

Improving Foundation Phase Learners' Addition Skills Using Digital Interventions: A Hermeneutic Meta-Synthesis

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Abstract: The purpose of this paper was to identify the predominant pedagogical roles of digital interventions in improving Foundation Phase learners' addition skills. Global curriculum education advocates for the integration of digital interventions to enhance numeracy, with additional skills being a critical topic for early mathematical success. However, a significant gap persists between this policy encouragement and its effective implementation in classrooms, particularly in contexts such as South Africa. Framed by the Technological Pedagogical and Content Knowledge (TPACK) framework, teachers require both content and pedagogical knowledge to utilise digital interventions effectively in assisting learners in acquiring mathematical skills beyond rote memorisation. This study employed a hermeneutic meta-synthesis to critically interpret and integrate findings from 16 qualitative studies conducted between 2020 and 2025, utilising the Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The findings indicate that digital interventions serve as conceptual bridges and cognitive scaffolds, making abstract ideas tangible and enhancing executive functions in the improvement of addition skills. However, their transformative potential is entirely mediated by teacher expertise. Significant systemic barriers, including inadequate teacher technological, pedagogical, and content knowledge, insufficient professional development, and constraining curriculum policies, routinely lead to the underutilisation or misuse of technology as mere digital worksheets. This paper concludes that improving addition skills requires the construction of a coherent pedagogical ecosystem rather than reliance on superior interventions. Consequently, it recommends a fundamental reconceptualisation of teacher preparation and support concerning digital interventions aimed at improving Foundation Phase learners' addition skills.

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Keywords: Addition skills, digital intervention, foundation phase, mathematics education, TPACK.

1. Introduction

Recent evidence from global frameworks suggests that digital transformation has altered the educational landscape, prompting the international community to reassess pedagogical approaches in the early years of schooling. This is supported by Laxman (2024), who highlights that within mathematics education, the Foundation Phase is a crucial period for laying strong basic numeracy skills. Central to this, as stated by Nanda and Rani (2025), are early mathematics skills, particularly the concept of addition, which serve as a primary building block; without them, other operations, such as subtraction, multiplication, and division, become challenging. Globally, curriculum frameworks are increasingly emphasising the integration of technology to enhance learning outcomes. Gilbert and Caena (2022) highlight that the Global Education Framework calls for the strategic use of digital technologies to strengthen foundational numeracy. They further corroborate this with initiatives such as the Organisation for Economic Cooperation and Development (OECD, 2019)'s Future of Education and Skills 2030 and the United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2018)'s Competency Framework for teachers, which underscore the importance of integrating digital interventions to support early mathematics development. These

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international directives indicate a shift towards pedagogies that integrate digital resources to make learning more engaging, accessible, and effective.

However, there remains a curriculum gap in the guidelines for supporting Foundation Phase teachers in mathematics pedagogy. The emphasis on addition is intentional, making it arguably the most crucial mathematical operation introduced during this phase. According to Chen and Yang (2023), when learners master addition in the early years, they significantly improve their chances of later mathematical achievement, as it underpins their understanding of the base-ten system, place value, and properties of operations. Similarly, Gracia and Lee (2024) highlight that a failure to grasp the concept of addition can lead to persistent difficulties and low self-efficacy. Therefore, implementing effective strategies to strengthen addition skills is a vital stepping stone for the entire mathematical future of a learner. As stated by Abramovich and Huang (2022), digital tools provide a dynamic medium for achieving this, moving beyond static worksheets to offer interactive visuals and an immediate feedback experience that reinforces abstract numerical concepts for young learners.

In European countries, as indicated by Niemelä et al. (2021), curricula such as England's National Curriculum for Mathematics and Finland's national core curriculum explicitly encourage the use of digital tools to foster problem-solving and conceptual understanding. Similarly, Manyasa (2022) noted that across Africa, there is a growing push for ICT integration, as evident in policy frameworks in countries such as Kenya and Rwanda, which aim to bridge educational gaps using technology. In South Africa, the Curriculum and Assessment Policy Statement (CAPS) for Mathematics in the Foundation Phase acknowledges the potential of educational media and tools; however, its guidance remains largely non-specific and peripheral to the core, with a worksheet-dominated pedagogy focused on procedural fluency (Department of Basic Education [DBE], 2011).

