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REVIEW ARTICLE

THE ROLE OF DIGITAL TOOLS IN COMMUNICATING MATHEMATICS RESEARCH: A CASE STUDY OF GHANA WITH POLICY COMPARISONS FROM GERMANY AND THE NETHERLANDS

Richard Frimpong^{a*}, Ebenezer Bonyah^a, Awal Mohammed^b^aAkenken Appiah-Menka University of Skills Training and Entrepreneurial Development^bAl-Faruq College of Education.*Corresponding Author Email: frichie1510@gmail.com

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ABSTRACT

The increasing impact of digital technologies in the modern educational system has transformed the methods of instruction and learning. This paper provides an in-depth analysis of the significance, advantages, and potential disadvantages of utilizing digital technologies in mathematics research, using a case study of Ghana and policy comparisons from Germany and the Netherlands. The use of digital tools in the classroom not only enhances the educational experience for students but also provides teachers with numerous opportunities to implement innovative teaching techniques. Research indicates that the accessibility, personalization, and quality of the educational process are significantly enhanced by mobile applications, interactive platforms, and AI-based learning efforts. The study identifies the possible advantages and future prospects of digital technologies by methodically analyzing their function in the educational system in the contemporary setting. Conversely, educators employ analytical tools to track pupils' intellectual development and provide them with chances to reach their greatest potential. The article emphasizes how crucial it is to improve digital literacy and fortify technology infrastructure in order to ensure the long-term viability of mathematics research.

KEYWORDS

Digital tools, Mathematics, Communication, Mathematics research

1. INTRODUCTION

Digital tools are essential for teaching, learning, and communicating mathematics as well as for assisting students in understanding basic concepts and problem-solving techniques. The use of digital technologies in mathematics research has piqued the interest of both researchers and educators. It has been demonstrated that digital tools can enhance learning outcomes, increase student engagement, and support differentiated instruction (Carlos, 2024). This study examines the current state of the art in the field of digital technology use in mathematics research, emphasizing the practical tools and techniques, difficulties faced, and implications for teacher preparation. To increase knowledge, solve real-world problems, and improve technology, mathematical research is crucial. The communication of mathematics research in the digital age has significantly changed as a result of the broad use of digital tools that facilitate collaboration, sharing, and visualization of mathematical concepts. Digital tools are a variety of software applications and technological advancements that facilitate the creation, sharing, and management of information in a digital format. Students and teachers are more likely to collaborate and communicate while using digital resources, which is essential for developing a deeper understanding of mathematics (Saat et al., 2024). Researchers now communicate with peers, share their discoveries, and reach a wider audience thanks to these tools.

Digital tools give researchers a crucial platform to get past obstacles including funding limitations, location restrictions, and access to high-quality publications in Ghana, where access to traditional academic resources may be limited. Although accessibility and efficiency have

increased with the use of technology like computer algebra systems, statistical software, and online collaboration platforms, there are still large gaps in the policy frameworks that allow their application. To learn more about the most effective ways to apply digital technology in mathematics research, Ghana's approach can be compared to that of Germany and the Netherlands. Thanks to well-structured rules, Germany, which is known for having a strong digital research infrastructure, has effectively integrated digital technology into professional and academic mathematical activity. In a similar spirit, the Netherlands has established robust frameworks that encourage open-access research and digital collaboration, which foster innovation and cross-border engagement.

1.1 Statement of the problem

Mathematical research was previously mostly communicated through printed papers, conference speeches, and direct interactions between scholars. But with the advent of digital technologies, this picture has drastically changed. Many digital tools are now available to researchers, including online journals, preprint servers, mathematical software, and social media for academic purposes, and virtual collaboration platforms (Borwein and Devlin, 2011). The way academic scholars perform their work, collaborate, and share their discoveries has been completely transformed by digital platforms. Drawing on observations from pertinent research publications, this answer investigates how academic research methods and results are affected by online journals, preprint servers, mathematical software, virtual collaboration platforms, and social media. Preprint servers and online publications have drastically changed how research findings are shared.

