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ENHANCING THE TEACHING OF FUNCTIONS IN THE FET PHASE IN THE SOUTH AFTICAN CONTEXT: A CRITICAL REVIEW OF DIGITAL TOOLS AND AI-DRIVEN METHODS

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Abstract: This study critically reviews the integration of digital tools in the teaching of Functions within the Further Education and Training (FET) phase in high schools, in the context of the rapidly evolving, AI-driven digitalization era. The increasing influence of artificial intelligence (AI) in education, accelerated by the demands of the Fourth Industrial Revolution (4IR) presents new opportunities for transforming mathematics instruction through dynamic, interactive, and technology-enhanced pedagogies. Despite the availability of advanced digital tools such as GeoGebra, Desmos, and various mobile applications, their use in teaching the topic of Functions remains limited and inconsistently applied. Many teachers continue to face challenges in effectively leveraging these technologies to support students' conceptual understanding, thereby reducing the overall impact of digital innovation in the mathematics classroom. To address this gap, the study employs a qualitative case study approach through a systematic literature review, drawing on secondary data from academic databases such as Scopus and Web of Science. The review is framed by the SAMR model and the TPACK framework, which provide a conceptual basis for analysing how digital tools are currently being integrated and how they might be used more effectively. Descriptive and exploratory methods are applied to synthesize insights across the literature. The findings highlight the potential of digital tools and AI-enhanced strategies to improve learner engagement and conceptual mastery in the teaching of Functions. The study concludes by emphasizing the need for intentional, well-supported integration of digital technologies in mathematics education practices.

Keywords: digitalization, digital technology tools, AI methods, functions (FET Phases), high school, mathematics teachers and qualitative research, SAMR and TPACK

Introduction

The rapid advancement of artificial intelligence (AI) and its growing presence in education are reshaping the way mathematics is taught and learned. In particular, the Fourth Industrial Revolution (4IR) has accelerated the need for integrating digital tools and artificial intelligence systems into classroom practice. Therefore, the 4IR has been the driving force for mathematics education towards technological integration. Artificial intelligence (AI) revolutionises mathematics education, offering learning experiences that promote individualised learning, analysing customised content, providing tailored

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instruction, and ensuring equal opportunities for all students (Roshanaei et al., 2023 & Mustafa, 2024). Scholars notably (Opesemowo & Adewuyi, 2024). argue that the integration of AI in mathematics education encompasses various applications, including real-time assessments, feedback and curriculum development. They further argue that the evolution of AI in mathematics education presents both opportunities and challenges that these platforms are designed to offer personalised learning and enhanced instruction. Balacheff (1993) views AI as a platform that creates opportunities for technologies that provide flexibility, customised explanations that allow for direct manipulations of abstract concepts in mathematics teaching and learning.

Reaves (2019) argues that the education system is evolving and thus, technology integration and AI adoption can be viewed as the future of education. It is also worth noting that research has distinguished that AI has a deeply ingrained concept into ICT and other technologies like three dimensions (3D), digital technologies, virtual reality (VR), and artificial reality (AR), which are all influenced by the 4IR. Hwang & Tu (2021) indicate that research trends in AI for mathematics education include exploring its roles in diagnosing learning problems and providing individualised support. This is further recognized through many AI tools such as CHATGPT and many others that can be increasingly utilised in education settings (Opesemowo & Adewuyi, 2024). Although AI has the potential to transform mathematics teaching and learning, debates have been sparked off around its effectiveness and impact on knowledge acquisition and whether AI, particularly in mathematics education, aligns with the demands of the 4IR and helps to address social and inequality disparities (Opesemowo et al., 2024). The adoption of AI, ingrained in the use of digital technologies, has gained momentum across the education sector. Its implementation in mathematics education, especially in the teaching of Functions within the Further Education and Training (FET) phase, remains inconsistent and underutilized by teachers and teacher educators. Research underscores this problem to teachers' lack of training or confidence in teaching using digital tools and AI-designed methods. There is also a gap in the consistent implementation of technology teaching in the Function teaching, particularly in high school mathematics. This underutilization limits the interactive and dynamic potential in teaching and learning mathematics.