While international and continental trends actively advocate for the integration of digital tools, a significant gap exists between this policy-level encouragement and the evidence-based, practical implementation within specific national contexts, particularly in South Africa. The South African CAPS curriculum, while mentioning the use of digital tools, lacks a structured pedagogical framework for effectively integrating them to teach specific foundational concepts, such as addition. Existing research from the Global North, conducted by Chen and Yang (2023) and Abramovich and Huang (2022), demonstrates the benefits of digital tools for learning addition. However, their findings are not automatically transferable to the South African Foundation Phase context, which faces unique challenges, including large class sizes, diverse linguistic backgrounds, and uneven access to resources. This limitation underscores the necessity for a synthesis-based interpretive approach. Rather than seeking empirical evidence, there is a critical need to synthesise and reinterpret existing knowledge to understand how the integration of digital interventions is conceived within frameworks like CAPS. The gap, therefore, lies in a coherent interpretive understanding of how digital interventions can be pedagogically framed to support the teaching of addition, moving beyond generic policy statements to develop a contextualised pedagogical perspective. This paper addresses this gap by interrogating and synthesising literature to identify the potential pedagogical roles of digital interventions, thereby contributing a contextualised interpretive framework for bridging the divide between global digital education policy and local pedagogical practice.

1.1 Problem statement

A growing body of literature examines the utilisation of digital interventions in early mathematics; however, a cohesive understanding of their specific role in the development of addition skills remains fragmented, necessitating a synthesised interpretation. As noted by Yadav (2022), a significant gap exists between the availability of digital applications and their alignment with foundational mathematical pedagogy, as many tools prioritise memorisation and repetition practices

without fostering the conceptual understanding that is essential for long-term skill retention. Furthermore, Cayabas and Sumeg-ang (2023) note that, in practice, educators frequently encounter obstacles such as inadequate technological infrastructure, a lack of sustained professional development pertaining to pedagogically sound technology integration, and limited access to high-quality, contextually relevant digital resources. From the authors' perspectives, while there is a growing corpus of qualitative studies exploring teacher and learner experiences with educational technology, there is a dearth of comprehensive syntheses that deeply interpret these findings to generate new, transferable theoretical insights regarding the phenomenon of using digital tools to improve addition skills. Based on this, the study answered the question: *What are the predominant pedagogical roles of digital interventions in supporting Foundation Phase learners' addition skills?* Using the following objectives as guide:

- To identify predominant pedagogical roles of digital interventions in supporting Foundation Phase learners' addition skills.
- To examine the factors that influence the Foundation Phase teachers' selection of specific pedagogical roles for digital interventions when teaching addition skills.

2. Theoretical Framework

This study is underpinned by the Technological Pedagogical Content Knowledge (TPACK) framework, which provides a crucial lens for understanding the effective integration of digital interventions in teaching addition to learners in the Foundation Phase. Initially conceptualised by Mishra and Koehler (2006), TPACK posits that meaningful technology integration necessitates an interconnected and dynamic understanding of three primary forms of knowledge: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). TPACK, as highlighted by Adipat et al. (2023), is a framework for understanding and describing the types of knowledge that educators need for effective educational practices in a technology-enhanced learning environment. This framework helps educators enhance their teaching competencies, especially in early learning.

For this review, which focuses on addition skills in the Foundation Phase, the framework is interpreted as follows: Content Knowledge (CK) involves a deep understanding of addition, its concepts, properties, and its role as a foundational arithmetic operation. As indicated by Willis and Lynch (2023), Pedagogical Knowledge (PK) relates to effective strategies for teaching addition skills to young learners, such as using digital tools. In contrast, Technological Knowledge (TK) refers to how educators understand the use of digital interventions for teaching addition skills in the Foundation Phase. Furthermore, Li, Vale, Tan, and Blannin (2024) revealed that for educators to effectively implement technology in their classes, they need to be well-informed about digital media cultures that are important for learners. This theory is relevant for guiding this study, as it assists educators in understanding how to use digital interventions effectively in teaching addition skills in the Foundation Phase.

According to Li and Nugraha (2025), the importance of TPACK lies in its ability to integrate content, pedagogy, and technology. They add that educators are well-equipped with the necessary tools and insights to integrate technology effectively when using this comprehensive framework. Supporting this statement, Huang et al. (2024) posited that for primary mathematics education, TPACK serves as a guiding light for educators as they design engaging and meaningful experiences, such as using digital interventions to improve addition skills. In this context, the framework serves as a guideline for teachers using digital interventions that support the development of foundational mathematical skills, particularly addition skills. For the purposes of this paper, the authors selected this theory as relevant for integrating digital interventions to develop addition skills in the foundation phase. TPACK guides teachers in choosing digital interventions, such as a virtual number frame (TK), that make the concepts of part-part-whole and bridging through (CK) visually explicit and flexible, while

