Integrating Technology in Mathematics Teaching At Technical Vocational Education and Training Colleges in Gauteng: Opportunities and Challenges

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ABSTRACT

The integration of digital technology in Mathematics education has emerged as an important consideration in Technical Vocational Education and Training colleges, with these institutions making efforts to improve student participation, understanding, and work readiness. Although the whole world is moving towards technology-enabled learning and teaching, there is a challenge in identifying research studies undertaken to assess how digital technology is used in Mathematics education in TVET colleges in South Africa. Research aims to establish opportunities and challenges associated with technology integration in Mathematics education in TVET colleges in Gauteng Province.

Conducting a qualitative study design based on an interpretivist paradigm, a semi-structured interview study among Mathematics lecturers and focus-group interviews among students were performed. The research subjects were purposively sampled in a selection of four public TVET colleges. A thematic analysis strategy was used to shed light on themes emerging in relation to participants' realities.

Findings show that digital technology opportunities to improve learning engagement and understanding of abstract mathematical concepts through mobile apps, digital platforms, and visualization tools exist in abundance but are hindered by effective implementation. Primaries include lecturer capacity-building, lack of infrastructure, lack of institutional support, and digital inequity among learners. Moreover, this study shows that lecturers have deep content knowledge but lack pedagogical and technological capacity to implement technology effectively in learning.

Based on the findings, achieving seamless integration of technology in Mathematics education in TVET colleges implies a need for support at an institutional level. The research piece adds to the increasing body of knowledge in educational technology in *vocational education and will allow readers to gain insights into improving Mathematics education in developing countries.*

Keywords: **TVET colleges, Digital Technology Integration, Mathematics Education, Teaching Challenge, Learner Engagement**

1. INTRODUCTION

Incorporation of information technology in the teaching paradigm has turned out to be an influential phenomenon during the 21st century. Worldwide, educational institutions shift towards technology-enriched modes for instruction and learning so as to address the needs of an increasingly dynamic information society. Even South Africa witnesses the same transformation, especially in TVET colleges in Gauteng Province, the hub for economic activities. The inclusion of digital tools in the curriculum is perceived as a vision for preparing the learners for challenges existing in the modern technical and professional environments. Mathematics is fundamental to the technical curriculum provided at TVET colleges, as it cultivates learners' problem-solving and analytical abilities crucial for disciplines such as engineering, electronics, and information technology. Notwithstanding its significance, Mathematics continues to be a difficult subject for numerous students, frequently leading to sub-par academic results and elevated failure rates. Although digital tools possess the capability to improve comprehension and involvement in Mathematics, their effective application within TVET environments is still constrained.

TVET institutions are vital in preparing students for technical careers, making digital tool integration both necessary and beneficial. Domingo and Garganté [1] highlight challenges in TVET education, including the need for practical instruction and alignment with industry standards, noting that technology use is often irregular due to limited institutional support and training. Despite global digital transformation trends, barriers persist, Moyo [2] points to resource constraints, inadequate training, and negative attitudes, while An and Reigeluth [3] stress that even with resources, educators often feel unprepared, underscoring the importance of ongoing professional development and supportive environments. In South Africa, studies show similar issues. Basitere and Ivala [4] found growing awareness of ICT integration but persistent infrastructural problems such as poor internet, outdated hardware, and low digital proficiency. Nkula and Krauss [5] propose a framework tailored to the South African TVET context, emphasising policies, training, and sustained support. Teacher preparedness is also critical, Onwuagboke and Singh [6] note that confident instructors with institutional backing integrate ICT more effectively, yet many lecturers feel inadequate due to skill and infrastructure gaps [7]. Digital inequality further complicates matters, as Van Deursen and Van Dijk [8] show disparities in quality and use, especially among marginalised groups. Reddy and Le Grange [9] argue that ICT integration requires robust policies addressing equity, curriculum, and teacher capability, while Makokoe [10] stresses national and institutional strategies for inclusivity and sustainability. Without such interventions, technology risks deepen existing educational inequalities.