The recommendations by the influential National and international mathematics education bodies like the National Council of Teachers of Mathematics (NTCM, 2000); National Research Council (1996), and the International Society for Technology in Education (ISTE, 2000a,b) emphasise a need for a technology-rich curriculum in mathematics and science that advocate for technology not as a supplementary tool, but an essential component embedded in the learning process. This implies there is a need to critically review how the growing presence of digital tools, AI platforms, and other digitalised platforms can be used to serve the need in mathematics education. An important aspect of this study is to establish how AI methods and digital technology tools can enhance the teaching of Functions in the FET phase within the evolving landscape of the AI-driven era. This paper critically reviews how digital tools are currently used in teaching at FET, highlights the digital instructional strategies and explores evidence-based strategies for effective integration. The study is situated within the context of AI-driven digitalization and draws on theoretical models that guide technology use in education.

Background and Rationale

Functions form a foundational part of secondary school mathematics and are often taught in abstract and procedural ways. Pettersson et al. (2013) recognize a function topic at the inception of mathematics in various forms as transformative, irreversible, integrative, bounded, and troublesome. According to Pettersson et al. (2013), the stages of a function in mathematics are defined as follows: transformative due to the understanding of the concept as leading to a new perception. A function is regarded as irreversible when the change in the observation of its nature remains unforgotten and integrative when a solid understanding of the concept evolves and relates to other mathematical topics (see Kgosi, 2021, p.1). Moreover, a function is described as bounded following its concepts, developing the margins of other mathematical disciplinary areas, and thus regarded as troublesome in that it is prevalent in the learning of mathematics (Kgosi, 2021). However, learners find it a challenging mathematical concept to understand, particularly conceptualising the inverse of a function. A function and its inverse function are regarded a crucial topic in the FET syllabus (Grade 10 -12) in the South African context. Digital tools such as **GeoGebra**, **Desmos**, and various mobile applications offer rich opportunities to visualize and explore functional relationships dynamically. These tools can help students grasp key concepts such as domain, range, transformations, and inverse functions through immediate, visual feedback and interaction. Despite their potential, these tools are not widely or effectively used in many South African mathematics classrooms. Educators often lack the training, support, or confidence to integrate technology meaningfully. The mismatch between the availability of digital resources and their use in pedagogy limits the impact of digital transformation in mathematics education. This gap necessitates a structured review of how digital tools and AI-embedded methods are effectively implemented in Functions teaching in FET.

The purpose of this study is to critically review current practices employed on digital tools and AI methods integration that enhance the teaching Functions in the FET phase. To also identify digital instructional strategies integrated into the teaching of Functions that enhance conceptual understanding.

Research Questions

This study seeks to answer the following research questions.

1. What digital tools are currently being used to teach Functions in the Further Education and Training (FET) phase in a high school setting?
2. Have any instructional strategies been identified as effective for using digital tools to enhance conceptual understanding of Functions?

Research Objectives

- To identify the digital tools currently used in teaching Functions in the FET phase
- To analyze instructional strategies using digital tools to enhance conceptual understanding of functions.

Theoretical framework

In the context of technology integration in education, two influential frameworks guide both the research and classroom practice that is, the **SAMR Model** (Substitution, Augmentation, Modification, Redefinition) and the Technological Pedagogical Content Knowledge **(TPACK) framework**. These two models offer complementary lenses, effectively identifying the digital tools used in teaching and learning.

The SAMR model, developed by Ruben Puentedura (2006), categorizes technology integration into four progressive levels: ***Substitution, Augmentation, Modification, and Redefinition*.** This model will help to evaluate the depth and impact of the technology use in the teaching of Functions. **Figure 1**. depicts the adaptation of Puentedura's (2006) SARM model.

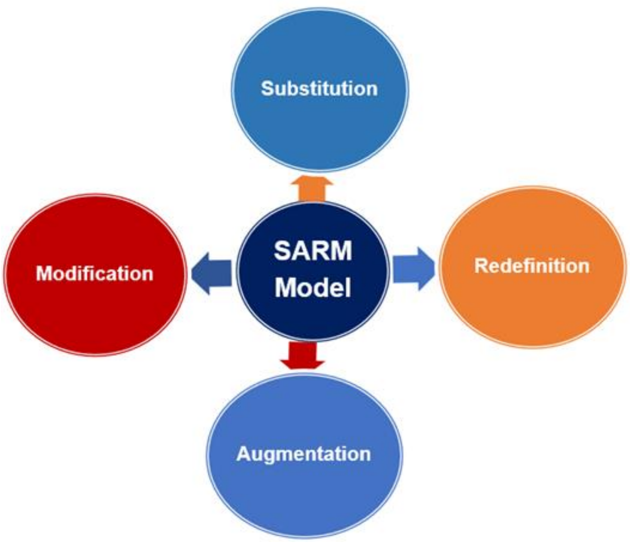

Figure 1. Adaptation of the SAMR Model (Puentedura, 2006)