aligning with the Foundation Phase pedagogy of learning through play and concrete experiences (PK). In this way, integrating digital interventions is purposeful and practical, allowing learners to acquire knowledge in a manner that suits them, thus making learning more engaging and fostering the strong development of addition skills. The effectiveness of the TPACK framework is revealed not in the isolated domains but in their dynamic intersections. It is at these intersections that digital interventions are transformed from novelties into powerful pedagogical instruments. The Technological Content Knowledge (TCK) intersection involves understanding how technology and content influence and constrain one another. In support of this statement, Yunianto et al. (2024) highlighted that when a teacher uses a specific digital tool, such as a virtual number frame (TK), it makes the mathematical concept of 'bridging through ten' (CK) visually explicit and manipulable for students. This represents knowledge about how certain technologies can best represent specific content. The Technological-Pedagogical Knowledge (TPK) intersection requires an understanding of how teaching and learning are altered when specific technologies are employed. Chen et al. (2023) stress that selecting tools that support broader pedagogical goals, such as using a gamified application that provides immediate feedback (TK) to improve motivation and enable mastery learning (PK), is a strategy shown to be effective in building foundational skills.

Finally, as posited by Jibril and Adedokun-Shittu (2024), full TPACK integration occurs when a teacher seamlessly blends all three domains. For example, a teacher might design a lesson where students use a digital camera (TK) to find and photograph real-world examples of addition problems, such as two groups of objects (CK), and then use these self-generated images in a collaborative storytelling activity (PK) (Bakar et al., 2020). This approach, which is both pedagogically sound and conceptually rigorous, moves learning beyond passive consumption to active construction. However, achieving this level of integration is a significant challenge. Studies by Nanda and Rana (2025) and Venketsamy and Hu (2022) consistently show that a primary barrier is the lack of teacher readiness in implementing TPACK, with many educators defaulting to using digital tools for low-level drills rather than conceptual exploration. This highlights a critical gap in their integrated TPACK. The literature, when viewed through the TPACK framework, clearly indicates that the potential of digital tools to improve addition skills is not an automatic outcome of their availability. The teacher's integrated knowledge base profoundly mediates their effectiveness. High-quality digital tools can act as conceptual bridges and cognitive scaffolds; however, their power is unlocked only when selected and implemented by a teacher with deep pedagogical knowledge, robust content knowledge, and the ability to synergise these with technological knowledge. Therefore, efforts to enhance addition skills in the Foundation Phase must focus not solely on procuring technology, but also on promoting the development of this essential, integrated TPACK among educators.

3. Methodology

This study employed a hermeneutic meta-synthesis to critically reinterpret and integrate findings from qualitative research documenting the use of digital interventions to enhance addition skills in Foundation Phase mathematics. The interpretivist paradigm informed this approach, recognising that knowledge is socially constructed and that a deeper understanding emerges from synthesising multiple qualitative perspectives (Sim & Mengshoel, 2023). The synthesis was conducted through a structured, iterative process designed to ensure transparency and rigour.

3.1 Procedure for study selection and screening

A systematic search and selection procedure was carried out following an adapted PRISMA framework (Islam et al., 2025). Peer-reviewed empirical and conceptual studies published between 2020 and 2025 were identified from Scopus, Web of Science, ScienceDirect, Google Scholar, and ResearchGate. The search terms encompassed combinations related to digital interventions, addition, mathematics, the foundation phase, and early childhood education. After eliminating duplicates, records were assessed against specific inclusion criteria: studies with a qualitative focus, situated in

a foundation phase context, and addressing the use of digital tools for addition. Guided by Ahmad and Wilkins (2024), excluded studies included those sourced from grey literature, editorials, and abstracts lacking full papers. The chosen studies collectively present evidence-based analyses of digital interventions designed to enhance addition skills among Foundation Phase learners. The entire process was meticulously documented using a PRISMA flow diagram. Figure 1 demonstrates the application of PRISMA in the selection and screening of relevant studies, highlighting the primary pedagogical roles of digital interventions in supporting mathematics skills.

