Digital Tool Integration in Primary School Mathematics Education: Evidence from a Rural Zimbabwean Primary School

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ABSTRACT

This study examined the integration of digital tools in the teaching and learning of Mathematics in a selected primary school in Mangwe District, Matabeleland South Province, Zimbabwe. Guided by the Technological Pedagogical Content Knowledge (TPACK) framework, the study employed a qualitative approach with a participatory action case study design within an interpretivist paradigm. Thirteen participants — comprising four Mathematics teachers, eight learners, and one school head — were purposively selected. Data were gathered through semi-structured interviews, focus group discussions, and classroom observations, and analysed using thematic analysis. Findings revealed that digital tool integration remains limited and inconsistent, constrained by inadequate infrastructure, unreliable electricity supply, limited access to digital devices, and insufficient subject-specific professional development. Teachers' attitudes and competencies emerged as significant mediators, while learners reported improved engagement and conceptual understanding when digital tools were used effectively. The study concludes that sustainable integration requires a holistic, TPACK-informed approach that simultaneously addresses infrastructure, teacher capacity, and institutional support. Practical recommendations are offered for policy-makers, school leaders, and teacher educators operating in similar resource-constrained contexts.

Keywords: Digital tools, mathematics education, TPACK, rural schools, professional development, ICT integration

INTRODUCTION

The rapid advancement of digital technologies has transformed educational systems worldwide, positioning digital tool integration as a central concern in contemporary schooling. In Mathematics education — a subject often perceived as abstract and challenging — digital tools offer particular promise by supporting visualization, simulation, and interactive engagement (Li & Ma, 2021; OECD, 2019). Globally, evidence suggests that well-integrated digital tools can improve learner outcomes, enhance motivation, and promote conceptual understanding.

However, the extent to which these benefits are realized varies significantly across educational contexts, particularly between urban and rural settings in developing nations. In sub-Saharan Africa, persistent infrastructural deficits, limited teacher preparation, and weak institutional support continue to undermine meaningful technology integration (Tondeur et al., 2020; UNESCO, 2021). Zimbabwe presents a compelling case in this regard: despite the existence of a National Digital Policy (Government of Zimbabwe, 2016) mandating the integration of digital tools across all levels of education, classroom practice in rural districts remains largely untransformed.

Mangwe District, located in Matabeleland South Province, exemplifies the challenges confronting rural schools in Zimbabwe. Classroom observations in the district reveal minimal use of digital tools in Mathematics instruction, despite growing national emphasis on technology-enhanced learning. This gap between policy aspiration and classroom reality constitutes the central problem of this study.

The study was guided by the following main research question: Why is there low uptake in the integration of digital tools in the teaching and learning of Mathematics in a selected school in Mangwe District? Sub-questions explored the specific challenges teachers face, the influence of teachers' attitudes and competencies, the potential effectiveness of digital tools, and existing strategies for empowering teachers.

This paper makes an original contribution by providing empirically grounded insights into the lived realities of digital tool integration in a rural Zimbabwean primary school. It extends the TPACK framework to a resource-constrained, Southern African context and offers context-sensitive recommendations for educators, administrators, and policy-makers seeking to improve Mathematics instruction through technology.

BACKGROUND

Globally, digital tools have become integral to effective Mathematics instruction. Research from developed countries demonstrates that dynamic geometry software, simulations, and computer-assisted instruction promote learner-centred approaches and improve Mathematical performance (Li & Ma, 2021). Successful national models, such as Singapore's deliberate embedding of digital tools within structured lesson planning and curriculum design, illustrate what is achievable when policy, teacher development, and curriculum innovation converge (Smith, 2018; UNESCO, 2019).

Nevertheless, international studies consistently identify challenges to integration including inadequate professional training, resistance to pedagogical change, and limited access to appropriate digital resources (Ertmer & Ottenbreit-Leftwich, 2019). These challenges are amplified in African contexts, where limited access to computers, unreliable electricity, high internet costs, and insufficient teacher training compound the difficulty of integration (Tondeur et al., 2020). Studies from Zambia, South Africa, and East Africa indicate that many teachers, though not unwilling, lack the professional development and pedagogical guidance needed to effectively integrate digital tools in Mathematics lessons (Dewa & Ndlovu, 2022; Uworwabayeho, 2016).