At the Substitution and Augmentation levels, technology enhances traditional tasks with minimal transformation, such as using a calculator instead of paper. Whereas the augmentation level, technology is a substitute with functional improvements, for example, using Desmos or GeoGebra to graph calculator or application rather than graphing manually. Yet, at the Modification and Redefinition levels, however, technology enables significant redesign or the creation of entirely new learning experiences, such as students manipulating graphs to explore transformations, as technology allows significant task redesign. The Redefinition levels mean technology enables new tasks entirely, like AI-driven tools for real-time graph feedback and analysis. These two levels represent the transformation of the traditional approaches to teaching and learning to the twenty-first-century approach, where active integration of technology is projected. What does it mean for this study, and how technology is used in education, to offer an understanding of how the adoption of technology can have an impact on teaching and learning from a simple to a complex concept? The research uses qualitative research methods to obtain detailed descriptions and narratives from mathematics teachers involved in the research and to determine how digital technologies are applied in their practices and what digital technologies are being used. By focusing on the concepts that inform the **SAMR model** for technology integration to analyse the research data, I intend to address the first research question and sub-questions, and objectives for this study.

The TPACK framework (Technological Pedagogical Content Knowledge), introduced by Mishra and Koehler (2006), expands on Shulman's (1986) conceptualisation of Pedagogical Content Knowledge (PCK) that describes how teachers' understanding of technologies and PCK interact with one another to produce effective teaching with technology (Saubern et al., 2000). TPACK guides the understanding of teacher knowledge and preparedness in integrating technology effectively. **Figure 2.** depicts the Technology Pedagogical Content Knowledge (TPACK), Mishra & Koehler (2013) framework.

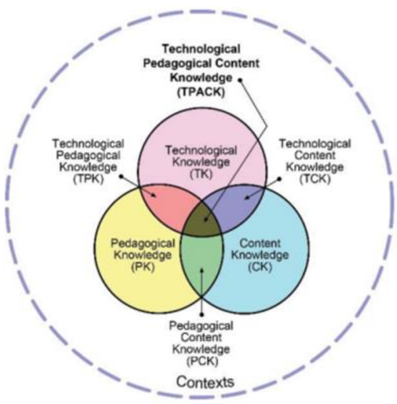

Figure 2. Technology Pedagogical Content Knowledge (TPACK), Mishra and Koehler (2013)

TPACK is particularly relevant in understanding how mathematics teachers can integrate technology in a way that complements both the content (Functions) and instructional strategies. TPACK framework,

developed by Mishra and Koehler, focuses on the intersection of three key domains: Content Knowledge (CK), which refers to the mastery of the subject matter to be taught, including its concepts, theories, and frameworks, that is, understanding of mathematical concepts (e.g., Functions). Pedagogical Knowledge (PK) refers to the understanding of teaching methods, instructional strategies, and classroom management practices, that is, the knowledge of how to teach those concepts effectively. Technological Knowledge (TK) refers to proficiency in standard technologies and the ability to operate specific digital tools effectively, that is, how to use digital tools and technology (e.g., GeoGebra, Desmos, mobile apps). What it means for this study, TPACK (Koehler & Mishra, 2009) is a framework that helps teachers integrate technology effectively into their teaching and represents the knowledge teachers need and it provides a lens that assess how well teachers are equipped to integrate technology when teaching Functions in the FET phase which speaks to the conception and use of technology. It also focuses on identifying gaps in teacher preparedness, in particular combining content, pedagogy, and technology, which involves pedagogical techniques that use technologies in constructive ways to teach the content. The framework further supports the analysis of teacher practices, which includes how digital tools enhance conceptual understanding of mathematical concepts that are technology-based mathematics instruction. With the focus on the **TPACK framework,** I intend to address the second research question and its sub-questions, and the objective of this study.

