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Technology Integration in Teaching and Learning of Mathematics: A Disruptive Pedagogy to the Conventional Approach

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Abstract
This paper examines the integration of technology in the teaching and learning of mathematics and presents it as a disruptive pedagogy that is capable of rewriting the mathematics educational narrative. This qualitative study sampled ten mathematics teachers and thirty intact class first year students from Offinso College of Education using a case study design and an interpretivist paradigm. Data were collected via semi-structured interviews and analysed via reflective thematic analysis. The research showed some findings that mathematics teachers and students preferred technology-based instruction because it helped to improve students' understanding and active engagement. However, both advocated Blended Approach, considering both, technology integrated and conventional methods. It was discovered that if more and more mathematics teachers are made to be relevant with technology tools or resources, teacher capacity development, government support and having a policy document in respect of technology integration, there will be an expected effectiveness in the overall integration of technology towards effective and integral part of mathematics instructions. These would all provide ways for mathematics teachers to overcome obstacles they encounter when implementing technology to transform the way mathematics is taught, thus providing disruptive pedagogy to the traditional approach. These findings point to the promise of leveraging technology to improve the teaching and learning of mathematics, while also offering insight into the challenges that must be considered in order to, as optimally as possible, enhance students' learning of mathematics.

Key Words: Technology Integration, Mathematics, Disruptive Pedagogy, Convectional Approach

Introduction

One of the most important transformations in contemporary education has been the integration of technology into the mathematics curriculum. The rapid progress in digital tools and education techniques has started questioning the traditional (or conventional) way of teaching leading to a path of something being referred to as "disruptive pedagogy". Disruptive pedagogy is when a generalized shift in teaching occurs, where traditional/conventional pedagogy is focused on, and replaced by, innovative teaching and other technology-based methods. The word disruptive pedagogy is embedded in disruptive innovation (Christensen et al. 2011). New models are created by the introduction of new technologies that transform teaching and learning (Seymour, 2015).

Disruptive pedagogy, which may occur in education at two or more conflicting levels, transpires when the advancement of some technologies changes the way that knowledge is delivered, assessed, and conceptualized, rendering conventional or traditional approaches to education increasingly ineffective. Instead, technology has transformed mathematics — a subject that relies far more on conceptual understanding, logical thinking and problem solving than on rote calculations. Innovative formats such as visual learning, project-based learning, digital tools, artificial intelligence, and interactive learning environments are replacing or complementing traditional methods of teaching, such as chalk-and-board explanations and paper-based exams (Mishra & Koehler, 2006). The implementation of technology into mathematics instruction has dramatically disrupted conventional pedagogical approaches, presenting both opportunities and challenges. They represent major disruptions in the transition from passive learning to individualized and interactive experiences, the perceived need for teacher capacity in technology, and the prospect of unequal access to resources, among others. To get the most benefit of technology used in education we need to overcome these issues. Technology has the power to completely reshape mathematics instruction, but it also sparks concerns about equity and teacher preparedness. Finding the right balance between these elements is crucial for maintaining an inclusive and productive learning environment. The students in our classrooms and schools today are the first generation in history to be raised in the highly technological world we live in and have never experienced life without technology and the Internet. However, there seems to be a huge inconsistency with the quality, quantity and the utility of technology in mathematics education today (OECD, 2016). Orlando & Attard (2017) posit that many teachers you meet in today's classrooms received their degrees and professional certifications long before technology entered today’s classrooms. It is also worth noting Bower (2017) contends that technology integration in the teaching and learning of mathematics is an educational imperative – it is seen as a necessity that needs to be in education in society. Bower states that technology emphasizes the importance of education for social equity, economic growth, social development, and personal growth. The idea of technology integration in the mathematics classroom responds to this need by advocating for rules and procedures that ensure access to equitable educational opportunities, lifelong learning, and development of technological skills and knowledge required to teach and learn mathematics in schools and colleges for all students or learners consistent with their demanding needs from the mathematics educational system to enhance their societal values. In another perspective, Prahmana and Kusumah (2016) state that the problem of accelerating change in the twenty-first century in mathematics education is about the identification and creation of technology. In addition, Young (2017) clarifies that technology as a knowledge tool that can challenge or modify the way of teaching the subject, practice on the one hand, and efficiency on the other, have an impact in the same direction. It also causes different technology to solve mathematical problem at different levels, hence making it easier to teach, and learn. Thus, technology can and should be viewed as a disruptive pedagogy (Attard and Holmes 2020).

According to Johnson and Smith (2021), disruptive pedagogy is a strategy that is counter intuitive to traditional teaching and learning methods. It involves reshaping and reframing the educational paradigm in a way that promotes students to think critically, creatively, and participate actively in their learning process. Although we expect and hope that the evolution of technology will change how we teach mathematics, Attard and Holmes found that disruptive innovation has not yet managed to keep pace with the technology used in our classrooms. There are many reasons people resist innovation. Despite the potential affordances of mobile technology for social constructivist teaching methodology which promotes collaboration, communication, creativity, and problem-solving skills, Tangney and Bray (2013) argue that most mobile technology applications in the classroom are still geared toward passive content consumption. With the current learning setup, mathematics has become so much more significant than it used to be. In fact, all subjects can exhibit such value to the subject that it is a prescribed or basic subject in most educational systems, especially pre-tertiary curriculum in Ghana. It is a universal truth that development relies on mathematics because mathematics is used in every single aspect of our daily lives. It is considered the basis for countries' social, economic, and technological growth, and minimal progress in a field of life is possible without knowledge, methods, strategies, and principles in mathematics and the related sciences. The students are taught the topic in the school to nurture their views towards life and develop their Problem-solving capabilities, logical and critical thinking along with a cognitive understanding of its real-life use and benefits. Because of the rapid advancement of technology, most countries have had to adapt their curricula accordingly. Such demand-driven changes in a nation's educational system should be responded to with the highest priority being given to the teachers. The science and technology threatening (definitely) something today, are the pedagogies for teaching and learning mathematics being done around our classrooms, colleges, and sometimes, universities.