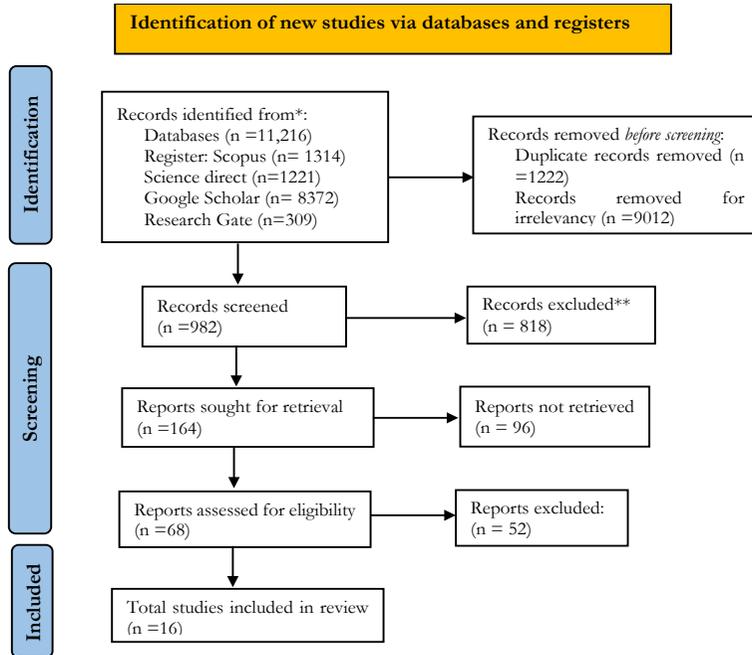


Figure 1: Schematic diagram detailing the screening process of selected articles

Figure 1 demonstrates the PRISMA flow process used in systematic reviews to ensure transparency and rigour in the selection of studies related to the ongoing research. The diagram provides a visual map of how the researchers narrowed a large pool of studies to a smaller, more appropriate set for analysis.

3.2 Analytic and interpretive process

The analysis was an iterative hermeneutic process involving repeated engagement with the texts to construct an integrated understanding. Useful data were extracted from 16 articles that answered the research questions. The procedure progressed through four interlinked phases. To analyse the selected studies, each was read in full to gain a holistic understanding. Initial descriptive codes were applied to key findings related to teachers’ perspectives, pedagogical strategies, and reported challenges. These codes were logged in an analytic memo. The initial codes were compared across studies to identify patterns and contradictions. This initiated the hermeneutic cycle, where understanding each part of the individual study findings was informed by a holistic understanding of the combined dataset. For example, an initial code like “technical issues” from one study was revisited in light of another study’s finding on “school infrastructure support,” leading to the broader theme of Systemic and Practical Barriers.

This cycle of moving between parts and the whole continued throughout the analysis. Guided by the research question and the researchers’ positionality as mathematics educators, the developed themes were critically interpreted. This phase moved beyond summarising findings to interrogating and

reconciling divergent insights. This interpretive work sought to generate novel insights that transcended the individual studies. The synthesised themes were organised into a coherent conceptual framework. The relationships between themes, such as how “Teachers’ Technological Pedagogical Content Knowledge mediates the encounter between ‘Pedagogical Affordances of Digital Tools’ and ‘Systemic and Practical Barriers,’” were explicitly mapped and described. This framework represents the novel theoretical understanding generated by the synthesis. Informed by Macqueen and Patterson (2021) to enhance rigour, the research team maintained a reflexive journal throughout the process. Our preconceptions as mathematics educators were documented and regularly discussed to ensure they informed, rather than biased, the interpretation. The analytic steps from codebook development to theme formulation and framework mapping were conducted collaboratively by the authors, with disagreements resolved through recursive reference to the primary study texts. This transparent, procedural account of the hermeneutic cycle and theme generation provides a clear audit trail for the synthesis.

4. Presentation of Results

In this systematic review, the procedure for selecting relevant studies is elucidated in the PRISMA 2020 flow diagram (see Figure 1). A comprehensive search of academic databases and registers initially identified 11,216 records. Following the removal of 1,222 duplicates and 9,012 records deemed irrelevant, the titles and abstracts of 982 records were screened against the eligibility criteria. This screening process resulted in 68 records being sought for full-text retrieval. A detailed assessment of these articles was conducted, leading to the exclusion of 52 studies for specific reasons, primarily related to ineligible study designs, populations, or interventions that did not fulfil the core requirement of integrating a digital tool for foundational addition instruction. Consequently, 16 studies were included for the final qualitative synthesis in this review. These studies collectively constitute the evidence base examining digital interventions aimed at enhancing addition skills among Foundation Phase learners.

Table 1: Predominant pedagogical roles of digital interventions in improving mathematics skills

Authors	Aim	Findings	Implication on improving addition skills through digital interventions
Mutenje (2022)	To describe teachers' experiences of using a CPA to integrate e learning into the teaching and learning of problem-solving techniques in mathematics to foundation phase learners	The study reveals that constructivist teachers, as facilitators of learning, should promote inquiry-based and discovery learning, leading to learners gaining skills to solve mathematics problems while learning online.	The effective use of digital interventions for addition depends on high-quality teacher training. Professional development programs must be specifically designed using a TPACK framework to help teachers understand how to integrate technology (the T) with the pedagogy (P) of teaching early mathematics, such as addition (the CK). This is a foundational requirement for any digital intervention to be successful.