In Zimbabwe, studies indicate that digital tool integration in schools remains limited, particularly in rural districts (Chabaya, 2019; Chinyoka, 2021). Despite the National Digital Policy and ZIMASSET frameworks, teachers in many rural schools continue to rely on traditional chalk-and-talk methods, citing inadequate infrastructure, digital skills gaps, and contextual constraints such as poor connectivity and power supply (Moyo & Chikodzore, 2021). Mangwe District — geographically isolated, largely agrarian, and severely under-resourced — represents one of the most challenging contexts for digital integration in Zimbabwe.

LITERATURE REVIEW

3.1 Theoretical Framework: TPACK

This study is anchored in the Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler (2006). TPACK extends Shulman's notion of Pedagogical Content Knowledge by incorporating technological knowledge as a critical domain of teacher expertise. The framework posits that effective digital integration requires a dynamic interaction between Content Knowledge (CK — what is taught), Pedagogical Knowledge (PK — how it is taught), and Technological Knowledge (TK — the tools used to teach).

In rural contexts such as Mangwe District, challenges related to digital tool integration are rarely isolated; they reflect overlapping deficiencies across all three TPACK domains. TPACK therefore provides an analytically appropriate lens for examining the interconnected nature of these challenges and for evaluating what constitutes meaningful integration in resource-constrained settings.

3.2 Challenges to Digital Tool Integration

The literature identifies several interrelated barriers to digital tool integration in Mathematics education. Limited access to digital devices, unreliable electricity supply, and lack of internet connectivity are consistently identified as primary structural constraints in developing contexts (Tondeur et al., 2020; UNESCO, 2021; MoPSE, 2020).

Even when hardware is supplied through government or donor initiatives, maintenance challenges — including lack of technical expertise and financial resources — rapidly render equipment non-functional.

Pedagogical inadequacy constitutes an equally significant barrier. Many teachers receive minimal exposure to digital pedagogy during pre-service training, and in-service professional development is often sporadic and theoretically oriented (Patton, 2017). Research by Darling-Hammond et al. (2017) emphasizes that effective professional development must be sustained, practice-oriented, and contextually grounded. One-off workshops rarely produce lasting behavioural change, particularly in the absence of follow-up mentorship.

Attitudinal and cultural factors also play a role. Teacher resistance to change, anxiety about technical failure, and institutional cultures that prioritize examination performance over innovation limit the adoption of digital tools (Ertmer & Ottenbreit-Leftwich, 2019; Livingstone, 2016). Where curriculum frameworks do not explicitly encourage digital integration, teachers may prioritize syllabus coverage over technological experimentation (Higgins et al., 2019).

3.3 Digital Tools and Mathematics Learning

Notwithstanding these challenges, the literature presents a compelling case for the potential of digital tools to enhance Mathematics learning. Interactive simulations, dynamic geometry software such as GeoGebra, and adaptive platforms such as Khan Academy have been shown to improve conceptual understanding, learner engagement, and academic performance (Zengin, 2017; Higgins et al., 2019). By enabling learners to visualize abstract mathematical relationships and receive immediate feedback, digital tools support deeper conceptual engagement than is typically achievable through traditional instruction.

However, the effectiveness of digital tools is strongly mediated by implementation quality. Puentedura's (2017) SAMR model distinguishes between substitution — where technology merely replicates traditional methods — and transformation, where technology enables fundamentally new learning activities. The literature suggests that many teachers, particularly in under-resourced contexts, operate at the substitution level, using digital tools to display notes rather than to facilitate interactive learning (Zengin, 2017).

3.4 Research Gap

While an extensive body of literature addresses digital tool integration in Mathematics education, studies specifically examining rural Zimbabwean primary school contexts from a TPACK perspective remain limited. Most existing Zimbabwean research has focused on secondary schools or urban settings (Chabaya, 2019; Chinyoka, 2021). This study addresses that gap by providing empirically rich, context-sensitive insights into the dynamics of digital tool integration in a rural primary school setting.

METHODOLOGY

4.1 Research Approach

A qualitative research approach, grounded in the interpretivist paradigm, was employed. Interpretivist inquiry is appropriate for exploring the subjective meanings, lived experiences, and contextual realities that shape participants' engagement with digital tools (Creswell & Poth, 2018). The case study design enabled an intensive, holistic examination of digital tool integration as it is enacted within a single, bounded school context (Yin, 2018). This approach is consistent with the study's TPACK-informed theoretical framework, which emphasizes context-specific enactment of teacher knowledge.