Mathematics education content and methodology change as well in order to get oriented to the new methods of instructions provided by the scientific and technological way of innovations. Thus, it is a must for pre-tertiary mathematics teachers to be aware of and keep up with Teaching Innovations, which focus on technology, pedagogy, and content in mathematics teaching and learning. Thus, to produce transformational knowledge, skills and technology required for basic education teacher training in Ghana, instructors of mathematics in Ghanaian Colleges of Education must be operable and efficient in the mathematics classroom. Evidence presented in the literature is enough to suggest that the presence of digital technology can change the negative perceptions that people have about learning mathematics, which have resulted in a lot of stress, anxiety, or dislike for the subject.

Problem Statement

On account of some problems with the normal system of instructing mathematics the overwhelming majority of the standard strategies for instructing mathematics haven't, throughout the years, further developed the educating and learning of mathematics in schools and colleges as expected. There is the shocking reality but the majority of mathematics teachers in Ghanaian schools and colleges are struggling to use technology to teach mathematics, hence improving them to technology is a big threat to the status quo since students are met with these current global technology trends. This situation likely stems from the misconception that teachers working in present-day classrooms obtained their qualifications when technology was substantially unlike it is presently (Orlando and Attard, 2017). Despite the fact that many sectors across the world are embracing the use of education and learning resources such as technological tools or digital devices such as Scientific Calculator, Tablets, and Laptops as a support tool in the teaching and learning of mathematics, the Ghana Education Service has placed a ban on the use of Mobile Phone in Senior High Schools and Technical and Vocational Institutions, probably, to minimize distraction. In spite of the fact that traditional pedagogical approaches can be accorded some merits in the teaching and learning of mathematics, the approaches are associated with various problems in mathematics. These issues include:

1. A lack of conceptual understanding that causes learning methods and formulas to take precedence over comprehending the underlying ideas.

2. The development of stress, fear, or anxiety related to mathematics has made it more difficult for the majority of pupils to understand and appreciate the subject.
3. Teacher-centred passive learning, in which the instructor serves as the main information source, results in low student engagement, a lack of drive to learn mathematics beyond the requirements, and a lack of capacity for independent thought and problem-solving.
4. Limited practical application: the abstract nature of teaching and learning, the lack of real-world applications for what is taught, students' lack of interest in and motivation for studying mathematics, etc.

With an emphasis on comprehension, problem-solving abilities, independent and critical thinking, high levels of self-engagement and collaboration, motivation, interactive exploration and interest, and the development of positive attitudes toward the subject of mathematics, these issues underscore the need for more creative, student-centred, technological approaches and the use of technological instructional resources in mathematics education. The goal of twenty-first century mathematics education is to identify and create technologies that can improve teaching and learning's effectiveness and value.

According to Bower (2017), people perceive technology as an educational imperative; something that is urgent, critical, crucial, and necessary for education in society. In mathematics education, there is a clear disconnect between content knowledge and pedagogical knowledge. In the face of these global technology developments and the educational values of technology over the drawbacks of the traditional pedagogies of mathematics teaching and learning, why are educational policy makers not proactively formulating policies to ensure the incorporation or integration of technologies in the teaching and learning of mathematics in schools and colleges to serve as disruptive pedagogy to conventional approaches to harness its full benefits to enhance students' performance? What is the effect produced by the mixing technology intended on the teaching and learning mathematics in schools and colleges who have a technology integration? What are the issues with the use of technology for teaching in mathematics? Mathematics coaching: How can technology be made an integral part of teaching and learning of mathematics?

Research indicates that improved mathematics teaching and learning can be achieved through adequate use of technology and integration of resources at appropriate best interest if technology supportive policies, instructional resources or tools, capacity building of teachers are in place. In what can be called the average classroom of colleges of education, one would definitely come across students using a range of technological gadgets like laptops, tablets and smartphones and they use them to interact or connect with their friends through various digital platforms. These are perceived as interruptions to instruction by some who lack both technological knowledge and skills. This is because these things are unusual in classes using traditional teaching and learning strategies. Importantly, Attard and Holmes (2020) argue that technology use and access are part of the fabric of today's classrooms and have the potential to transform the way in which mathematics instruction occurs and is assessed, creating opportunities for enhanced engagement, development, innovation, rethinking learning environments, and deeper learning. As Attard and Holmes state, several nations, including the United States, Australia, United Kingdom, and several others, have expressly established educational policies aimed at integrating technology into teaching and learning. Can Ghana be such a proactive, education-focused country? With this research project, I am motivated to examine how technology as a pedagogical tool, integrated into the mathematics teaching and learning process, serve as a disruptive pedagogy compared to traditional approaches of teaching mathematics.

Research Objectives

These research objectives guided the study.

1. To explore how to effectively integrate technology in the teaching and learning of mathematics to serve as a disruptive pedagogy to conventional approaches to teaching.
2. To assess the challenges associated with technology integration as a disruptive pedagogy in mathematics education.
3. To discover the technological tools and resources that are available for usage as a disruptive pedagogy in mathematics education.

