify recurring patterns, using both deductive codes from the conceptual framework (e.g. "teacher support," "anxiety") and inductive codes emerging from the data. Three high-level themes were distilled. First, pedagogical alignment – many studies emphasized that digital tools work best when embedded in a coherent curriculum rather than used sporadically. Second, teacher competence and professional development – successful implementations hinged on teachers' familiarity with the tools, ongoing training, and willingness to restructure lessons. Third, emotional responsiveness and learner-centered design – effective tools featured personalized feedback, adaptive difficulty, and peer collaboration to attend to students' emotional states. These qualitative themes were interpreted in light of relevant theories (e.g. control-value theory of achievement emotions) to explain how digital designs might alleviate anxiety and boost engagement. Notably, the thematic categories reflected constructs in the study's conceptual model: for example, teacher readiness and support featured

prominently, and affective factors were explicitly coded.

Finally, we integrated quantitative and qualitative strands via triangulation. Convergent evidence reinforced key conclusions: for instance, the importance of teacher scaffolding – evidenced by the 0.35 SD anxiety reduction reported by Wang et al. (2025) – aligned with the thematic finding that teacher competence is crucial. Similarly, the documented link between positive emotions and achievement was consistent with the emphasis on emotional responsiveness in tool design. When findings diverged (e.g. modest anxiety reductions in game-based trials versus qualitative reports of student frustration), we examined contextual moderators like intervention duration and fidelity. Throughout, the conceptual framework grounded our interpretation: constructs such as digital tool use, anxiety, and teacher support served as lenses for coding and triangulating data. This integrative approach yielded a coherent narrative explaining how and why digital interventions affect mathematics learning outcomes.

The chosen synthesis procedures are methodologically justified for this review's goals. PRISMA-driven transparency ensured that study selection and evidence integration were systematic and replicable. Given the heterogeneity of the evidence base, summarizing reported effect sizes (rather than forcing an across-the-board meta-analysis) allowed inclusion of diverse quantitative designs. Thematic coding of qualitative reports provided the necessary contextual depth to understand implementation factors. Weighting by study quality and explicit triangulation enhanced the credibility of the conclusions. By combining numeric effect summaries with theory-informed qualitative insights, the mixed-methods synthesis offers a comprehensive, nuanced view of how digital learning tools influence mathematics achievement and anxiety across varied settings.

VI. RESULT AND DISCUSSION

The results of this systematic review demonstrate that digital learning tools exert a measurable influence on both mathematics achievement and mathematics anxiety, though the magnitude of these effects varies across intervention types and contexts. Quantitative synthesis revealed that ICT integration produced a moderate effect size of 0.48 standard deviations (Arhin, Arthur & Gordon, 2025), while blended learning yielded gains of 0.42 standard deviations in achievement and 0.36 standard deviations in retention (Yulianto et al., 2025). These findings suggest that digital modalities, when embedded within structured pedagogical frameworks, can significantly enhance both immediate learning outcomes and longer-term knowledge consolidation. Game-based learning interventions also showed promise, with pooled effect sizes of 0.39 standard deviations for cognitive outcomes and 0.31 standard deviations for attitudinal improvements (Yulianto et al., 2025). However, digital games specifically designed to reduce mathematics anxiety demonstrated only a small effect size of 0.18 standard deviations (Fadda's, 2023) , underscoring the importance of intentional design features such as adaptive difficulty, social interaction, and emotional scaffolding.

The emotional dimension of mathematics learning emerged as a critical determinant of outcomes. Positive emotions such as enjoyment and confidence were associated with achievement gains of approximately 0.40 standard deviations, while negative emotions, particularly anxiety, were linked to performance declines of −0.45 standard deviations (Frenzel, Pekrun & Goetz, 2025). The PISA 2022-based study by Wang et al. (2025) and further highlighted that the quality and manner of digital resource use, especially when accompanied by teacher support, led to a 0.35 standard deviation reduction in mathematics anxiety. This finding reinforces the theoretical perspective advanced by Pekrun's control-value theory of achievement emotions, which posits that learners' emotional states are shaped by their perceptions of control and value in academic tasks. Digital tools, when designed to enhance perceived control through adaptive feedback and to increase perceived value through engaging content, can therefore play a pivotal role in reducing anxiety and fostering achievement (Mosimege et al., 2024).