Methodology

A qualitative case study approach was adopted through a systematic literature review. The systematic literature review (SLR) was guided by Keele et al. (2007). This process involves three distinct stages: the planning stage, which entails the inclusion and exclusion criteria to identify eligibility for the review, conducting the review, and the reporting stage. This stage is critically developed and evaluated to ensure that it provides effectiveness for the study. Descriptive and exploratory analysis was used to identify patterns, gaps, and effective practices across the literature review. The process, like the PRISMA (2020) allows the literature review stages to be as transparent as possible (Sefton-Green, 2004; Higgins et al., 2019). The process begins with the review planning, which encompasses the inclusion and exclusion criteria, and the conduct review up to the reporting stage:

Table 1. Articles for the Study

Database	Articles Included	Articles Excluded			Total
		First Rejected	Second Rejected	Duplicated Articles	
Scopus	7	1	2	1	11
Web of Science	40	19	10	9	78
DOAJ	12	1	1	7	21
IJOE	5	4	7	10	26
Total	**64**	**25**	**20**	**27**	**136**

Review Planning Stage

The Secondary data was sourced from databases such as Scopus, Web of Science (WoS), ERIC, Wiley, Directory of Open Access (DOAJ) and International Journal of Education (IJOE). Articles were selected based on relevance, peer-review status, and their focus on the integration of digital tools in teaching mathematics specifically Functions. The databases used for the study were carefully selected, bearing in mind the research questions and objectives that the study aims to answer. The process of article selection is within 10 years of research, and the specific inclusion and exclusion criteria were followed to define the required research parameters. The selection criteria considered a broad coverage of scholarly literature as documented by researchers, notably (Li & Ma, 2019; Harzing et al., 2016), among others. A sample of the articles used in the study has been reviewed below, and the purpose was to critically analyse the use of digital tools and AI methods in teaching at high school, particularly Functions at the FET phase in the South African context. By analysis of the digital tools and AI strategies in Table 2, the study aims to answer the first research question. Subsequently, respond to the second research question using Table 3 information. The inclusion and exclusion criteria are as follows:

Inclusion Criteria

i. Relevance to the critical analysis of digital tools and AI-driven methods in the teaching of mathematics, particularly Functions in High School in the FET phase.
ii. Empirically scientific papers that entail systematic literature research and theoretical studies.
iii. Articles relating to technology-based instructional strategies, such as the integration of digital tools and AI technologies, and peer-reviewed high-quality journals.

Exclusion Criteria

i. Articles focused on Primary teaching and learning.
ii. Articles unrelated to the study and the core theme.
iii. Publications from non-peer-reviewed and non-accredited journals.
iv. Articles which do not address the technology-instructional issues.

Table2. Digital Tools and AI technologies in the study (Exact Matches) _Sample of the articles

Articles $(n = 64)$	**Digital Tool** $(n \approx 918)$	**Artificial Intelligence** $(n \approx 184)$	**High School** $(n \approx 74)$
The Role of Reality-Enhancing Technologies	0	12	0
A meta-review of literature on educational approaches for teaching AI at the K-12 levels in the Asia-Pacific region	0	94	6
Exploring teachers' preconceptions on AI	2	25	14
Impact and Implications of AI methods and tools on future education	1	9	0
Mobile technology learning and achievement	2	1	1
Teacher preparedness and professional development	2	2	0
Classroom-based professional expertise	122	0	0
Digital tools to support teacher professional development in the lesson: Systematic literature review	173	0	0
Teachers' perspective on digital tools for pedagogic planning	22	1	0
Using different digital tools in designing and solving modelling problems	268	0	1
Integrating digital technology in mathematics education	43	0	3
Use of digital tools as a component for STEM Education	95	13	0

Transformation of teaching and learning through digital technologies	87	0	0
Total	**843**	**170**	**25**

Articles $(n = 64)$

Table3. Identified uses of digital tools, AI, and instructional strategies for the study

Digital Tool $(n \approx 14)$	Number of uses in studies	Instructional Strategies $(n \approx 74)$
GeoGebra digital technology	135	8
Mobile technologies or apps	39	116
Multimedia technologies	20	23
Simulations	29	29
Tablets	31	0
Virtual Reality	46	26
Smart Whiteboards	1	16
Flipped Classrooms	8	0
Digital Media	104	55

Digital Tool ($n \approx 14$)	**Number of uses in studies**	**Instructional Strategies** ($n \approx 74$)
Artificial Intelligence	184	1
Learning Management Systems	13	14
CHATGPT & Generative AI	24	0
Interactive digital tools	3	0
Augmented Reality	115	8
Total	**752**	**296**

Conducting the review

The article searches initially yielded 134 articles with 27 duplicates excluded. The initial screening of the articles was conducted, taking into consideration the article abstracts, titles, and quality and scope of journals. A thorough perusal of the journals selected, also considering the research questions for the study, led to the rejection of 25 articles, followed by 20 articles, as they did not serve the purpose of this study. A final selection was narrowed down to 64 articles for in-depth analysis. A sample of these articles were used (***see Table 2 and Table 3)*** for the study analysis.