The status of technology integration in teaching Mathematics in four Gauteng TVET colleges was investigated in this study. Its objective was to identify the opportunities that digital tools afford as well as the challenges that the students and lecturers encounter when using these tools. The study aims to shed light on lived realities and institutional processes.

1.1 Problem Statement

Notwithstanding the increasing focus on digital transformation within the educational sector, the successful incorporation of technology into Mathematics teaching at South Africa's TVET colleges is still notably inadequate. Although technology possesses the capacity to improve learning outcomes and student engagement in Mathematics a discipline vital for technical professions, numerous TVET institutions continue to encounter obstacles, including insufficient infrastructure, limited preparedness among lecturers, and variable institutional support. These challenges impede the realisation of technology's comprehensive advantages within the educational environment. There exists a deficit of profound, context-specific insights regarding how lecturers and students experience and interpret the implementation of digital tools in Mathematics education at TVET colleges located in Gauteng Province. In the absence of such insights, policy and practice may fail to align with actual circumstances, resulting in ineffective interventions and ongoing underachievement in Mathematics education.

1.2 Research Questions

1. Which digital tools are already applied for facilitating the teaching and learning of Mathematics in the selected TVET College?

2. How do lecturers and students understand the effect on teaching quality and learning performance caused by digital technologies?

3. What institutional or infrastructural factors influence the integration of digital tools in teaching Mathematics?

4. What strategies could be implemented to enhance the use of digital technology in Mathematics education in the TVET context?

2. Materials and Methods

A qualitative research methodology paradigm with an interpretivist orientation was used in this research to investigate experiences and perspectives on technology integration in Mathematics teaching in TVET colleges. A purposive sampling technique was used to obtain information from four public TVET colleges in Gauteng Province, which were sampled to represent diversity in terms of facility and technology readiness.

A total of 130 participants took part in this study, which consisted of Mathematics lecturers and students pursuing NC(V) Mathematics. The lecturers were chosen because they teach Mathematics, while students were recruited based on participation in classes where technology tools were used to different extents. Semi-structured interviews were conducted among lecturers, whilst focus group discussions took place among students.

Data collection ended when each case reached thematic saturation, which meant no new themes were produced in subsequent interviews. Audio recording and transcription were performed with participant consent, and all transcripts were anonymized before analysis.

The analysis of the collected data used a technique called thematic analysis in accordance with a six-phase model described by Braun & Clarke [11]. Manual coding of themes by research authors increased rigor in analysis.

Table 1: Profile of Survey Participants (n = 130)

Role at College	**Frequency**	**Percentage (%)**
Students	97	74.6
Lecturers	33	25.4
Total	**130**	**100.0**

Table 1 presents the distribution of survey participants by role at the TVET college.

2. Results and Discussion

This paper examined the integration of digital technology in mathematics instruction in Gauteng chosen TVET colleges. The interviews results are presented in thematic form to bring out the advantages and limitations of the application of technology in the classroom. Themes that were generated in the analysis are as follows: enhanced engagement and improved comprehension, infrastructure and resource challenges, need for professional development and ongoing support, increased learner autonomy and self-directed learning, positive impact on teaching efficiency and lesson delivery and barriers to student participation and digital inequality.

3.1 Enhanced Engagement and Improved comprehension

Respondents highlighted that technology greatly enhances learner engagement and understanding in mathematics by making abstract concepts more visual and interactive. As L2 noted, “When I show a graph on GeoGebra, you can literally see students leaning forward... it’s like something suddenly clicks for them.” Similarly, S4 observed that active, inquiry-based learning emerges when students manipulate digital objects: “When they drag a point on the screen and see the whole shape changing, they start asking questions I’ve never heard them ask before.” Motivation was also seen to rise, with L3 remarking, “They’re so used to phones and laptops... so when maths looks like that too, they enjoy it more, hey.” Collectively, these voices suggest that technology transforms the learning environment, fostering curiosity, deeper interaction, and improved performance in mathematics.

Figure 1 shows that digital technology is used inconsistently in Mathematics teaching, with the majority of respondents reporting rare or no use, indicating limited institutional embedding.