4.2 Research Design

The study was a Participatory Action Research (PAR) which focused on how mathematics teachers and learners collaboratively integrate digital technologies into teaching and learning within a selected Zimbabwean rural primary school. This design was appropriate in this study because it allowed the researcher to study digital tool

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integration in a real-life context and also developed a rich qualitative understanding of participants' experiences. The design also helped to generate practical improvements in mathematics teaching and learning.

4.2 Participants and Sampling

Purposive sampling was employed to select participants with direct experience of digital tool integration in Mathematics instruction (Palinkas et al., 2015). The final sample comprised 13 participants: four Mathematics teachers, eight learners (ages 10–13, equal gender distribution), and one school head. This sample size was considered adequate given the study's emphasis on depth of understanding; thematic saturation was achieved during data collection, with no new themes emerging from later interviews (Guest, Namey, & Mitchell, 2017).

4.3 Data Collection

Three complementary methods were employed to facilitate triangulation. Semi-structured interviews were conducted with the four Mathematics teachers and the school head, exploring their understanding, experiences, challenges, and perceptions of digital tool integration. A focus group discussion was held with the eight learners to explore their experiences and perceptions of technology-enhanced Mathematics learning. Classroom observations — guided by a TPACK-aligned observation checklist — were conducted to examine digital tool use in authentic instructional settings (Koehler, Mishra, & Cain, 2017).

4.4 Data Analysis

Thematic analysis was conducted following Braun and Clarke's (2021) six-phase framework: familiarization with data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and writing up. While themes were allowed to emerge inductively from participants' narratives, the analysis was sensitized by the TPACK framework to ensure theoretical coherence.

4.4.1 Biographical Data of Teachers and Administrators

Table 1: Teachers and Administrators Data

Codes	Gender	Role	Professional Qualification	Work experience
T1	Female	Teacher in charge	Bachelor's Degree in Education	20 years
T2	Female	Grade 5 Teacher	Diploma in Education	12 years
T3	Male	Grade 6 Teacher	Diploma in Education	15 years
T4	Male	Grade 7 Teacher	Diploma in Education	5 years
AD 1	Male	Head of the School	Master's Degree in Education	25 years

4.4.2 Biographical Data of Learners

Table 2: Learners' Biography

Codes	Gender	Grade
L1	Female	5
L2	Female	6
L3	Female	7

L4	Female	7
L5	Male	5
L6	Male	6
L7	Male	7
L8	Male	7

4.5 Trustworthiness and Ethics

Trustworthiness was established through triangulation of data sources and methods, member checking, prolonged engagement in the field, and reflexive journaling (Creswell & Poth, 2018; Nowell et al., 2017). Before data collection, formal permission was obtained from the Ministry of Primary and Secondary Education and the selected school. Informed consent was secured from teachers and the school head; learner assent was obtained in compliance with ethical protocols governing research with minors. Confidentiality was maintained through the use of participant codes (T1–T3, L1–L3, AD1–AD2) and secure data storage.

FINDINGS

The following findings were deduced after data analysis:

5.1 Limited Extent of Digital Tool Integration

The findings indicate that the integration of digital tools in Mathematics teaching remains at an emergent, inconsistent stage. These findings are, however, context-specific since the research was done at a single rural Primary School in Mangwe district. For that reason, the findings are not nationally representative.
Observations revealed that digital tools were used sporadically and primarily for presentational purposes, with limited evidence of higher-order use such as learner-centred activities or collaborative problem-solving. T1 described a common scenario:

> *"In many cases we prepare our lessons expecting to use digital tools... However, when the time for the lesson arrives there may be no electricity... Because this situation happens frequently, some teachers feel discouraged from planning lessons that depend on digital tools." (T1)*

Learners confirmed this picture, noting that computer room access was infrequent and often limited to passive observation rather than hands-on engagement. L2 remarked:

"I enjoy lessons where we use digital tools because they make learning more interesting. However, those lessons do not happen frequently."

Despite the challenges, participants identified clear benefits when digital tools were used effectively. Teachers highlighted the value of visual demonstrations and interactive simulations for making abstract Mathematical concepts accessible. T3 noted:

> *"When digital tools are incorporated into lessons, learners tend to be more attentive and motivated."(T3)*

Learners corroborated this, with L2 explaining that graphical representations on the screen helped them understand how numbers are related to each other.

