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Applications of Information and Communication Technology (ICT) in Teaching Mathematics in Nigeria: Challenges and Prospects

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ABSTRACT

The paper theoretically and qualitatively explored the applications of Information and Communication Technology (ICT) tools in teaching mathematics in Nigeria. The goal is to review and highlight the challenges and prospects of ICT tools in mathematics education in Nigeria. The findings indicate that several learning theories supported ICT tools in teaching mathematics. Several countries have successfully adopted the principles, with attendant positive results. The result also indicates that ICT in teaching mathematics influences the effective visualization of abstract mathematical concepts, enhances students' engagement, collaboration, and differentiated learning, and eases assessment. Besides, it supports effective remote learning and the development of computational thinking skills, preparing the learner for further studies and future career prospects in the global digital economy. Hence, the Nigerian government should fast-track the integration of ICT in all facets of mathematics education.

***Keywords**: ICT, Mathematics Education, Educational Technology, Visualization, Collaborative Learning, Remote Learning*

INTRODUCTION

Mathematics is the science of quantity, structure, space, and change. It is often perceived as a challenging subject because it involves abstract concepts, yet it is a great tool for

describing and modeling the physical world. Knowledge of mathematics is crucial for academic progress and the professional of individuals as well as instruments of national development. Mathematics is a collection of facts and figures, a way of thinking, a method for solving problems, and a language that helps to describe patterns and relationships in the abstract and physical worlds (Devlin, 2000). It is necessary for understanding the natural sciences, engineering, economics, and social sciences (Stewart, 2017). Yet, many students are experiencing difficulty in understanding its concepts and applications.

Information and Communication Technology (ICT) refers to the diverse technological tools and resources used to create, store, communicate, and manage information. ICT tools include computers, the internet, broadcasting technologies (radio, television), and telephony. ICT enhances communication, improves access to information, and fosters innovations in education, health, and business (UNESCO, 2015).

The digital age has brought significant advancements in educational technology, thereby reshaping traditional teaching methodologies. Scholars have demonstrated that Information and Communication Technology (ICT) offers numerous benefits that enhance the teaching and learning processes. ICT enhances the learning experience, facilitates access to information, supports collaborative learning, enables personalized learning, improves administrative efficiency, and promotes lifelong learning (Newhouse, 2002; Levy, 2003; Voogt & Knezek, 2008; Schmid et al., 2009; Selwyn, 2011 & Johnson et al., 2016). The field of education has particularly benefited from these technological innovations.

The influence of Information and Communication Technology (ICT) has pervaded every sphere of human endeavour, including education. The integration of ICT in education has revolutionized the teaching and learning process. The key questions prompting this study are: how does the application of ICT affect the effectiveness of mathematics teaching? Are there educational theories in favour of or against the use of ICT tools in teaching mathematics? To what extent has the Nigerian education system fared with ICT tools in teaching mathematics? What are the challenges and prospects of ICT tools in mathematics teaching in Nigeria? This article explored the applications, challenges, and prospects of ICT in mathematics education in Nigeria.

THEORETICAL FRAMEWORK

ICT is an aspect of educational technology that has much connection with many educational theories. Information and Communication Technology (ICT) in teaching mathematics has transformed traditional pedagogical approaches. The theoretical

framework outlines the underpinning theories and models that support the applications of ICT in mathematics education.

Constructivist Learning Theory: Constructivist learning theory (Piaget, 1973 and Vygotsky, 1978) posits that learners construct their understanding and knowledge of the world through experiences and reflecting on those experiences. In the context of mathematics education, ICT tools provide interactive and dynamic environments where students can explore mathematical concepts, test hypotheses, and receive immediate feedback. For example, dynamic geometry software like GeoGebra allows students to manipulate geometric shapes and observe the transformations, thereby deepening their understanding through active engagement (Hohenwarter & Jones, 2007).