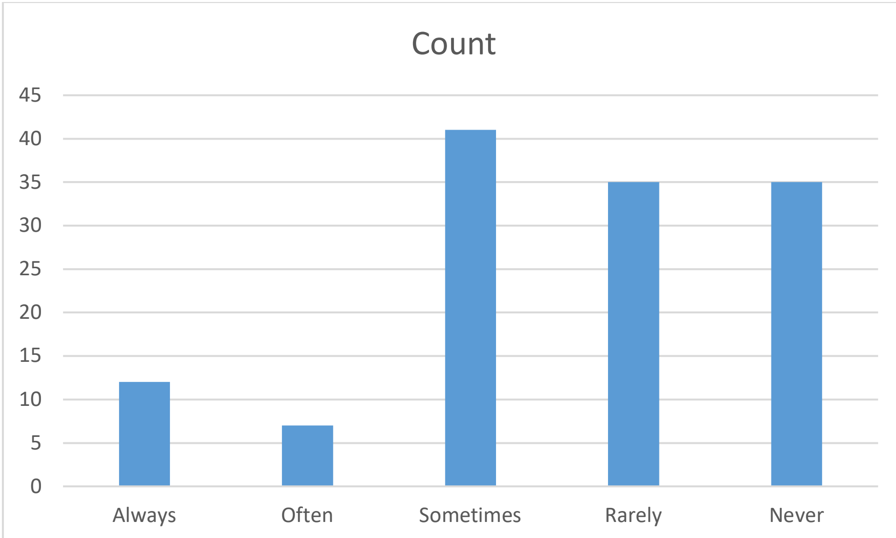

Figure 1: *Frequency of digital technology use in Mathematics classes at TVET colleges (n = 130).*

3.2 Infrastructure and Resource Challenges

Participants acknowledged significant infrastructural and resource challenges that hinder effective technology integration in teaching. Poor internet connectivity was a recurring frustration, with S2 lamenting, “There are times when I have everything ready, but the Wi-Fi will refuse to cooperate... and you have to work with what you have at your disposal.” Hardware shortages also limited participation, as L1 explained, “We attempt group work, but we have one laptop per group and some of the students just sit and watch rather than learn.” Outdated equipment further discouraged use, with L4 sighing, “You turn it on and wait... and wait... before it opens you have lost the attention of the class.” These voices collectively highlight that without consistent investment, maintenance, and equitable access, the promise of technology in mathematics education is undermined by systemic barriers.

Figure 2 illustrates mixed perceptions regarding training adequacy, suggesting uneven preparedness among lecturers and students.

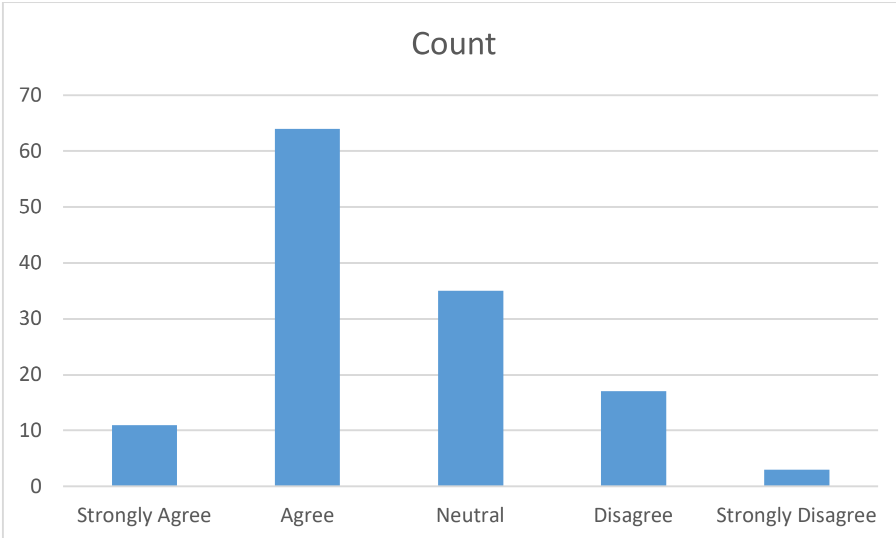

Figure 2: *Participants' perceptions of adequate training for integrating technology into Mathematics teaching.*