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These platforms shorten the gap between the completion of research and its public availability by facilitating quick publication and open access to knowledge. These gaps must be filled because digital tools present a revolutionary opportunity to improve mathematical research and education in Ghana, where access to cutting-edge research infrastructure is still difficult. They also guarantee that Ghanaian researchers can participate fully in the global mathematical community and contribute to scientific discoveries.

1.2 Research Question

The study seeks to answer the following questions

- What are the opportunities of using digital tools in communicating mathematics research?
- What are the challenges in using digital tools in communicating mathematics research?

1.3 Objectives of the study

The current study seeks to:

- Explore the opportunities in using digital tools in communicating mathematics research in Ghana.
- Discover the challenges in using digital tools in communicating mathematics research in Ghana.

1.4 Purpose of the study

The purpose of the study is to explore the role of digital tools in Ghanaian mathematics research, highlighting significant obstacles and possibilities in the current policy environment. In order to identify strategies that could improve Ghana's digital research ecosystem, the paper compares policies in Germany and the Netherlands.

2. LITERATURE REVIEW

By offering dynamic and captivating resources for practice and learning, digital technology can improve integrated mathematics education. The following tools can help incorporate digital technology in communicating mathematics research:

Internet-based resources: Researchers can use a variety of online tools, like as interactive simulations, video lectures, and practice problems, to improve their teaching and communication of mathematical topics in the classroom. According to the study, students' understanding of geometric relationships and properties is enhanced by GeoGebra's interactive geometric form manipulation capabilities (Hohenwarter and Fuchs, 2004). Studies have shown that using such software can lead to improved spatial reasoning and problem-solving skills (Jones, 2000).

Applications for Education: A number of applications are available to help children learn mathematics in a fun and engaging way. Apps like Khan Academy give students immediate feedback and help them monitor their progress. Teachers now use computers and other technology to accomplish their work-related duties. Teachers utilize computers to make lesson plans, assess student grades and marks, and communicate with students and other teachers. Despite this, many teachers do not use computers in the classroom, and many do not encourage their students to do so.

According to the study, one of the first studies, the use of digital tools does not always imply great teaching and learning because they can also be used to encourage unethical or pointless activity (Dellit, 2002). Research indicates that when technology is used effectively in the classroom, it helps students become engaged and productive members of increasingly democratic communities (John and Sutherland, 2004).

Despite this fact, a large number of educators do not use computers in the classroom, and even fewer encourage their pupils to do so. They assert that the learning process was enhanced when ICT skills were successfully included into teaching and learning (Condie and Munro, 2007). ICT use has been shown to benefit students in a number of ways.

While they argued that ICT use allowed students to obtain instant feedback and prizes, asserted that ICT use may improve both access to education and the delivery of instruction (Wishart and Blease, 1999; Kozma, 2005). By introducing new curriculum based on real-life situations, providing chances for reflection and feedback, and offering a variety of instruments to facilitate learning, concluded that ICT was revolutionizing education (Kozma and Anderson, 2002).

2.1 The Methodology of the Study

A document analysis of research papers from journals, books, edited

books, reports, and online documents reviewing the literature on digital tools, opportunities, and challenges in Ghana with policy comparisons with Germany and the Netherlands was used to collect and analyze qualitative data for this interpretative study.

2.2 Trajectories of digital tool policy and education in Ghana

Policies like the Ghana ICT for Accelerated Development Policy (ICT4AD) and others mandate that information and communication technology (ICT) methods be incorporated into the curriculum of Ghanaian pre-tertiary schools. ICT has the ability to impact all aspects of educational activities. Schools must thus encourage the efficient use of ICT in order to foster creativity, professional growth, information management, and improved teaching and learning strategies. Although the use of ICT for teaching and learning is becoming more and more popular worldwide, government support for these initiatives in Ghana has just lately started to grow.