Critically, participants distinguished between passive and active use. When digital tools were used merely to display notes, their educational impact was minimal. L1 observed:

> *"It would be more helpful if we could interact with the digital tools ourselves or see demonstrations that make difficult topics easier to understand."(L1)*

This distinction reflects Puentedura's (2017) SAMR continuum and underscores the importance of TPACK-informed pedagogy

5.2 Challenges Faced by Teachers

Participants identified a range of interrelated challenges. Infrastructural constraints — including unreliable electricity, limited computers, and absent internet connectivity — were cited by all teachers and administrator as primary barriers. T2 noted that class sizes of over forty learners sharing a handful of computers severely restricted meaningful individual interaction with technology.

Pedagogically, teachers reported a gap between basic computer literacy and the subject-specific knowledge required for effective integration. T1 stated:

> *"Using digital tools to teach specific topics in Mathematics such as fractions, graphs, or geometry requires more specialised skills. Sometimes we are not sure which programs... can best explain these concepts." (T1)*

This finding aligns with TPACK theory, which requires the intersection of technological, pedagogical, and content knowledge for effective integration.

Administrator reinforced these observations, with AD2 emphasizing systemic constraints:

> *"Professional development opportunities are not always regular or subject-specific, which means teachers may struggle to apply general ICT training to Mathematics teaching."(AD2)*

5.3 Influence of Teachers' Attitudes and Competencies

Teachers' attitudes and technological self-efficacy emerged as critical mediating factors. Teachers who demonstrated positive attitudes and higher digital competence were more willing to experiment with digital tools, even in resource-constrained conditions. T1 articulated the confidence challenge:

> *"Sometimes I hesitate to use them because I am not always confident operating the technology in front of learners. If something goes wrong during the lesson, it can interrupt the teaching process."(T1)*

Learners perceptibly noticed these differences. L1 observed:

> *"When a teacher is confident using digital tools, the lesson becomes more interesting and easier to follow... when the teacher is not confident, the lesson sometimes becomes slow because they spend time trying to fix technical problems."(L1).*

AD2 added that teachers who demonstrated confidence became role models, motivating colleagues through peer influence.

5.4 Strategies to Empower Teachers

Existing professional development strategies were found to be insufficient. Teachers reported attending occasional workshops focused on general computer literacy rather than subject-specific pedagogical integration. T2 summarized the limitation:

> *"Short training sessions are helpful, but they are not enough... Teachers need continuous training that allows them to practise using educational software, explore new teaching strategies, and share experiences with colleagues."(T2)*

Informal peer mentoring emerged as a positive practice, though it was inconsistent and dependent on individual initiative. AD1 called for structured, long-term professional development programmes:

> *"Schools must prioritise professional development that equips teachers with the knowledge and confidence needed to use digital tools effectively."(AD1)*

DISCUSSION AND CONCLUSION

6.1 Discussion

From the findings, it is apparent that low-tech and offline digital learning solutions are increasingly relevant in rural Zimbabwe, where many schools face unreliable electricity, limited internet connectivity, textbook shortages, and high data costs. In such contexts, offline-first educational technologies provide a practical alternative for expanding access to quality learning resources, especially in mathematics and science education.

One important solution is Kolibri, an offline learning platform developed by Learning Equality. Kolibri is an ecosystem of open digital products and tools centered around an offline-first learning platform and specifically designed for low-resource environments. It is especially designed to enable quality teaching and learning with technology but without the internet, and so, allows schools to access digital educational content without continuous internet connectivity. The platform can be installed on low-cost devices such as laptops, Raspberry Pi servers, tablets, or local school servers. Learners connect through a local wireless network and access videos, exercises, quizzes, simulations, and digital textbooks entirely offline.

Kolibri is particularly suitable for rural Zimbabwean schools because it supports:

- Offline access to mathematics, science, and literacy materials;
- Teacher-created lessons and assessments;
- Self-paced and differentiated learning;
- Content sharing across devices without internet access;
- Curriculum customization aligned to local syllabi

Another relevant innovation is the use of offline Khan Academy content through platforms such as KA Lite and Kolibri. These systems allow schools to preload Khan Academy videos and exercises onto local servers or tablets for use without internet connectivity. In mathematics education, offline Khan Academy resources can support remediation, examination preparation, and individualized learning, particularly in schools with large class sizes and limited teacher support.