3.3 Need for Professional Development and Ongoing Support

Participants emphasized that successful technology integration requires continuous training, guidance, and support, as many lecturers lack confidence despite their willingness to use digital tools. L5 admitted, "I am familiar with the fundamentals but when something does go wrong... I only stiffen a little since I am not quite trained yet." L2 echoed this, noting that workshops are too brief: "By the time you have time to practice, you can hardly remember half of it." Peer collaboration was seen as crucial, with L3 explaining, "Sometimes it is more convenient when a colleague demonstrates, you know, a person who can comprehend your problems at school." Without technical assistance, lecturers often abandon technology mid-lesson, which discourages future use. Overall, these voices highlight that beyond devices, sustained investment in training, peer support, and reliable technical help are essential for effective mathematics teaching in TVET colleges.

Figure 3 demonstrates that participants prioritise access to devices and professional development over curriculum changes, highlighting the centrality of infrastructure and capacity building.

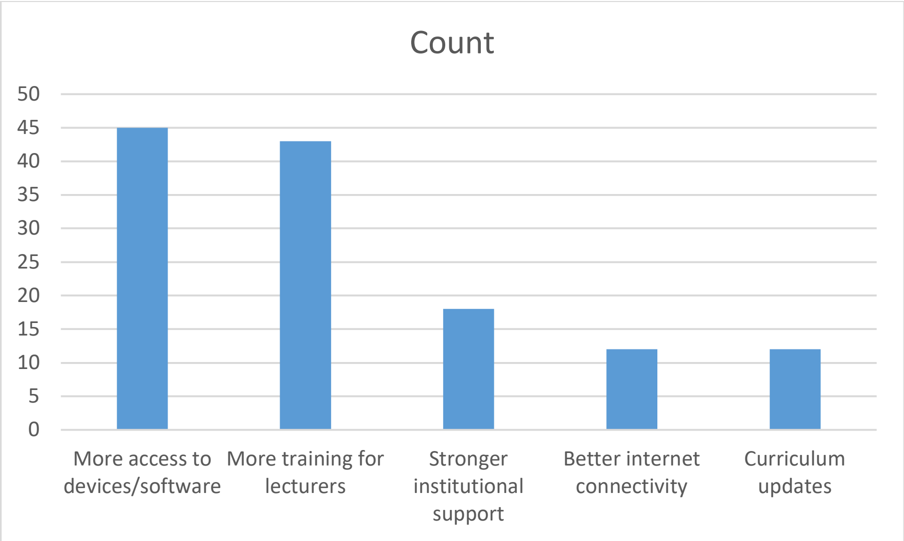

Figure 3: *Preferred strategies for enhancing technology integration in TVET Mathematics education.*

3.4 Increased Learner Autonomy and Self-Directed Learning

Participants observed that technology fosters learner autonomy and self-directed study, allowing students to learn at their own pace and beyond the classroom. L1 noted, "Some students will revisit the simulations at night... you can see they are in charge of their own learning." S3 added, "They do not need to wait till I repeat myself but watch the video or visit the interactive example and you can hear them whispering, Oh, now I know." L2 highlighted increased investment, saying, "They will send me pictures at 9 pm such as, Sir, is this right?" Student L7 also echoed this saying, "I like maths when we use computers" These voices show that digital tools encourage regular practice, confidence, and exploration, turning students into active contributors rather than passive consumers of mathematics learning.

3.5 Positive Impact on Teaching Efficiency and Lesson Delivery

Participants agreed that technology improves teaching efficiency by simplifying explanations, enhancing organisation, and reducing preparation time. L3 noted, "I only have to make a single click, and all the diagrams are there... it saves me so much time," while L5 added, "You can demonstrate an entire change in a few seconds... and that would have been half the lesson to do by hand." L2 appreciated the organisation benefits, saying, "All there, saved, labelled, and easy to update. I don't lose papers anymore," and L4 highlighted assessment advantages: "Learning analytics enable them to customise the revision sessions." Collectively, these voices show that technology streamlines lesson delivery, promotes clarity, and supports more responsive teaching.