The Ghanaian government created a number of ICT policies to direct the process of integrating ICT into education and other economic sectors. The Ghana ICT for Accelerated Development Policy (ICT4AD), created in June 2003, is the country's first ICT national policy. The National Pre-tertiary Education Curriculum Framework's promotion of ICT in education is one of the 14 pillars of the ICT4AD. In order to guarantee the provision of educational services at pre-tertiary and tertiary institutions and improve access, the primary goal of this policy is to promote an improved educational system that is powered by the deployment and utilization of ICT (National Pre-Tertiary Education Curriculum Framework, 2018). Computers will be introduced into all pre-tertiary institutions, and Internet access will be promoted in all Ghanaian educational institutions (schools, colleges, and universities) as part of the tactics to accomplish the goals. The ICT in Education Policy, created in November 2008, was the second national ICT policy.

This policy's overarching objective is to give Ghanaian university graduates a platform to confidently use ICT skills to create knowledge, meaning, and start creative technical creations (Ministry of Education ICT in Education Policy, 2008). Providing a platform for ICT integration into the teaching and learning process at all levels of the educational system, re-tooling teacher training colleges to train innovative and creative teachers, guaranteeing Ghanaian teachers receive basic training in ICT skills, and introducing ICT as a teaching subject were some of the strategies used to accomplish this (Ministry of Education ICT in Education Policy, 2008). The government's next policy was the ICT in Education Policy (2015). ICT as a learning and operating tool, ICT integration into teaching and learning, and ICT as a career opportunity for students are the three pillars upon which this policy is based. The introduction of ICT at all levels of the Ghanaian curriculum is considered a crucial way to maintain ICT integration and pique students' interest (Ghana ICT in Education Policy, 2015). The government has taken a number of actions to carry out these policies, such as requiring ICT study at all educational levels, providing laptops to teachers, distributing computers and Uninterruptible Power Supplies to 926 basic, senior high, and a few tertiary institutions, and training basic school teachers in technology use. Additionally, wireless Internet access has been installed in roughly 700 senior high schools nationwide, as well as a few colleges of education and nursing training institutions.

Globally, more and more people are using digital learning materials to help give lectures (Mereku, 2015). Through the process of digitizing the curriculum. In order to improve the efficient delivery of lessons and the accessibility of curricular materials throughout the nation, the Ghana ICT policy included the creation of an educational portal/website in its plan (MOE, 2008). Although it hasn't received much notice yet, the Ghana Mathematics Society (GMS) has also started digitizing the pre-tertiary mathematics curriculum for tablets in an effort to promote mathematics instruction and learning. The recently reviewed ICT in education policy document also noted that there was a "general absence of rich content that was fit-to-purpose as far as the national school curriculum was concerned" (MOE, 2015). To catch up to countries like the Netherlands, where as of 2014, over 70% of teachers used digital learning materials in their pedagogical practices, the Curriculum Research and Development Division of the Ghana Education Service must regularize the activities of individual small-scale businesses that are digitizing learning materials (Kennisset, 2015). The availability of teaching and learning software is another important factor for the effective integration of ICT in Ghanaian pre-tertiary education. Microsoft Office, Microsoft Encarta, AutoCard, CorelDraw, and Mavis Beacon are the only programs installed on computers in senior high schools nationwide, according to the 2009 Pedagogical Integration of ICT project of the Pan African Research Agenda. Auto Card and CorelDraw applications were only available on PCs in Technical Secondary Schools (Mereku et al, 2009). Accordingly, the most

popular educational tools that were available and accessible in Ghanaian schools were Microsoft Office and Microsoft Encarta (MOE, 2009). This implies that most Ghanaian schools lacked the mathematical software. Without more financial resources, the country might begin utilizing open source software such as GeoGebra, Maxima, ExtCalc, R, QtiPlot, FreeMat, Octave, Sage, Maple, and Scilas (Wick, 2009). Notwithstanding the government's pledge to improve ICT infrastructure in pre-tertiary institutions, many schools in the country still do not have internet access. Furthermore, internet prices in the country are exorbitant (Kubis, 2010). Therefore, in order for instructors and students to effectively utilize interactive online learning, it is imperative that the government and others working in the field of education make the internet more affordable and accessible. Required for effective instruction. School computers must have application software loaded that illustrates mathematical ideas.