Literature Review

Theoretical Framework

The Disruptive Innovation Theory served as the theoretical framework for this study. Disruptive Innovation Theory describes how new technology can radically change established practices by providing better and more innovative ways to deliver education. Disruptive innovation refers to an innovation that helps create a new market and value network, or enters at the low end of an existing market and ultimately displace established firms, products, and alliances. Christensen's theory of disruptive innovation has tremendously influenced the business world. There has been thorough discussion surrounding this theory since it was first introduced, with some scholars and researchers debating its applicability and relevance in various contexts (Christensen, 1997; Lepore, 2014). For example, in digital photography, the emergence of digital cameras disrupted the film photography business by offering a more convenient and accessible alternative. Likewise in the wake of the internet, the internet disrupted traditional media, communication, and commerce business.

Disruptive Pedagogy as Grounded in Educational Theory

In education, disruptive pedagogy refers to a completely radical alteration of educational pedagogy in which the older, traditional methods are cast away in favour of modern, new-fangled teaching styles powered by technology. In the context of mathematics education, disruptive pedagogy marks a significant shift from traditional, lecture-based instruction toward more dynamic, student-centred approaches that leverage digital technologies to foster critical thinking, creativity, and active engagement. This pedagogical model challenges established norms or status quo by promoting adaptability, innovation, and cross-disciplinary thinking, key competencies in contemporary mathematics classrooms. Disruptive pedagogy utilizes mobile and accessible digital technologies such as GeoGebra, Desmos, and other dynamic mathematics tools to transition from teacher-centred instruction to learner-driven exploration. These technologies enable students to visualize abstract concepts, test conjectures, and engage in real-time problem-solving, thereby enhancing conceptual understanding and mathematical reasoning (Hutchings & Quinney, 2015; Hedberg, 2011).

Within this framework, students are positioned as active co-constructors of knowledge, engaging actively with mathematical tasks rather than passively receiving information. This aligns with constructivist principles and supports deeper engagement, self-directed inquiry, and collaborative learning environments that are essential for developing mathematical proficiency (Hutchings & Quinney, 2015). Disruptive pedagogy also encourages learners to approach mathematical problems through critical and creative lenses. For example, incorporating real-world scenarios and interdisciplinary themes fosters not only procedural fluency but also the ability to critically evaluate mathematical models and creatively apply mathematics to complex, authentic contexts (Ball, 2015). This approach facilitates the integration of mathematics with other disciplines, such as the arts, science, and technology, using systems thinking to present mathematics as part of a broader network of knowledge. Such transdisciplinary practices promote holistic learning experiences and highlight the relevance of mathematics beyond the classroom (Marshall, 2014). Disruptive pedagogy offers a transformative lens for mathematics education, emphasizing the integration of digital tools, active student engagement, critical inquiry, and transdisciplinary learning. This paradigm supports the development of mathematically literate citizens equipped for the demands of a rapidly evolving, technology-rich world. Disruptive pedagogy is a new paradigm for mathematics education towards truly innovative ways to encourage student engagement, personalize learning and outcomes (Christensen, Horn, and Johnson, 2011). By incorporating technology-based methodologies, learners will acquire the essential thinking and problem-solving skills needed to thrive in the twenty-first century.

Disruptive pedagogy in education occurs when technology alters how knowledge is transferred (taught), assessed (tested or measured), and conceptualized — making traditional practices less effective. Core characteristics of disruptive pedagogy in mathematics include:

- Shift from Teacher-centred pedagogies to Student-centred pedagogies.
- Integration of Digital Learning Platforms
- Gamification and Student Engagement
- Artificial Intelligence and personalized learning

Collaborative and global learning disruptive innovations, for a time, may not outperform traditional approaches at their intended or core function, but over time their adoption becomes widespread due to their progress in approaching their intended function and doing so in a more accessible and effective manner (Christensen et al. 2011). Examples of disruptive innovation in the field of mathematics education have come in the forms of digital learning platforms, Artificial Intelligence (AI) powered tutors, or adaptive learning systems that personalize student experience. With the advent of interactive, self-paced, and captivating learning environments technology-driven pedagogical changes have revolutionised the teaching and learning of mathematics. Khan Academy and GeoGebra are just a couple of examples of online mathematics resources that provide individualized learning paths that defy the one-size-fits-all approach characterizing conventional teaching. The theory of disruptive innovation suggests that technology can revolutionize mathematics education by making high-quality learning experiences more affordable and engaging. Such changes must be embraced by both educators and institutions for a resilient and future-ready academic system.

Evidence and Pedagogical Impact

Emerging evidence highlights the transformative potential of Disruptive Pedagogy in mathematics education, particularly in fostering student engagement and promoting conceptual understanding. By integrating innovative instructional strategies, mathematics educators can cultivate more dynamic and responsive classroom environments, ultimately enhancing both teacher efficacy and student learning outcomes. Improved student achievement in mathematics is closely tied to teachers' pedagogical competence. As König et al. (2021) demonstrate, high-quality instructional practices contribute significantly to students' mathematical performance, reinforcing the imperative for robust teacher preparation and continuous professional development.

The use of analogical reasoning, embodiment, and interactive strategies, exemplified by the Embodied, Analogical, and Disruptive (EAD) approach in AI education has also shown promise for mathematics instruction. Dai et al. (2024) found that these pedagogies significantly advanced learners' comprehension, suggesting that engaging, cognitively rich methods can be effectively transferred to mathematics education. Moreover, collaborative learning models in teacher professional development have been associated with measurable improvements in instructional effectiveness. Chong and Kong (2012) reported that when mathematics educators engage in collaborative inquiry and reflection, their pedagogical efficacy improves, which correlates positively with student achievement.