Cognitive Load Theory: Sweller's (1988) Cognitive Load Theory emphasizes the importance of designing instructional materials that do not overload the learner's cognitive capacity. ICT presents information in multiple formats (visual, auditory, interactive simulations) that reduce cognitive load and make complex mathematical concepts more accessible. For example, multimedia resources, such as video tutorials and interactive simulations, can break down complex problems into manageable steps, thus aiding comprehension and retention (Mayer & Moreno, 2003).

Technological Pedagogical Content Knowledge (TPACK) Framework: The TPACK framework, developed by Mishra and Koehler (2006), highlights the intersection of technological, pedagogical, and content knowledge. Effective integration of ICT in mathematics teaching requires teachers to understand how technology can enhance pedagogical strategies and content delivery. Niess (2005) finds that ICT enhances teachers' instructional methods and confidence in teaching mathematics. Besides, using ICT tools such as graphing calculators and mathematical software requires teachers to understand how to use these tools pedagogically to teach calculus concepts (Niess, 2005).

Social Learning Theory: Bandura's Social Learning Theory (1977) emphasizes the role of observation, imitation, and modeling in learning. ICT provides platforms for collaborative learning where students can share ideas, solve problems collectively, and learn from each other. A typical example is the online collaborative platforms like Google Classroom or discussion forums that allow students to work on mathematical problems, fostering a community of practice and enhancing learning through social interaction (Blau & Caspi, 2009).

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Bloom's Taxonomy and Higher-Order Thinking Skills: Bloom's Taxonomy (Bloom et al., 1956) categorizes cognitive skills into lower-order thinking skills (LOTS), like remembering and understanding and higher-order thinking skills (HOTS) like analyzing, evaluating, and creating. ICT tools can promote HOTS in mathematics education by providing opportunities for students to engage in problem-solving, critical thinking, and creative tasks. Interactive problem-solving software and online mathematical games can challenge students to apply, analyze, and synthesize mathematical concepts, thus promoting higher-order thinking (Anderson & Krathwohl, 2001).

The integration of ICT in mathematics education is supported by various theoretical frameworks that highlight its potential. By leveraging constructivist principles, managing cognitive load, applying the TPACK framework, fostering social learning, and promoting higher-order thinking skills, educators can effectively incorporate ICT to improve mathematics teaching and learning.

ICT TOOLS AND MATHEMATICS TEACHING

Several empirical studies have demonstrated the impact of ICT tools in mathematics education. This includes but not limited to:

Enhancing Visualization and Conceptual Understanding: ICT tools such as GeoGebra, graphing calculators, and interactive whiteboards are instrumental in visualizing mathematical concepts. These tools enable students to manipulate geometric figures, observe transformations and aid in comprehending abstract concepts. For instance, GeoGebra allows students to explore geometric properties and relationships dynamically, enhancing their understanding of symmetry, congruence, and geometric proofs (Adenegan, 2013). In a study conducted in a secondary school in Lagos, Nigeria, teachers reported that using GeoGebra helped students understand the properties of circles and tangents more effectively than traditional teaching methods. This is because students could see the effects of altering radii and angles, leading to a more intuitive grasp of the concepts (Adenegan, 2013). Visualization is crucial in mathematics as it bridges the gap between abstract theories and tangible understanding. ICT tools provide visual representations and help students grasp complex ideas more effectively. This approach aligns with the cognitive theory of multimedia learning, which suggests visual and verbal information enhances learning (Mayer, 2009). The interactive nature of ICT tools allows for better visualization of mathematical concepts.

Improving Interactive Learning and Engagement: Interactive software and online platforms, such as Khan Academy and Mathletics offer personalized learning

experiences through engaging activities and immediate feedback. Interactive ICT tools improve student motivation, engagement, and better learning outcomes (Yushau, 2006 & Ruthven, 2012). The interactive games and activities were particularly effective in keeping students motivated, with teachers reporting higher levels of participation and enthusiasm during mathematics lessons (Wood et al., 2013). Engagement is a critical factor in effective learning. ICT tools provide interactive elements that capture students' attention and sustain their interest in mathematics. For instance, gamified elements, real-time feedback, and adaptive learning pathways make the learning process more dynamic and responsive to individual needs (Plass et al., 2015).