Bakar et al. (2020)	This study explored young children's use of digital cameras to exhibit their understanding of the addition concept.	The findings showed that young children were capable photographers and that their visual representation images supported their understanding of the addition concept	Simple digital interventions, such as cameras, can be powerful for building a conceptual understanding of addition. By having learners create their own visual representations, they move beyond rote memorisation. This shows that digital tools can make abstract addition concepts concrete and personally meaningful for young children.
Casanova et al. (2025)	To explore the association between inhibitory control and mathematical performance in early childhood: A systematic review	Significant yet variable relationship between IC and early mathematics, with some showing weaker or stronger association. The need for further research to inform targeted educational strategies and interventions	Digital games and apps used for practising addition can be designed to simultaneously train cognitive fundamentals, such as inhibitory control (e.g., by having children resist the impulse to click on a distractor and instead choose the correct sum). This suggests that well-designed digital activities can support the underlying cognitive skills necessary for mathematical success.
Giblin, Butler, and Kingston (2022)	To understand how the use of digital tools can support numeracy development in early childhood, primary and post-primary mathematics education	Findings indicate that the use of technology-assisted systems for instruction, such as computer-assisted instruction, computer-managed learning systems, comprehensive models, intelligent tutoring systems, computer-based scaffolding, and technology-mediated mathematics interventions, can have a positive impact on students' achievement in mathematics.	The primary implication is that the design and implementation of these digital interventions and must be intentionally aligned with established mathematical learning trajectories to ensure they develop genuine conceptual understanding.
Chen, Hou and Wu (2023)	The purpose of this study was to investigate the learning outcomes of a scaffolding-	The results showed that the gamified activity with the scaffolding-based mind tool significantly improved students' learning effectiveness;	The findings imply that educators should adopt these interventions and use them as effective teaching strategies that can support learners' motivation and provide structured support

	based mind tool integrated with gamified learning activities applied to a science course.	however, the learning effectiveness did not differ significantly from that of the students in the lecture-based instruction.	
Bouzid (2025)	To investigate the integration of digital tools, specifically games like "Numeros Amigos," to enhance basic mathematical skills, including addition, in early education.	Findings highlight the effectiveness of combining digital and physical materials to support learners' understanding and engagement.	Based on these findings, digital interventions when integrated adequately with physical manipulatives in a blended approach can be effective for improving addition skills. This implies that digital games should serve as a bridge to reinforce conceptual understanding developed through hands-on activities, not replace them. In addition, educators need to select interventions that can be complemented with physical resources and design lessons that combine both to support learners' engagement when learning addition skills.
Ahmad Nur Efendi et al. (2024)	To develop a digital based number of pocket media as a tool for mathematics learning	. Findings revealed that digital-based number pocket media are deemed feasible, practical, and effective for use as an interactive learning medium to enhance students' understanding of addition and subtraction concepts.	When digital interventions are used in a strategic manor become a decisive paradigm shift for teaching addition in the foundation phase. The implication is that digital tools transform existing practice
Gomes et al.	To investigate the use of Digital Educational Resource (RED), as well as the teaching of concepts aimed at addition and subtraction, or that is, the additive structures	Findings revealed that there is a need for the emergence of new research that presents the use of RED in teaching the additive field, in view of the need to teach concepts related to the additive field using RED, which can favour teaching and learning.	Based on the findings of Gomes et al., digital interventions must be designed to teach the core concepts of addition. It is essential that educators utilise these interventions to enhance conceptual understanding, as this concept is less well-investigated.

Yunianto et al. (2024)	Students were active in learning mathematics and CT, primarily when they were engaged in programming and debugging tasks.	This study presents some activities that integrate computational thinking (CT) into mathematics lessons utilising GeoGebra to promote constructionist learning.	Digital interventions should not just be used as electronic worksheets where students input answers. They must allow learners to construct and manipulate mathematical objects
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Table 1 shows the studies reviewed and grouped into categories that align with research objective 1 in this study. The results indicate that digital interventions are not only technologically enhanced tools but also support inquiry-based learning, cognitive development, and learner engagement. Furthermore, the results reflect a shift in understanding technology from a teaching mechanism to mediated tools that improve learners’ mathematical thinking, strengthen the active construction of mathematical concepts, and support teachers’ pedagogical strategies in enhancing addition skills for Foundation Phase learners.