Finally, the integration of technology in mathematics teacher education has been shown to shift pre-service teachers' instructional beliefs and attitudes. Li (2005) found that exposure to technology-enhanced pedagogy fosters more progressive views on teaching mathematics, indicating that innovation in teacher education can lead to more effective future practices. Collectively, these findings affirm the value of Disruptive Pedagogy in advancing mathematics education. By challenging conventional instructional norms and embracing innovative, student-centred methods, educators can more effectively meet the diverse needs of 21st-century learners.

Integrating Technology in the Teaching and Learning of Mathematics

Mathematics is the building block for all subjects. It develops critical thinking, logical reasoning, and problem-solving skills — all of which are essential in many professions, including science, engineering, and technology. Mathematics forms the foundation of knowledge and is an essential tool for stimulating creativity and developing new methods for problem-solving. Recent studies highlight the importance of mathematics education for the advancement of these competencies. Yalti et al. (2024), for example, stress that mathematics education develops the skills of critical thinking that are required in the modern industrial age. Integrating practical applications into mathematics education also makes possible the development of critical thinking and problem-solving skills. It motivates students to use mathematical theories in practical situations that can help them in critical thinking, data analysis, and decision making. Such skills are critical for mathematics but also transferable to many areas of life and future careers (Atlantis Press, 2023). Technology has changed how we teach and learn mathematics a lot since it was invented. Many schools today have integrated some sort of technology to enhance student learning. The benefits of technology in teaching mathematics have been well established (Bray & Tangney, 2017; Hillmayr et al., 2020; Olsher & Thurm, 2021). These researchers have generated evidence for how to have a highly healthy learning environment with the most optimal mathematics classes through the use of technology. Recent times have witnessed the emergence of a wide array of innovative tools and platforms which aid mathematics education and present impactful teaching resources for teachers.

However, effectiveness in mathematics teaching is vital to facilitate learning and effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well (National Council of Teachers of Mathematics). According to Strickland, Coffland (2004) effectiveness in mathematics teaching should be provided continual support for uses of mathematics in authentic context. Effective instruction in mathematics "engages students in meaningful learning through individual and collaborative experiences that promote their ability to make sense of mathematical ideas and reason mathematically" (National Council of Teachers of Mathematics, 2014, p. 7). So, according to them, mathematics education as well as technology integration in mathematics classroom play an important role in improving effectiveness. The Association of Mathematics Teacher Educators (AMTE, 2021, October) indicates the following technologies to aid in teaching of mathematics. While interactive whiteboards give teachers the ability to present and modify mathematical concepts in real time, educational software and mobile applications can provide quizzes, mathematical games and interactive lessons to students anywhere. In addition, they are able to learn by reviewing online learning platforms and video tutorials. These resources also provide instant feedback which students can leverage for self-improvement.

Learning Management Systems (LMS) provide the traditional structure for organizing and delivering digital courses, while discussion forums and online collaboration tools promote the development of online communities, where learners engage in problem-solving exercises. Learner engagement is a prior issue in learning, in that goals can be best served by the creation of communities of learners in which students are actively engaged in the process of mathematical sense making. Digital devices can stimulate learners to participate in the learning process (Momani, 2023). These devices can potentially motivate learners intrinsically to engage in mathematical thinking. With the help of technological devices, learning becomes engaging which makes a higher level of motivation. The application of such electronic devices to learn and teach mathematics allows teachers to refine their classroom teaching and display mathematical concepts in an effective and dynamic way.

Graphing calculators and programmes such as GeoGebra can establish an environment of use and experimentation for learners in a reasonable way which increases their understanding of the concept (GeoGebra. (n.d.)). Garofalo, et al. (2000) argue that in mathematics education, technology serves the purpose of ensuring the efficiency of instruction and learning. It is important to use technological devices while learning and teaching mathematics because they provide an exchange of information in the process of teaching mathematics; the ability to find Internet sources to exercise; the demonstration of mathematical content; graphical software sing, and saving more time in class.

According to Momani (2023), the integration of technological devices is particularly advantageous for teachers too, as these tools aid them in managing their course materials, assignments, and assessments. With the use of these tools, teachers can track the learning progress of their learners, give them feedback, and also tell them the areas of improvement. Clearly, the use of technology devices has benefits of both teachers and learners. Teachers are using them to deliver effective instruction and learners to understand mathematical concepts easily. The advantages of the use of technological devices in the teaching of mathematics cannot be overemphasised. These include; improving reflective and critical thinking; supporting problem-solving skills; creating opportunities for collaboration and interaction; fostering constructive learning and creating an environment with a learner-centred approach.

Challenges in Integrating Technology in the Teaching of Mathematics

There are many advantages of integrating technology in mathematics education, yet there are many barriers to implementing it effectively. Research has established several of these barriers to inclusive use technology, including limited resources, lack of teacher preparation, and resistance to change. For instance, a study by Abedi et al. (2023) in Ghana revealed that professional development programmes often focus primarily on basic technical skills, neglecting the pedagogical aspects necessary for effective technology integration. This weak link in the chain is one reason teachers are reluctant or unable to use technology in meaningful ways as they teach. Moreover, inequities in mathematics learning are compounded by the digital divide, where students from lower-socioeconomic backgrounds have limited access to technological devices, both within school walls and outside of them.