2.3 Ghana's digital tool policy comparisons with Germany and the Netherlands

Strong ICT policies that support teacher preparation and resource distribution have been put in place in Germany and the Netherlands, encouraging a more integrated approach to the use of digital tools in mathematics research. Ghana should learn from these nations' emphasis on collaborative approaches and ongoing professional development for educators (McMahon et al., 2024). Digital tools have a lot of potential for teaching and communicating mathematics, but there are still obstacles in Ghana's way of successfully implementing them. By addressing these obstacles with focused legislation and training, the educational system may be improved and brought closer to the successful models of the Netherlands and Germany.

3. FINDINGS AND DISCUSSIONS

3.1 Research question 1. What are the opportunities of using digital tools in communicating mathematics research in Ghana?

Over time, digital tools have broken down and opened up numerous obstacles to information sharing that transcend national borders (UNCTAD, 2019). Digital tools have made it possible for people all around the world to communicate instantly, no matter how far away they are. According to the study, many internet users have created new media websites for online news in an effort to stay up to date with global trends (Gill et al., 2013). Digital tools are a great way to share information and improve data accessibility, according to (Paek and Lee, 2018).

According to the study, instructors' use of digital tools in the classroom is influenced by their self-efficacy and epistemological beliefs in addition to their knowledge (Thurm and Barzel, 2022). The use of digital technology in idea creation refers to creating an educational environment that encourages a specific cognitive function and helps students develop their mathematical reasoning skills (Jupri et al, 2015). The effectiveness of technology instruments in aiding the learning and understanding of mathematical concepts has been the subject of extensive scholarly investigation.

For example, research showed that using the GeoGebra environment improved students' academic performance (Saha et al., 2010; Akkaya et al., 2011). This was ascribed to the fact that the intervention improved students' spatial skills, specifically their ability to explore the relationships between algebraic formulas and geometric objects. According to the study, a teaching strategy that makes use of GeoGebra can help students internalize the basic reasoning behind a mathematical topic (Akkaya et al., 2011).

Spreadsheets can improve students' mathematics learning outcomes, according to earlier study (Benning and Agyei, 2015).

The idea that using Excel spreadsheets into high school algebra training can improve student engagement for students who previously had unfavorable attitudes toward learning algebra was empirically supported by the study by (Neurath and Stephens, 2009).

According to the study, spreadsheets' dynamic modeling features have led to its use as a tool for addressing mathematical problems (Niess, 2005).

3.2 Research question 2. What are the challenges of using digital tools in communicating mathematics research in Ghana?

Digital tools have the potential to revolutionize academic communication on a worldwide scale, but there are a number of important obstacles that must be overcome before they can be effectively used to spread mathematical research in Ghana. These barriers to access and utilization stem from sociocultural, educational, and infrastructure-related issues.

- Restricted digital infrastructure access

Inadequate digital infrastructure is one of the most urgent issues. High-speed internet, contemporary computers, and software required for digital communication and mathematical modeling are consistently unavailable at many Ghanaian colleges and research organizations (Asunka, 2008). Broadband restrictions and erratic connectivity can interfere with video conferencing, online journal access, and the usage of cloud-based collaborative tools like Zoom for virtual conferences, Overleaf, and LaTeX editors, even in areas with internet services. In addition, there are technical challenges including device malfunctions and communication issues. Both teachers and students may become frustrated by these problems, which can interfere with the learning process (Ertmer and Ottenbreit-Leftwich, 2010).

- Gaps in technical skills and digital literacy

Many scholars are less adept at using digital technologies for academic communication, especially those from older academic generations. Even while younger academics might be more accustomed to utilizing technology, there is still a big skills gap when it comes to using interactive visualization tools, programming languages like Python or MATLAB, or specific platforms like LaTeX for mathematical writing (Amoako-Gyampah, 2010). Inconsistent levels of competency result from workshops and digital training options that are not always available or standardized across schools.