Facilitating Collaborative Learning: ICT facilitates collaborative learning through online forums, discussion boards, and collaborative projects. These platforms allow students to work on problem-solving tasks, share ideas, and receive peer feedback. ICT supports collaborative learning, fosters a deeper understanding of mathematical concepts, and develops critical thinking and communication skills (Resta & Laferrière, 2007). Students share their findings and discuss interpretations, establish a better understanding of data analysis, and improve their collaborative skills (Johnson *et al.*, 2016). Collaborative learning is essential for developing higher-order thinking skills. ICT tools allow students to engage in meaningful discussions, collaborate on complex problems, and learn from diverse perspectives. This collaborative approach mirrors real-world problem-solving scenarios, preparing students for future challenges (Johnson, D. & Johnson, R., 2009).

Supporting Differentiated Instruction: Differentiated learning is an educational approach that tailors instruction to meet the diverse needs, learning styles, and abilities of all students within a classroom to provide each student with appropriate levels of challenge and support to maximize their learning potential (Tomlinson, 2001, and Heacox, 2012). ICT enables differentiated instruction by providing resources that cater to diverse learning needs. Teachers can use adaptive learning technologies to offer customized learning experiences and ensure that all students, regardless of their proficiency levels, can progress at their own pace. For example, educational software like Assessment Learning Knowledge Space (ALEKS) provides tailored learning paths based on individual student performance, helping to address specific learning gaps (Pane et al., 2013). The adaptive nature of ALEKS allowed students to work on topics at their own pace, ensuring that they mastered foundational concepts before moving on to more complex subjects (Pane et al., 2013). Differentiated instruction is crucial in addressing the diverse needs of students. ICT tools allow for personalized learning environments where students receive targeted support and resources. This approach ensures that each

student can achieve their full potential, regardless of their starting point (Tomlinson, 2014).

Enhancing Assessment and Feedback: ICT tools offer innovative ways to assess students' understanding and provide timely feedback. For instance, online quizzes, digital assignments, and formative assessment tools like Secretive and Cahoots allow teachers to evaluate students' performance efficiently. These tools provide instant feedback, enabling students to understand their mistakes and improve their learning promptly (Hattie & Timperley, 2007). At a university-level calculus course, Socrative allowed for real-time assessment during lectures. Students answered questions using their smartphones, and the immediate feedback helped students and instructors identify areas of misunderstanding quickly, leading to more focused and effective instruction (Bruff, 2012). Assessment is an integral part of the learning process. ICT tools provide diverse assessment methods that cater to different learning styles and preferences. The immediate feedback helps students to identify areas of improvement and take corrective actions promptly, leading to continuous learning and improvement (Black & William, 1998).

Enabling Remote Learning and Access to Resources: The advent of ICT has made remote learning possible, ensuring continuity of education during disruptions such as the COVID-19 pandemic. Online learning platforms and video conferencing tools like Zoom and Microsoft Teams have enabled teachers to deliver lessons remotely, ensuring that students can access quality mathematics education from anywhere. Moreover, digital libraries and educational websites provide a vast array of resources that support self-paced learning and continuous improvement (Means et al., 2010). During the COVID-19 pandemic, a high school in Italy successfully transitioned to remote learning using Microsoft Teams. Mathematics teachers used the platform to conduct live lessons, share resources, and assign homework. Students reported that the structure and accessibility of online lessons helped them stay on track with their studies despite the challenging circumstances (Ferrari, 2020). This would not be possible without ICT. Remote learning has become a critical component of modern education. ICT tools provide the flexibility and accessibility needed to ensure that learning continues regardless of physical location. This approach democratizes education, making high-quality learning resources available to a broader audience (Anderson & Dron, 2011).