A systematic literature review conducted by researchers supported the notion that technology integration remains a considerable challenge for many rural schools, where physical infrastructure and internet access remains lacking, exacerbating the widening educational gap for students facing economic hardship. Training on these challenges requires broad based professional development programmes that not only teach mathematics teachers technical skills but also teaching methods on how technology can be effectively integrated into their teaching practice. Another important consideration includes policies that target bridging the digital divide as a way to promote equitable access to technology available to all students, thus increasing the overall effectiveness of technological integration in mathematics education.

Teacher Perceptions of Technology Integration

Teachers' attitudes towards technology and their beliefs about its effective use in mathematics classrooms have a deep impact on its integration (Dada et al., 2012; Ertmer et al., 2012; Wang et al., 2006; Winther et al., 2018). Teachers who see technology positively are more likely to adopt technology use (Kuhlthau, 2002). For example, Thurm and Barzel (2021) show how teachers' epistemological beliefs and their beliefs about teaching with technology are linked to how they use technology in class. In a similar vein, Ertmer et al. (2012) argue that teachers have pedagogical beliefs that are either implicit or explicit and that these beliefs directly inform their practices in integrating technology in the classroom, so addressing and developing these beliefs through professional development programmes is crucial. But worries about the reliability of digital tools and the possible fade-out of traditional problem-solving techniques are shared by some mathematics teachers (Drijvers et al., 2010). So, maintaining positive mindset by implementing specific professional development programmes is crucial to promote meaningful use of technology in mathematics learning.

Best Practices of Technology in Mathematics Education

Technology has to be strategically implemented to get the most out of it. According to Polly et al. (2013) for best practices such as alignment of technology with curriculum standards, collaboration and data-driven personalization of learning. Furthermore, research emphasizes the need for technology to be employed not just as a replacement for classical experiences but as a tool to transform mathematics learning experiences to ultimately act as disruptive pedagogy (Puentedura, 2014).

Methodology

This qualitative paper utilised a case study design and interpretivist paradigm. Data were obtained via semi-structured interview and observation, analysed using reflective thematic analysis. The study's interpretivist paradigm emphasizes the need to understand how people make sense of the world around them (Creswell & Poth, 2018), and to explore how teachers and students view and experience the disruptive changes that have been forced upon them by technology in pedagogy; particularly as technology integration in mathematics education is a human interaction with beliefs and practices. A qualitative approach was preferred, as this approach aligns with disruptive innovation theory, and again, the objective of the study was to understand experiences as opposed to quantifying outcomes. This approach enabled a thorough investigation of the ways in which technology challenges conventional pedagogical approaches in mathematics education (Merriam & Tisdell, 2016). The role of a case study design enabled an in-depth examination of the ways technology integration functions as a disruptive pedagogy within actual classroom settings that have integrated technology into their mathematics instruction (Yin, 2018). Ten mathematics teachers and thirty students in an intact class were conveniently sampled in Offinso College of Education, where technology has been integrated into the curriculum. Sampling in this manner is an appropriate means of ensuring that participants share experience with the phenomenon of interest (Creswell, 2013). In this study, trustworthiness was established by employing triangulation to cross-check the findings using different data sources (interviews and observations) for credibility (Denzin, 2012). Additionally, member checking was performed to verify that participants' responses were accurately interpreted.

Ethical Considerations

Ethical protocols were strictly adhered to. Informed consent was obtained from all participants, and confidentiality was maintained throughout the study (Cohen, Manion, & Morrison, 2018). Participants were assured of their right to withdraw at any stage without penalty.

Results

Thirty college of education students of an intact class and ten mathematics teachers were interviewed on technology integration in the teaching and learning of mathematics. This interview centred on five things which include their general view of technology integration in mathematics teaching and learning, effectiveness of technology integration in the teaching and learning of mathematics, comparison of the conventional and technology-based teaching approaches, challenges in technology integration as well as technological resources in mathematics education. Data collected were analysed using reflective thematic analysis. For the purpose of ensuring anonymity as well as meeting ethical considerations, students were named S1-S30. S1 means first students interviewed, S2, second students and so on. Likewise, mathematics teachers were named T1-T10, where T1, means first teacher interviewed, T2, second teacher interviewed, etc.

RESPONSES FROM STUDENTS

A. EFFECTIVENESS OF TECHNOLOGY INTEGRATION IN TEACHING AND LEARNING OF MATHEMATICS

The effectiveness of technology integration in the teaching of mathematics elicited positive responses from respondents. Two major themes emerged which included “Preference of technology integration over traditional instruction”, measures in improving technological integration

Theme 1: Preference of Technology Integration over Traditional Instruction

It was evident from the responses of the respondents interviewed that those students generally preferred technology integration into mathematics teaching over traditional instruction. S1, S5, S7, S9, S12, S23, S24, S25 and S28 for example justified this by indicating that, “Technology *offers instant feedback on mathematics problems, helping students identify their mistakes*”. S5, S9 and S23 supported this by further indicating that “it saves the teacher the time of providing lengthy content delivery and learning”. This idea of students supports Momani (2023) who posits that the integration of technological devices is useful for teachers because these tools help teachers organize their course materials and saves more time of the teacher in the mathematics class. S12 also added that "the use of projectors, phones and others can help me understand mathematics concepts better". These three responses represent the typical Reponses of the respondents interviewed for the study. It was therefore not surprising that students interviewed indicated technology makes mathematics lessons more engaging.