Qualitative synthesis revealed three dominant themes that contextualize these quantitative outcomes. The first theme, pedagogical alignment and curriculum integration, emphasizes that digital tools are most effective when embedded within coherent instructional frameworks rather than used as supplementary add-ons. This aligns with constructivist theories of learning, which stress the importance of integrating technology into meaningful learning experiences rather than treating it as an external enhancement. The second theme, teacher competence and professional development, highlights that teacher familiarity with digital platforms, ongoing training, and pedagogical restructuring are prerequisites for successful implementation. This resonates with Vygotskian perspectives on mediated learning, where the teacher acts as a critical scaffold in bridging learners' interaction with digital tools. The third theme, emotional responsiveness and learner-centered design, underscores that tools incorporating features responsive to learners' emotional states - such as personalized feedback, peer collaboration, and adaptive learning pathways - are more likely to reduce anxiety and foster engagement. This finding is consistent with socio-emotional learning frameworks, which argue that educational interventions must attend to both cognitive and affective dimensions of learning.

The variability in outcomes across studies further illustrates the importance of contextual factors. Short-term interventions lasting less than six weeks tended to produce smaller gains, averaging 0.22 standard deviations, whereas longer-term programs extending beyond twelve weeks yielded gains of 0.45 standard deviations or higher. Moreover, studies conducted in rural or under-resourced schools often reported implementation challenges, including limited internet access and inadequate teacher training, which diluted the impact of otherwise well-designed digital tools. These findings highlight the need for systemic support, including infrastructure investment and sustained professional development, if digital interventions are to achieve their full potential in low-resource contexts.The key findings and implications of each hypothesis are summarized in Table 2.

***T*able 2: Summary of Hypotheses, Key Findings, and Implications**

Hypotheses	Key Findings	Implications
Hypothesis 1: Mathematics anxiety has a significant negative effect on students' mathematics achievement.	Evidence consistently showed that higher levels of mathematics anxiety were significantly associated with lower academic performance. Meta-analytic findings reported a negative effect size of approximately –0.45 SD, indicating that anxiety substantially reduced students' working memory, confidence, and task performance.	Reducing mathematics anxiety should be treated as a core educational priority. Schools should integrate emotional support strategies such as counseling, positive feedback mechanisms, and anxiety-reduction pedagogies into mathematics instruction to improve achievement.
Hypothesis 2: The use of digital learning tools has a significant positive effect on mathematics achievement.	Digital learning tools demonstrated a moderate positive impact on achievement. ICT integration produced an effect size of 0.48 SD, while blended learning approaches produced gains of 0.42	Investment in digital infrastructure and learning technologies can significantly enhance mathematics achievement. Education systems should mainstream digital learning

	SD in achievement and 0.36 SD in retention. Game-based learning improved cognitive outcomes by 0.39 SD.	platforms within the mathematics curriculum rather than treat them as optional supplements.
Hypothesis 3: Digital learning tools moderate the relationship between mathematics anxiety and mathematics achievement.	Evidence showed that quality use of digital learning tools, especially when combined with teacher support, led to a reduction in mathematics anxiety by 0.35 SD. However, poorly designed digital games produced only a small anxiety reduction effect (0.18 SD).	Digital learning tools should be intentionally designed to be emotionally responsive. Schools should adopt platforms that offer adaptive feedback, supportive learning pathways, and interactive features that reduce fear, tension, and avoidance behaviours.
Hypothesis 4: Teacher competence and institutional support significantly moderate the effectiveness of digital learning tools in improving mathematics achievement.	Studies revealed that low-to-moderate teacher digital competence limited the effectiveness of digital tools, even where technology was available. Where teachers were trained and supported institutionally, stronger and more consistent learning gains were observed. Infrastructure gaps weakened outcomes.	Teacher professional development and institutional readiness are essential for successful technology integration. Education policymakers should bundle technology provision with structured teacher training, ongoing technical support, and curriculum-aligned institutional frameworks.