3.6 Barriers to Student Participation and Digital Inequality

Participants highlighted that unequal access and digital inequality hinder student participation, with L1 noting, “Not all learners have access to smartphones and data... and therefore they lag behind using online tasks.” S2 added that some students panic at basic tasks, saying, “There are some people who are panicking upon hearing the word log in... they are frozen.” Financial hardship also limited continuity, as L3 explained, “They would like to work, but when the lab is shut, they can do nothing more at home.” Behavioural distractions were another challenge, with S4 sighing, “One minute of turning around and they are on TikTok... it is such a pain.” These voices reveal that while technology enhances learning, without equitable access, digital literacy, and classroom management, it risks widening existing disparities.

Some of the above results align with the findings of scholars such as Musasa, Goto [12], who observed that although digital technologies can enhance teaching efficiency and learner engagement, mathematics educators continue to encounter barriers including limited institutional support, insufficient training, inadequate infrastructure, and unequal access to devices.

4. Discussion

The findings show that technology integration in the teaching of TVET Mathematics is influenced by a combination of pedagogical capability, institutional capacity, and student access. Using a TPACK theoretical model approach by Koehler & Mishra (2008), the findings show that lecturers have adequate content knowledge but lack sufficient technological pedagogical capabilities to effectively integrate technology into their teaching.

The continued presence of access issues is consistent with the principles of Digital Divide Theory, which asserts a divide not only in technology access but in a broader digital divide including internet access, cost, digital skills, and more (Van Deursen & Van Dijk, 2019). Furthermore, a limited level of support offered corresponds with existing literature on teacher readiness and technology adoption in South African TVET colleges (Mlitwa, 2021; Nkula & Krauss, 2019).

Collectively, these findings suggest that technology integration in Mathematics teaching and learning is largely opportunistic in nature, thus undermining its transformative potential.

5. Limitations of the Study

The research provides important information with regards to technology integration within TVET Mathematics learning; however, some limitations are important to highlight. To begin with, the research conducted using a qualitative approach limits the possibility of achieving generalized results outside of the research colleges. Secondly, this research focused on colleges within a province; this can be an insufficient representation of other provinces in South Africa. Thirdly, this research used self-reported information, which can provoke individual research participant bias. Fourth, despite using a smaller research population sufficient for a qualitative approach, other research parameters using a quantitative research approach would have provided important additional information with regards to technology usage intensity and impact on learning.

6. Conclusion and Recommendations

The study found that digital technology in mathematics instruction at the Gauteng TVET College offers major opportunities by enhancing learner engagement, conceptual understanding, autonomy, and confidence, while also improving teaching efficiency through dynamic explanations, lesson preparation, and real-time feedback. However, challenges such as poor internet connectivity, outdated hardware, limited institutional support, unequal access to devices, socioeconomic barriers, and low digital literacy restrict these benefits, while lecturers also require ongoing training and technical assistance to use specialised tools effectively. To address these issues, TVET colleges should prioritise infrastructural investment in reliable internet and updated devices, ensure equitable student access, and implement continuous professional development with peer mentorship. Measures such as device lending, subsidised data, and digital literacy training can reduce inequality, while embedding technology into curricula with clear pedagogical goals will maximise its advantages, minimise distractions, and ultimately improve mathematics teaching, learner autonomy, and academic performance in a technological world.

7. Future Research

Future studies can make use of a mixed-method approach in order to complement qualitative research with quantitive student performance and technology usage data. Long-term research studies can be conducted to gauge the impact of continuous professional learning and institutional investment on technology integration. Other studies can focus on developing and validating technology learning models for TVET Mathematics education in a specific context, and inter-provincial or inter-secondary/TVET school comparisons can be conducted.

8. Acknowledgement

The authors would like to express sincere gratitude to our institution for generously covering the registration fee for the publication of this paper. This support has enabled our work to be disseminated more widely and made accessible to fellow scholars, thereby contributing to ongoing dialogue and advancement in the field.

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