Theme 2: Measures in Improving Technological Integration

Despite students' remarks concerning their preference for technology integration in the teaching of mathematics, students generally expressed concerns about how technology integration in mathematics can be made more effective. Sub-themes which emerged from this generally included aligning the technology integration with instructional objectives, provision of technological resources and using technology continuously in mathematics lessons. These sub-themes are in lie with typical responses of respondents such "By aligning with learning objectives, teachers can ensure that technology is used in a meaningful way", "by adequate use of technology in mathematics class" and "it can be made more effective if teachers are provided with the needed technological equipment for learning" by S3, S6 and S20 respectively. The first sub-theme "by aligning technology with learning objective" consolidates Polly et al. (2013) who contend that best practices include aligning technology with curriculum standards, fosters collaborative learning environments, and use data-driven decision-making to personalize instruction. These statements suggest that, students think lessons are not made meaningful enough due to lack of improper usage of technology in the mathematics class. It is also suggestive from their responses that, technology is seldom used in the teaching of mathematics. Technological resources if made available could help in effective technological integration of technology in mathematics class.

Comparison with Traditional Approach

Students interviewed were asked leading questions which sought to find out their opinion on whether they prefer technology to traditional approach, the ease of using technology and if a fully technology-based instruction would be preferred to a blended approach. It is suggestive from their responses that even though they generally preferred technology-based instruction to traditional instruction, a blend of both was also seen to be the best. Emerging themes therefore centred on "preference for blended approach"

Preference for Blended Approach

Students made a lot of affirmative comments about the importance of using technology in mathematics which was a preferred option to the traditional approach. Response from S3, S7, S10, S15, S17, S21, S24, S25, S26, S28 and S30 that "*Technology can help students understand and retain mathematical concepts more effectivel*y" which was not much different from that of S1, S2, S5, S13, S14, S23, and S27 who also opined that *"Learning with technology is reliable and easy as compared to the traditional approach"*. These two responses represented typical responses of respondents. Follow up questions however suggest that, students may prefer that even the traditional approach could also have some positives which could complement that of a technology-based instruction and hence calling for a blended approach. A statement by S4, S8, S11, S12, S16 and S29 that *"I prefer the blended approach because I think that one will give more understanding*" is central to follow-up responses gathered from respondents.

B. CHALLENGES IN TECHNOLOGY INTEGRATION IN MATHEMATICS INSTRUCTION

Students were also interviewed to find out challenges they encounter in using technology in mathematics class. Major themes that emerged based on the responses of the respondents included "access to technological resources", and "lack of stable power supply".

Access to Technological Resources

It could be judged from the responses of the respondents that access to technology resources like internet facilities, functional ICT laboratories, and other technological software challenges prevent teachers from fully integrating technology into mathematics instructions. For example, S4, S5, S8, S10, S12, S15, S16, S18, S21, S23, S24, and S27, stated that "they face poor internet access to online resources" which was similar to that of S2, S3, S6, S9, S13, S17 and S25, who indicated that "availability of technological devices, distractions from internet and access" due to unstable internet connections make it difficult to use technology in the mathematics class. These challenges outlined by respondents in this study confirm the findings of Abedi et al. (2021) about challenges of technology integration in the classroom in general.

Lack of Stable Power Supply

It was also clear from the responses of the students interviewed that; lack of stable power supply negatively impacts on effective integration of technology into mathematics instruction. The response of almost all respondents interviewed pointed to the debilitating impact of power outages on technology integration. Students therefore suggested the provision of stable power supply to school as well as improving internet access in schools to improve technology integration in mathematics instructions. Others also suggested technical support to in terms of maintaining technological resources as well as training and education of their teachers on best practices. They argued further that, teachers can improve the use of technology in mathematics class mainly through training of teachers and continuous usage since practice they say makes one perfect. These were implied in statements from respondents such as S1, S5, S7, S8, S13, S17 and S24 who stated that teachers should be provide with *"appropriate technology courses that will make them digitally literate"*. This is supported by S2, S4, S10, S15, S20 and S26 who indicated that "persistent use of the technology can help improve mathematics".

C. TECHNOLOGICAL TOOLS OR RESOURCES IN MATHEMATICS EDUCATION

Several technological resources are often used in schools and colleges in teaching mathematics. Students were interviewed to find out the technological resources they know, and are available to help them understand mathematics concepts. These resources mentioned fell generally under hardware and software components of technological resources. For example, S1, S3, S5, S6, S9, S12, S15, S18, S23, and S28 mentioned "Laptops, projectors, and desktop computers" which could all be classified as hardware. S2, S4, S7, S8, S11, S17, S22, S24 and S26 mentioned apps and calculators which fit into both hardware and software components. GeoGebra, Mathematica, maple and photo maths which are all applications were also mentioned by S10, S16, S19, S27 and S30. This indicates that other hardware and software components of technological resources are known by students. However, only few of them are available in the college as majority of respondents mentioned one or two of the resources, they know to be available. For example, despite the response by these students on the technological resources known, only GeoGebra and Mathematica was mentioned to be available in the College. S13, S14, S20, and 25 also mentioned calculators, projectors and laptops. Interactive mathematics software's like GeoGebra was mentioned to have helped improve students understanding. The few remaining mentioned mobile apps like Photo math and Socratic.

RESPONSES FROM TEACHERS

A. EFFECTIVENESS OF TECHNOLOGY INTEGRATION IN TEACHING AND LEARNING MATHEMATICS

Teachers were also interviewed on their views on effectiveness if technology integration in teaching and learning mathematics. Two broad themes emerged which represent typical responses of the respondents.