Table 2: Factors influencing teachers' selection of pedagogical roles of digital interventions when

Aim	Aim	Findings	Implications
Akudo (2025)	To examine most of the teachers' utilisation of computer animation for managing pre-primary school pupils' social skills in Delta State.	The study's findings revealed, among other things, that teachers less frequently utilised computer animation to manage pre-primary pupils' social skills in areas such as literacy, numeracy, manipulative, and communication skills in Delta State.	There is an insufficient existence of practical digital interventions is inadequate. The study highlights a significant gap between awareness of technology and its practical application in teaching numeracy.
Venketsamy and Hu (2022)	To explore the challenges faced by foundation phase teachers in using technology for teaching and learning in two schools within one district in Gauteng Province, South Africa	Teachers faced challenges due to a lack of knowledge and understanding of how to utilise technology effectively for teaching and learning, a lack of support from management to promote its use, and inadequate, inappropriate, and outdated technological resources and equipment.	Simply having digital interventions available is insufficient. A lack of teacher training, institutional support, and modern resources is a critical barrier. For digital tools to improve addition skills, schools must first address these infrastructural and support challenges; otherwise, the interventions will remain unused or ineffectively used.
Nanda and Rana (2025)	To examine the proficiency of primary mathematics teachers in basic	The results indicate that some teachers utilise manipulatives, interactive play, and experiential techniques in their teaching	The implications, therefore, centre on how digital interventions can transform effective teaching practices

Badmus and Jita (2022)	<p>addition facts and what instructional approaches they use to teach addition to the students.</p> <p>This study examines the foundational mathematics curricula of South Africa and Australia.</p>	<p>approaches. However, most of them still rely on traditional methods, such as using the blackboard and fingers</p> <p>This study reveals how context, national priorities, and educational visions intersect to guide early years mathematics teaching. It underscores the importance of balancing these immediate needs with broader long-term aspirations to ensure that all learners are supported in building solid mathematical foundations for future success</p>	<p>and add skills in the Foundation Phase</p> <p>The study reveals that early years mathematics teaching is shaped by the intersection of context, national priorities, and educational visions, which carries profound implications for curriculum designers and policymakers.</p>
Mou et al. (2024)	<p>To identify the standard features of previous TPACK research on primary mathematics education and identify the research gaps based on their contexts</p>	<p>Findings from this systematic review of the literature can assist educators in designing more effective professional development programs to help primary mathematics teachers enhance their ability to integrate digital technology into classroom teaching. Also, the findings can assist researchers in locating TPACK instruments that are appropriate and relevant for their research</p>	<p>Digital interventions empower learners to build a deep and confident understanding of addition by enabling personalised, conceptual, and engaging practice</p>
Badmus et al. (2025)	<p>To examine the foundational mathematics curricula of South Africa and Australia. These countries have distinct educational systems and unique approaches to mathematics education.</p>	<p>Results indicate that Australia's foundational and early primary mathematics curriculum promotes flexibility, teacher autonomy, critical thinking, problem solving, technology integration, enhancing higher-order thinking and global functioning, while South Africa's foundational mathematics curriculum offers procedural fluency development, mastery of</p>	<p>It underscores the importance of balancing these immediate needs with broader long-term aspirations to ensure that all learners are supported in building solid mathematical foundations for future success.</p>

		mathematical concepts, numeracy development and standardisation to close learning gaps	
Papadakis et al. (2021)	The primary aim of the research was to investigate the potential benefits of using tablets and developmentally appropriate applications (apps) to implement the principles of Realistic Mathematics Education (RME) in kindergarten classrooms.	The use of developmentally appropriate apps, which were designed based on the three levels of Realistic Mathematics Education (RME), was found to be an effective method for teaching fundamental mathematical concepts to young children.	There is a strong implication that educational apps for young children should be developmentally appropriate and grounded in sound pedagogical frameworks, such as Realistic Mathematics Education (RME), rather than being simple drill-and-practice games.

Table 2 presents findings related to the second research objective of this paper, indicating that factors such as teacher competence, the availability of technological resources, institutional support, curriculum demands, and alignment with sound pedagogical frameworks significantly influence the utilisation of digital interventions for enhancing learners' mathematics skills. Furthermore, insufficient training, limited infrastructure, and a lack of management support frequently hinder the meaningful integration of digital technologies, which may adversely impact the effective enhancement of addition skills among Foundation Phase learners.

6. Discussion of Findings

The findings are discussed to answer the following question: What are the predominant pedagogical roles of digital interventions in supporting Foundation Phase learners' addition skills? The results highlighted that digital interventions play a significant role in improving Foundation Phase learners' addition skills, including learner engagement, participation, and assisting them in moving beyond abstract concepts. The findings are organised into three emerging themes that respond to the objectives of this study: Theme 1: Predominant pedagogical roles of digital interventions in improving Foundation Phase learners' addition skills; Theme 2: Factors influencing Foundation Phase teachers' selection of specific pedagogical roles for digital interventions when teaching addition skills; and Theme 3: Reconceptualising TPACK in teaching addition in the Foundation Phase, which aligns well with the theoretical framework underpinning this study and contributes to the body of knowledge.