E Granary Digital Library, is another important offline solution often called the “Internet in a Box.” eGranary stores millions of educational resources—including websites, books, videos, and academic materials—on a local server that can be accessed through a school network without internet access. In rural Zimbabwe, eGranary can help address shortages of textbooks and reference materials by giving teachers and learners access to extensive educational repositories at very low operational cost. Because content is stored locally, schools avoid recurring internet expenses, which remain a major barrier in many rural communities.

Zimbabwe has also begun adopting localized offline learning initiatives. For example, the UNICEF Zimbabwe Learning Passport Offline Hub, developed with the Ministry of Primary and Secondary Education and private-sector partners, provides offline curriculum resources to schools in remote areas such as Nyanga and Masvingo. In the near future, these initiatives will spread to other rural communities across Zimbabwe. The initiative enables learners to access past examination papers, interactive lessons, and teacher guides even where internet connectivity is unavailable.

Similarly, locally developed systems such as Computer Aided Learning Management Suite (CALMS) demonstrate how Zimbabwean innovators are designing offline-first educational platforms tailored to rural conditions. CALMS supports lesson delivery, assignments, grading, and analytics locally, synchronizing only when internet connectivity becomes available.

However, despite their potential, several challenges remain. These include limited access to hardware, unreliable electricity supply, inadequate teacher digital literacy, maintenance difficulties, and insufficient technical support in rural schools. Sustainability also depends on government support, community involvement, and ongoing teacher training.

Overall, low-tech, offline digital solutions such as Kolibri, eGranary Digital Library, and offline Khan Academy platforms offer realistic, context-appropriate strategies for addressing educational inequalities in rural Zimbabwe. These technologies demonstrate that meaningful digital learning can still occur even in environments with minimal internet infrastructure.

6.2 Conclusion

This study explored the integration of digital tools in Mathematics teaching and learning in a rural Zimbabwean primary school. The findings reveal a significant gap between national ICT policy aspirations and classroom reality. Digital tool integration remains limited, inconsistent, and largely substitutive — constrained by structural, pedagogical, and attitudinal factors that interact in complex ways.

The TPACK framework proves analytically productive in this context. The findings demonstrate that meaningful integration requires not merely the presence of technology, but the simultaneous development of all three TPACK knowledge domains within a supportive institutional environment. Teachers' technological self-efficacy and pedagogical confidence are critical mediators; where these are lacking, digital tools are avoided or used superficially, regardless of availability.

The study contributes empirically grounded insights to a relatively underexplored context — rural primary school Mathematics education in Zimbabwe — and offers a nuanced account of how structural, professional, and attitudinal factors intersect to shape integration outcomes. Future research could usefully extend this work through comparative multi-school studies, longitudinal investigations of professional development interventions, and explorations of learner digital literacy development over time.

RECOMMENDATIONS

7.1 Infrastructure Investment

Educational authorities and development partners should prioritize investment in reliable electricity supply, adequate digital devices, and stable internet connectivity for rural schools. Solar power solutions and shared community resource centres offer practical alternatives in off-grid contexts. Without a reliable technological infrastructure, even the most capable teachers cannot integrate digital tools consistently.

7.2 Subject-Specific Professional Development

Professional development programmes should be redesigned to focus on TPACK-informed integration of digital tools within Mathematics specifically. Training must move beyond general ICT literacy to equip teachers with practical strategies for using digital tools to teach specific Mathematical concepts. Programmes should be continuous, practice-oriented, and supported by ongoing mentoring and classroom-based coaching.

7.3 Institutional Support Structures

Schools should establish formal ICT support structures — including ICT committees, mentoring systems, and professional learning communities — to facilitate knowledge sharing and peer collaboration. School leaders play a pivotal role in creating cultures of innovation and providing teachers with the time, resources, and encouragement needed to experiment with technology.

7.4 Curriculum and Policy Alignment

The Mathematics curriculum should explicitly incorporate digital tool use as part of teaching, learning, and assessment practices. Clear pedagogical guidelines should be provided to teachers on how to integrate specific tools — such as GeoGebra for geometry and graphing — across different topics. National ICT policies should be accompanied by robust monitoring and evaluation mechanisms to track implementation progress and identify systemic barriers.

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