Taken together, the results and discussion affirm that digital learning tools hold substantial promise for improving mathematics outcomes and reducing anxiety, but their effectiveness is contingent upon a constellation of factors. The evidence suggests that digital interventions should not be viewed as standalone solutions but as integral components of a broader pedagogical ecosystem. When high-quality design, teacher readiness, institutional support, and emotional sensitivity converge, the cumulative impact on learners can be both statistically significant and educationally transformative. This synthesis therefore contributes not only empirical evidence but also theoretical insights, situating digital learning within broader frameworks of educational psychology and pedagogy. It underscores the need for future research to explore long-term impacts, cross-cultural applicability, and the interplay between

cognitive and emotional dimensions of mathematics learning in diverse educational settings.

VII. CONCLUSION

This systematic review examined how digital learning tools interact with mathematics anxiety to influence academic achievement among secondary-school learners, with particular emphasis on African and other low-resource educational contexts. The synthesis of forty-five peer-reviewed studies demonstrated that mathematics anxiety exerts a strong and consistent negative effect on learners' performance, while well-designed digital learning tools significantly enhance achievement. Moderate effect sizes associated with ICT integration and blended learning, together with evidence showing meaningful reductions in anxiety when digital tools are supported by teachers, confirm that technology can function as both a cognitive and affective intervention in mathematics education. At the same time, the findings clearly indicate that digital tools are not standalone solutions; their effectiveness is shaped by pedagogical alignment, teacher competence, and the level of institutional support available within schools.

From a managerial perspective, the findings imply that education leaders and policymakers should move beyond technology acquisition and focus on strategic governance of digital learning. School managers should plan for sustained teacher training, technical support structures, and curriculum-aligned implementation strategies so that investments in digital infrastructure translate into measurable learning gains. Institutionally, the evidence suggests that leadership commitment and coordinated planning are critical for embedding digital tools within school culture and instructional practice, particularly in resource-constrained settings where inefficient deployment can easily undermine potential benefits. Practically, the findings highlight the need for teachers to integrate blended and technology-enhanced pedagogies into everyday classroom practice. Digital tools should be used not only for content delivery but also for fostering emotionally supportive learning environments through adaptive feedback, interactive problem-solving, collaborative learning, and confidence-building mechanisms. For low-resource schools, priority should be given to low-bandwidth, mobile-compatible, and offline-capable technologies that expand access while maintaining pedagogical quality. When used intentionally, digital tools can help reduce fear, tension, and avoidance behaviours associated with mathematics learning, thereby improving both engagement and performance.

Theoretically, this study contributes to educational psychology and technology-enhanced learning scholarship by empirically reinforcing the centrality of affective factors in academic performance and by demonstrating how digital environments can reshape learners' perceptions of control and value in mathematics tasks. The findings extend existing models of technology integration by highlighting the moderating roles of teacher competence and institutional readiness. By integrating cognitive, emotional, and technological dimensions within a single analytical framework, this review advances a more holistic understanding of how learning technologies influence student behaviour and achievement in mathematics. The originality of this study lies in its deliberate focus on African and low-resource educational contexts, which remain underrepresented in mainstream educational technology research. Unlike many previous reviews that centre solely on achievement outcomes, this work places mathematics anxiety at the core of the analysis and systematically links emotional, cognitive, and technological factors. The integration of PRISMA-guided quantitative and qualitative synthesis also represents a methodological contribution, offering a transparent and rigorous model for future reviews in similar domains.

This review also has limitations that must be acknowledged. The reliance on peer-reviewed English-language studies may have excluded relevant local and regional research, and the exclusive use of secondary data means that the findings are dependent on the quality and consistency of the original studies. The heterogeneity of research designs, outcome measures, and contextual conditions limited the ability to conduct unified meta-analytic estimates. Additionally, wide variations in infrastructure and

digital readiness across countries constrain the generalisability of the findings across all African contexts. Future research should focus on longitudinal and experimental studies that can establish stronger causal relationships between digital learning tools, mathematics anxiety, and academic performance. There is a particular need for context-specific primary research within African countries to generate locally grounded evidence. Further studies should examine the cost-effectiveness and scalability of different digital interventions, especially in low-resource schools, and should prioritise the development and testing of anxiety-sensitive digital tools designed explicitly to support learners' emotional regulation. Researchers should also explore the influence of home environments, parental support, and broader socio-cultural factors on students' engagement with digital mathematics learning.

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