6.1 Theme 1: The roles of digital interventions in improving foundation phase learners' addition skills

The findings show that the integration of digital interventions in Foundation Phase mathematics serves distinct and powerful pedagogical roles that extend far beyond the simple digitisation of traditional tasks. A primary finding is that these tools are uniquely capable of transforming the abstract concept of addition into concrete, manipulable representations. The work of Bakar et al. (2020) demonstrates that even accessible tools like digital cameras empower children to become creators of their own learning, using self-captured images to construct and explain addition concepts, thereby moving beyond rote memorisation. This pedagogical role as a visualisation and construction

tool is reinforced by Ahmad Nur Efendi et al. (2024), whose interactive digital pocket media provided a feasible and effective medium for visualising number combinations. Furthermore, sophisticated tools like GeoGebra, as used by Yunianto et al. (2024), facilitate constructionist learning, where students actively manipulate mathematical objects and discover principles such as commutativity through programming and debugging. This collective evidence highlights that digital interventions function most powerfully not as electronic worksheets, but as dynamic platforms for making the abstract nature of addition tangible and personally meaningful. Beyond content delivery, digital interventions play a crucial role in strengthening the underlying cognitive architecture required for mathematical thinking. The systematic review by Casanova et al. (2025) establishes a significant link between inhibitory control and mathematical performance, suggesting that well-designed digital games can be engineered to train this executive function, for instance, by requiring children to resist impulsive clicks on distractors during addition tasks. In this role, interventions function as cognitive trainers. Complementing this, they also serve as supportive scaffolds. Chen, Hou, and Wu (2023) demonstrated that scaffolding-based mindtools significantly enhanced learning effectiveness by providing structured support, a finding echoed by Giblin, Butler, and Kingston (2022), who emphasised that technology-assisted systems must be aligned with learning approaches to support genuine understanding.

Finally, the pedagogical power of digital interventions is maximised not when they are used in isolation, but when integrated into a broader, blended pedagogical strategy. Bouzid (2025) provides compelling evidence for this approach, finding that digital games, such as *Numeros Amigos*, are most effective when combined with physical manipulatives. This positions the digital tool as a bridge that reinforces and extends conceptual understanding developed through physical play, rather than as a replacement for it. This synergy not only sustains engagement but also supports a more holistic learning experience, effectively connecting the affordances of the digital world with the tactile experience of concrete objects to build a robust foundation in addition.

6.2 Theme 2: Factors influencing teachers' pedagogical roles in digital addition skills teaching

The selection of pedagogical roles for digital interventions is not a random or arbitrary decision made by teachers; rather, it is shaped by a complex interplay of teacher capacity, systemic support, and curricular philosophy. The teacher is regarded as the backbone of successful integration; however, studies consistently reveal a significant gap in teacher readiness. Nanda and Rana (2025) and Akudo (2025) document a prevailing reliance on traditional methods and a marked underutilisation of available technology. This is not necessarily a deficit of will but rather a lack of support, stemming from an absence of the essential Technological, Pedagogical, and Content Knowledge (TPACK) required to organise digital learning effectively. Mou et al. (2024) identify this as the foundational challenge, asserting that high-quality, TPACK-focused professional development is an essential requirement for any digital tool to be successful. Without such development, teachers often leave new interventions unused or employ them inappropriately, as they lack the understanding of how to integrate technology with the pedagogy of teaching addition. Furthermore, the teacher's capacity to act is fundamentally shaped, empowered, or significantly restricted by the broader systemic context in which they operate. Venketsamy and Hu (2022) identify critical infrastructural barriers, including inadequate resources, outdated equipment, and a lack of support from school management. This creates a reality where tools are physically unavailable or dysfunctional. Teachers cannot select a tool as a conceptual bridge if the hardware is broken or the software is inaccessible.

Beyond physical infrastructure, the synthesis reveals the profound influence of curriculum policy on pedagogical choice. The comparative work of Badmus and Jita (2022) and Badmus et al. (2025) highlights this, demonstrating that a curriculum such as Australia's, which promotes flexibility and critical thinking, naturally fosters the use of tools as conceptual bridges for deep understanding. In

contrast, a curriculum focused on procedural fluency and formalisation, like South Africa's, may unintentionally encourage a more limited, drill-based use of technology, illustrating how national priorities directly shape classroom practice and constrain the roles teachers feel empowered to assign to digital tools. The primary outcome of this synthesis is that the digital tool, the teacher, and the educational system are interdependent. A pedagogically sound tool, for instance, one based on Realistic Mathematics Education principles as detailed in Papadakis et al. (2021), is not successful without a teacher possessing the TPACK to deploy it effectively. That teacher, in turn, is fundamentally challenged without a supportive system that provides resources, leadership, and the curricular freedom to innovate. Conversely, a supportive system investing in modern interventions achieves little if teachers are not professionally prepared to integrate them meaningfully. The chasm identified by Gomes et al. (2021) between the need for digital resources in teaching additive structures and their practical application is a direct symptom of a breakdown in this symbiotic ecosystem. Therefore, efforts to improve Foundation Phase addition skills must address all three elements simultaneously, recognising that a teacher's selection of a pedagogical role for a digital intervention is the outcome of this dynamic and interdependent relationship.