Theme 1: Preference for Technology Integration Over Traditional Instruction

Majority of teacher respondents expressed a clear preference for integrating technology into their mathematics instruction. Apart from T1, all contended that "the instant feedback that technology provides is invaluable—students can identify their mistakes and learn from them right away". T2, T4, T5 and T8 added, "Technology creates opportunities for students to engage with material in unique ways, which I think is essential for deeper understanding". These sentiments reflect a consensus that technology integration into the teaching of mathematics not only makes lessons more dynamic but also enhances student comprehension.

Theme 2: Measures to Improve Technological Integration

Despite recognizing the benefits, the mathematics teachers also identified significant measures needed to improve technology integration in mathematics classrooms. Many highlighted the necessity for targeted professional development. T2, T4, T5, T7 and T8 emphasized, "Training is essential so that we can use technology effectively in ways that align with our learning goals". Recommendations for adequate resources and infrastructure were prevalent, as T1, T3, T6, T9 and T10 pointed out, "If we have the needed digital devices and better internet access, we could truly maximize technology's potential in our lessons". This feedback illustrates the need for colleges to support teachers with the necessary tools and training to optimize technology's impact on learning.

B. COMPARISON WITH TRADITIONAL APPROACHES

Teachers also compared the traditional teaching approach with technology-based approach. It was realized that teachers unanimously indicated their desire for blended approach which combines both technology-based and traditional teaching strategies.

Theme: Preference for Blended Approach

While teachers acknowledged the substantial merits of technology in teaching, there was also a prevailing sentiment that blended approaches yield the best results. T1, T3, T4, T6, and T7 remarked, "I prefer using both technology and traditional methods, as together they create a more comprehensive learning experience". This blending allows teachers to craft lessons that take advantage of technology's capacity for automation and instant feedback while also fostering a collaborative and interactive classroom atmosphere. T2, T5, T8 and T9 emphasized, “Blending approaches enables us to cater to different learning styles. Some students thrive on traditional methods while others excel with technology”.

C. CHALLENGES IN TECHNOLOGY INTEGRATION IN MATHEMATICS INSTRUCTION

Theme 1: Access to Technological Resources

Teachers discussed several challenges in integrating technology into mathematics lessons, with access to resources being a dominant concern. T1, T2, T4, T5, T7, and T8 recounted that the college struggles with limited internet connectivity, which seriously hampers our ability to use technology in the classroom. This lack of access can lead to frustration for both teachers and students, as T3and T6 illustrated: “Students often miss out on valuable learning opportunities due to outdated technology or inadequate resources.”

Theme 2: Lack of Stable Power Supply

The issue of infrastructure further complicates technology integration, especially with unstable power supplies. T4, T5, T6 and T8 expressed how often power outages disrupt lessons, stating, “These outages inhibit our ability to use technology effectively, creating a disconnect in learning”. Majority of the teacher-respondents agreed that improvements in infrastructure and training are essential to overcoming these barriers, which, if addressed, would enable mathematics teachers to utilize technology without interruptions.

D. TECHNOLOGICAL TOOLS OR RESOURCES IN MATHEMATICS EDUCATION

Teachers recognized a variety of technological resources that can facilitate mathematics instruction. Hardware such as laptops, projectors, and interactive whiteboards were commonly mentioned.

Discussion

This study explored the integration of technology into mathematics teaching and learning through the theoretical lens of Disruptive Innovation Theory. The findings reveal that while mathematics teachers broadly acknowledge the transformative potential of digital technologies in enhancing instructional quality, systemic and infrastructural constraints continue to limit their full-scale adoption. The theoretical grounding in Christensen’s (1997) Disruptive Innovation Theory aptly contextualizes the pedagogical transition from traditional, teacher-centred approaches to more interactive, student-centred practices enabled by digital tools. This observation is consistent with Christensen, Horn, and Johnson's (2011) argument that disruptive innovations reconfigure existing paradigms by promoting personalization and engagement through tools such as artificial intelligence, gamification, and digital platforms.

Qualitative insights from student interviews underscore a strong preference for technology-mediated mathematics instruction over conventional methods. This trend aligns with Christensen's notion of low-end disruption, whereby innovation initially addresses less prioritized instructional challenges—such as differentiated instruction and student engagement—by offering more accessible and affordable alternatives. Students highlighted the instructional benefits of tools such as projectors, mobile applications, and platforms like GeoGebra, noting improvements in conceptual understanding, motivation, and lesson interactivity. These findings corroborate existing research (e.g., Bray & Tangney, 2017; Hillmayr et al., 2020), which emphasizes the role of technology in fostering mathematical reasoning, learner autonomy, and collaborative engagement.

Teacher interviews similarly indicated a widespread preference for technology integration, with respondents identifying increased student engagement, immediate feedback, and deeper conceptual understanding as key advantages. Such perspectives align with previous scholarship asserting that meaningful integration of technology enhances learners' critical thinking and supports conceptual development (Bray & Tangney, 2017; Hillmayr et al., 2020). Applications like GeoGebra and Khan Academy serve as exemplars of disruptive technological tools that enable exploratory and personalized learning, in line with the theoretical framework guiding this study.

Despite the pedagogical benefits, the findings suggest that most educators favour a blended instructional model that combines digital tools with traditional face-to-face methods. This hybrid approach reflects a pragmatic orientation, wherein technology complements rather than replaces conventional teaching practices. Such a model supports diverse learning preferences and is consistent with calls for technology to serve as a transformative—rather than purely substitutive—force in education (Polly et al., 2013; Puentedura, 2014).