Report

Following the study review, the results of the first research question are presented**.** The analysis of selected literature on digital tools and artificial intelligence (AI) in education reveals varying degrees of academic attention and implementation relevance, as measured by the number of citations, mentions, and rejections per study. Facilitating this study provides a clear insight on the use of digital tools and AI in mathematics teaching and learning. Moreover, the purpose they serve as digital instructional strategies when integrating technology into learning. It is worth noting that teaching mathematics in the context of digital tools and AI technologies is prevalent, considering the volume of research undertaken with the integration of digital tools and AI technologies. Amador et al. (2019) note that there is an increased accessibility and use of technology in classrooms hence the demand to support teachers on the implementation of these technologies. This is based on the argument that these digital tools offer various learning opportunities that improves teaching and learning. On a similar note, McGlynn-Steward (2019) asserts that technology plays a pivotal role in improving the classroom environment for both students and teachers. Therefore, teaching mathematics with digital technologies have become an essential part of classroom practice and it is encouraged in many primary, secondary and even at university level (Clark -Wilson, 2020). One of the key digital tools used in mathematics technology teaching and learning is GeoGebra, a dynamic software with encompasses a robust and strong combination of functions that is, the dynamic geometry system (DSG) and the computer algebra system (CAS). GeoGebra is known for its effective software application for teaching and learning that provides students and teachers with meaningful learning opportunities, which seamlessly integrates the graphing calculators, algebra functionality, geometric properties, spreadsheets, statistics and other mathematical topics and concepts (Szilvia, 2023; Zulnaidi et al., 2024; Viberg et al., 2024). It is also important to consider various digital tools highlighted by the study as evidence that digital tools and AI methods are used significantly globally to enhance teaching and learning and improve classroom performance. These technology-aided methods are regarded as important to facilitate interactive, dynamic, and stimulating classroom environments during a lesson. Moreover, they are considered to promote students' conceptual understanding of mathematical concepts, specifically the abstract concepts (Cîrneanu and Moldoveanu, 2024).

Discussion

The findings underscore the transformative potential of digital tools when thoughtfully integrated. Moving beyond basic use requires a shift in teacher beliefs, training structures, and curriculum design. Educators need not only technical skills but also pedagogical strategies that entrench technology as a tool for deeper and conceptual learning. Furthermore, meaningful technology integration supports student-centred learning, enabling visualization, exploration, and immediate feedback, especially useful when teaching abstract topics like Functions. Aligning teaching practices with the higher levels of the SAMR model can help unlock this potential.

Conclusion

Many educators rely on digital tools for demonstration rather than student exploration. In the context of the Fourth Industrial Revolution, digital tools are no longer optional additions to the mathematics classroom—they are essential instruments for enabling 21st-century teaching and learning. This study highlights the current underutilization of these tools in teaching Functions and presents evidence-based strategies to bridge the gap between potential and practice. By integrating technology through structured frameworks such as SAMR and TPACK, educators can enhance conceptual understanding, foster engagement, and prepare learners for a digital future in mathematics.

While digital tools are acknowledged as valuable resources in teaching Functions, their use is predominantly at the Substitution or Augmentation level of the SAMR model. Few studies report integration at the Modification or Redefinition levels, where technology significantly enhances or transforms learning.

As a result, students often remain passive observers instead of active participants in constructing mathematical understanding.

- Key barriers to effective implementation include:
- Lack of professional development focused on TPACK
- Inadequate access to technology in under-resourced schools
- Time constraints and curriculum pressure
- Limited support for designing tech-enhanced lessons
- Despite these challenges, several promising strategies were identified:
- Using GeoGebra to explore transformations of function graphs interactively
- Encouraging learners to use mobile apps for investigating real-world function models
- Embedding formative assessment through technology (e.g., Desmos activities)
- Collaboratively co-designing lessons that align with TPACK principles

Recommendations

To promote effective use of digital tools in teaching Functions, the following recommendations are proposed:

1. Mandatory digital training in pre-service and in-service teacher development programs, with a focus on TPACK framework adoption.
2. Curriculum alignment to explicitly include digital tools as part of instructional planning
3. Policy-level support to ensure schools have access to reliable devices and connectivity
4. Communities of practice for teachers to share resources and co-develop tech-integrated lessons

Declarations

Conflict of Interest: The authors declare that they have no conflict of interest.

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