6.3 Theme 3: Reconceptualising TPACK in teaching addition skills in the foundation phase

The interpretation of this synthesis reveals that a collaborative approach is required to achieve effective results successfully. This is supported by Olawale et al. (2024), who indicate that while it is vital to develop digital interventions to support addition skills, these tools must be complemented by sustained collaboration to achieve a transformative impact. Furthermore, Olawale et al. (2024) posited that the foundation must be the preparation of pre-service teachers through a TPACK-focused curriculum that utilises collaborative models. This preparation must train them to select and use digital interventions relevant to early childhood development that can generate meaningful assessment data to inform instruction in core mathematics skills, such as addition. In this model, the digital tool is an instrument, and the prepared teacher is the essential conductor of learning. The quest to improve addition skills cannot be framed as a search for a superior digital tool. Instead, it must be understood as a systemic endeavour to build a coherent pedagogical ecosystem. Success hinges on simultaneous, aligned action across all levels: Policymakers must design curricula that value conceptual understanding; School Leaders must build cultures of support and provide ongoing TPACK development; Teachers must be empowered as pedagogical designers; and developers must create interventions grounded in sound learning theory. In this model, the digital interventions are a powerful catalyst, but the prepared teacher, supported by a responsive system, is the essential conductor of learning.

7. Conclusions and Recommendations

In conclusion, the synthesis of findings reveals that the predominant pedagogical roles of digital interventions in supporting Foundation Phase addition skills are threefold to act as conceptual bridges that render abstract numerical relationships tangible through dynamic visualisation and manipulation; to serve as cognitive and motivational engines that cultivate foundational executive functions such as inhibitory control and enhance engagement through gamified, structured support; and to function as instructional levers that facilitate personalised, adaptive practice, thereby shifting pedagogy towards inquiry-based and constructivist approaches. However, this paper also identifies significant limitations and gaps that temper this potential. A primary limitation is the stark disconnect between technological potential and classroom reality, characterised by a pervasive lack of teacher Technological Pedagogical Content Knowledge (TPACK), inadequate institutional support, and outdated resources, as highlighted in several studies. Furthermore, a notable research gap exists regarding the specific use of digital educational resources to teach the core conceptual structures of addition and subtraction, known as the additive field, with more studies needed to

move beyond general efficacy and explore precise conceptual applications. The literature also reveals a practical gap, wherein digital interventions are often underutilised or misapplied as electronic worksheets, failing to exploit their capacity for deep conceptual and cognitive development. The paper posits that, even with limited access, the primary barrier to effective digital interventions for supporting addition skills lies in the integration of pedagogical strategies with technological resources in early mathematics. Therefore, while digital interventions hold transformative promise, their effective integration is not merely a matter of access but is critically dependent on addressing these systemic, pedagogical, and research-based limitations to create an ecosystem where technology serves as a meaningful extension of skilled teaching rather than a substitute for it.

Based on the synthesised findings and identified gaps, the following recommendations are proposed to advance the effective use of digital interventions in teaching addition. Professional development should extend beyond technical skills to focus on strategic Technological Pedagogical Content Knowledge (TPACK). This will empower teachers to critically select and integrate digital interventions that align with specific learning objectives for addition. Classroom integration should shift from drill-and-practice applications towards developmentally appropriate digital tools that support visualisation, manipulation, and problem-solving. Effective practice involves blending these digital interventions with physical manipulatives within a structured instructional sequence, such as Constructivist Pictorial Abstract, to build conceptual understanding. To sustain this shift, systemic support is required, including ensuring reliable classroom infrastructure and curriculum guidance that promotes meaningful technology use. Concurrently, future research should investigate digital interventions for specific additive structures, while developers are urged to design applications grounded in pedagogical frameworks such as Realistic Mathematics Education (RME), ensuring they are both conceptually sound and practically usable. This integrated approach, focusing on teacher capacity, classroom pedagogy, and systemic support, is essential for realising the potential of digital interventions to enhance foundational mathematics learning, particularly in addition.

8. Declarations

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