- Proprietary software is expensive.

The price of high-end digital research tools is another obstacle. Programs like MATLAB, Mathematica, and certain sophisticated statistical programs are costly and frequently out of reach for individual researchers or even academic institutions. This restricts the availability of strong tools that might greatly improve the analysis, modeling, and demonstration of intricate mathematical ideas (Mensah, 2021). Although there are open-source alternatives like Octave or R, Ghanaian universities don't always promote or teach them in great detail.

- Limited Local Platforms for Collaboration and Research Repositories

To share their work, many Ghanaian researchers turn to international publications and repositories. However, these platforms frequently demand institutional logins or expensive subscriptions, which aren't always accessible. Furthermore, there aren't many academic social networks or local digital repositories devoted only to mathematics research in Ghana or West Africa (Boakye and Ampiah, 2017). This makes locally relevant research less visible and inhibits intraregional collaboration.

- Barriers to Communication and Language

Despite the fact that mathematics is a universal language, research findings must be presented using effective narrative framing, especially in public forums or interdisciplinary settings. Lack of training in scientific communication often hinders this. Many Ghanaian researchers may find it challenging to communicate extremely complex mathematical discoveries for wider academic audiences or policy makers when employing digital tools that require interactive presentations and clear, understandable writing (Owusu-Ansah, 2019).

- Institutional and Cultural Opposition to Change

Furthermore, certain academic circles oppose the adoption of digital procedures or new technologies. Writing, reviewing, and presenting research using conventional techniques, such as handwritten proofs, in-person seminars, and hardcopy journal submissions, is still common in many departments. They assert that resistance can result from unfamiliarity, fear of making a mistake, or a sense of institutional insufficiency (Tagoe, 2012).

4. CONCLUSION

Ghana's ability to effectively communicate mathematics research through digital methods is hindered by a complex interplay of technical, cultural, pedagogical, and infrastructure challenges. Specific expenditures in infrastructure, training, and local content production are required to get beyond these barriers, as are institutional adjustments that encourage the integration of digital tools into academic procedures. With the right support, Ghanaian mathematicians may leverage digital platforms to boost their influence, visibility, and collaboration both locally and globally. In order to go from "analog" to mobile phones and the internet and to

produce the essential content that is accessible to the vast majority of people, all stakeholders involved in digital tools in Ghana and Africa must collaborate in order to develop the frameworks needed for the turbulence existence. The legislative framework controlling digital media is also essential if Ghana is to emerge as an African digital powerhouse. Digital media should be seen as a tool for success and development. Our lives have been improved by digital tools, but they also carry the risk of causing turmoil and unintended harm to our society. We must carefully maximize digital tools' potential and limit their downsides if we want to get the most out of them.

RECOMMENDATION

To promote the use of technology in mathematics education in Ghana, a thorough strategy including the cooperation of government organizations, academic institutions, teachers, and other relevant stakeholders is needed. The following recommended approach offers a potential path way:

- Funds must be committed by stakeholders to the development of digital infrastructure, with a focus on underserved and rural areas. It is essential to guarantee that educational establishments have consistent access to electricity and internet connectivity. Increase network availability in isolated areas by collaborating with telecom providers.
- All stakeholders must actively support the fair allocation of funds and resources to educational institutions. To guarantee that every student has equitable access to digital resources, funding for technology-enhanced mathematics education must be allocated specifically.
- Education stakeholders should prioritize developing comprehensive teacher training programs that emphasize the integration of technology into mathematics instruction. Provide teachers with access to courses, certifications, and continuous professional development programs to keep their skills and knowledge current with the latest technological developments.
- Teachers in education should work together to develop thorough guidelines and the best practices for integrating technology into math instruction. The standards ought to include a number of topics, such as the choice of appropriate technology, software, and teaching strategies.
- Curriculum planners must actively promote the creation of math applications and content that are particularly appropriate for the local environment. Collaborate with regional educators and developers to produce digital learning materials that enhance Ghanaian cultural norms and the curriculum.

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