Nevertheless, the integration of digital tools is hindered by persistent infrastructural and systemic barriers. Students identified limited access to technological resources and unstable power supply as significant impediments, especially in rural and under-resourced contexts. These challenges echo the concerns raised by Abedi et al. (2023) and others regarding the digital divide and educational equity. Without adequate infrastructure, targeted investment, and equitable resource distribution, the transformative capacity of technology in mathematics education may remain unrealized. The study reinforces the argument that addressing structural limitations—such as outdated resources, unreliable power, and insufficient teacher training—is critical for sustainable technology integration.

Furthermore, the research highlights the crucial role of teacher training and pedagogical alignment in maximizing the educational impact of digital technologies. While students recognized the instructional value of technology, they also noted inconsistencies in its use, often attributable to teachers' lack of strategic integration. This observation mirrors the gaps identified in the literature, wherein professional development tends to prioritize technical proficiency over instructional design and pedagogical coherence (Ertmer et al., 2012; Thurm & Barzel, 2021). As disruptive technologies reshape educational landscapes, there is a pressing need to equip teachers not only with digital competencies but also with pedagogical strategies for meaningful implementation.

A significant implication of these findings is that disruptive technologies—such as AI-powered tools, digital manipulatives, and learning management systems—may initially struggle to replicate the familiarity of traditional instruction but ultimately foster new-market disruption by creating novel learning ecosystems. Student references to platforms such as GeoGebra and PhotoMath highlight the growing relevance of personalized, gamified, and student-driven environments in enhancing mathematical understanding. Consistent with Puentedura's (2014) SAMR model, the most profound educational transformations occur when technology transcends substitution and enables the redefinition of learning processes.

Finally, the study reaffirms the pivotal role of teachers' beliefs and attitudes in shaping the integration of technology. Educators who embraced digital tools and aligned them with their pedagogical objectives demonstrated more innovative and effective classroom practices. This finding supports prior research (Ertmer et al., 2012; Thurm & Barzel, 2021) emphasizing the influence of epistemological beliefs on the depth and quality of technology use. Moreover, the results highlight the importance of embedding pedagogical training within broader professional development frameworks to ensure the long-term viability and efficacy of technology-enhanced mathematics education.

Conclusion

This study examined the integration of digital technology in mathematics education through the lens of Disruptive Innovation Theory, providing insights into how emerging technologies are reshaping pedagogical practices. The findings demonstrate that while both students and teachers recognize the value of technology in enhancing engagement, conceptual understanding, and individualized learning, systemic challenges—particularly infrastructure deficits, inconsistent access, and limited pedagogical training—continue to impede its effective implementation.

The use of platforms such as GeoGebra, mobile applications, and AI-driven tools reflects a gradual but meaningful shift from traditional teacher-centred instruction toward more student-centred, interactive, and exploratory learning environments. This transition aligns with Christensen's concept of low-end and new-market disruptions, indicating the potential of educational technology to democratize access to high-quality instruction, particularly in underserved contexts.

However, the study also highlights the need for a blended instructional approach, wherein technology complements rather than replaces traditional methods. Such a pragmatic model allows for greater adaptability to varied learning contexts and supports differentiated instruction. Importantly, the success of technology integration is strongly mediated by teacher beliefs, digital competence, and pedagogical alignment. Thus, professional development initiatives must move beyond technical training to emphasize instructional design and meaningful classroom application.

Policy implications from this study point to the urgent need for sustained investment in educational infrastructure, particularly in rural and resource-constrained settings. Ensuring equitable access to devices, stable power supply, and internet connectivity is foundational to realizing the full potential of technology-enhanced learning. Additionally, embedding pedagogical training into teacher education and in-service programs is essential for fostering deeper integration of digital tools in mathematics instruction.

Recommendations

Based on the findings of this study, the following recommendations are proposed to enhance the integration of technology in mathematics education:

First, to strengthen infrastructure and resource allocation, ministries of education and relevant stakeholders should prioritize investments in digital infrastructure, particularly in rural and under-resourced schools. This includes providing reliable electricity, stable internet connectivity, and access to up-to-date technological devices and software to ensure equitable participation in technology-enhanced learning.

Second, to embed pedagogical integration into teacher training, teacher education programs should go beyond technical training by embedding pedagogical strategies for integrating digital tools effectively into mathematics instruction. Professional development should focus on instructional design, classroom management in tech-rich environments, and the use of technology to support differentiated and inquiry-based learning.

Third, to promote blended learning models, schools/colleges should adopt blended instructional models that combine traditional face-to-face teaching with technology-enhanced approaches. Such models offer flexibility to cater to diverse learning needs and can mitigate over-reliance on either method. Policy frameworks should support the design and implementation of contextually appropriate blended learning strategies.

Fourth, to support teacher beliefs and motivation, initiatives aimed at promoting technology integration should address not only skill acquisition but also teacher attitudes and beliefs about technology. School leaders and policymakers should create enabling environments that recognize and incentivize innovative teaching practices, thereby fostering a culture of digital pedagogy.

Fifth, to develop locally relevant and culturally responsive content, educational technology solutions should be adapted to local contexts by incorporating culturally relevant examples, local languages, and curriculum-aligned content. Collaboration with local developers and educators can ensure that digital tools meet the specific learning needs of students in various regions.

Last, to monitor and evaluate technology integration, education authorities should establish mechanisms to continuously monitor and evaluate the effectiveness of technology integration in mathematics classrooms. Data collected from such evaluations can inform evidence-based adjustments to policies, training programs, and resource distribution.

Recommendation for future Researchers

Further research is recommended to explore the long-term effects of disruptive technological innovations on mathematics learning outcomes, student engagement, and teacher practices. Comparative and longitudinal studies across different educational settings will provide a deeper understanding of the conditions under which technology can most effectively enhance learning.

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