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Promotion of Computational Thinking and Problem-Solving Skills: ICT tools like programming languages (Python, Scratch) and coding platforms (Code.org) introduce students to computational thinking and problem-solving skills essential in modern mathematics education. By engaging in coding activities, students learn to break down complex problems into manageable parts, develop algorithms, and test solutions, enhancing their logical reasoning and analytical skills (Grover & Pea, 2013). Computational thinking is a critical skill for the 21st century. ICT tools enable the students to engage in computation through coding and problem-solving activities. These skills are essential for understanding and solving complex mathematical problems, preparing students for future academic and career opportunities (Wing, 2006).

Enhancing Positive Attitude and Improving Performance: ICT tools also brought improved performance and a positive attitude towards mathematics. Research by Papanastasiou et al. (2003) indicates that ICT use in mathematics education positively influences students' attitudes towards the subject, making them more interested and motivated to learn. It was equally demonstrated that students using computers for mathematical problem-solving showed improved performance on standardized tests compared to those who did not use computers (Wenglinsky, 1998).

SIGNIFICANCE OF ICT IN MATHEMATICS EDUCATION IN NIGERIA

Mathematics education has a crucial role to play in National development. ICT has a positive impact on mathematics education. Information and Communication Technology (ICT) in mathematics education in Nigeria holds significant promise and potential to transform the teaching and learning experience. Here are some aspects of its significance and lessons for Nigeria.

Enhancing Understanding and Engagement: ICT tools such as interactive software, virtual simulations, and educational games can make abstract mathematical concepts more concrete and understandable. These tools can help students visualize complex problems and engage with the material more interactively and enjoyably, leading to better comprehension and retention (Adejoh, 2021).

Facilitating Differentiated Learning: ICT allows for personalized learning experiences, catering to the diverse needs of students. With the help of adaptive learning technologies, teachers can provide customized instruction and practice activities that suit individual students' learning paces and styles. This differentiation addresses the varied proficiency levels within a classroom, ensuring that all students can progress effectively

(Adebayo, 2018). If used in appropriate teaching and learning situations, ICT tools can go a long way in providing differentiated learning for students of diverse backgrounds, abilities, and learning styles.

Improving Accessibility: ICT can significantly improve access to quality educational resources, particularly in remote and underserved areas. Digital platforms can deliver up-to-date content and teaching materials that might otherwise be unavailable in traditional textbooks. This accessibility ensures that students across Nigeria, regardless of their locations receive a high standard of education (Ogunleye, 2020). This will, in particular, be useful for a multi-cultured environment like Nigeria.

Promoting Collaboration and Communication: ICT facilitates better communication and collaboration among students, teachers, and students. Online forums, collaborative software, and virtual classrooms allow students to work on projects, share ideas, and learn from one another. This collaborative approach can enhance critical thinking and problem-solving skills essential in mathematics (Nwosu & Chikwendu, 2019).

Preparing Students for the Future: Proficiency in ICT is increasing in the modern workforce. Integrating ICT in mathematics education equips students with essential digital skills valuable in higher education and future careers. This technological fluency ensures that students are well-prepared for the demands of a digital economy (Akinyemi & Okafor, 2021).

Supporting Teacher Effectiveness: ICT provides teachers with powerful tools for planning, delivering, and assessing instruction. Digital resources and platforms can help teachers create dynamic lesson plans, track student progress, and provide timely feedback. This support can enhance teacher effectiveness and improve educational outcomes (Babalola & Adeoye, 2022). Proficiency in ICT and mathematics opens up various career opportunities in industries such as technology, finance, and academia. It creates employment opportunities for the citizens, the youth in particular.

Encouraging Continuous Professional Development: ICT in education promotes continuous learning and professional development among teachers. Online courses, webinars, and digital resources enable teachers to update with the latest teaching strategies and technological advancements. This ongoing development is crucial for maintaining high standards of education (Adebayo, 2018). ICT can enhance the learning process, making it more interactive and accessible. ICT has a positive impact on mathematics education, which is crucial to Nigeria's national, technological, and

economic developments. However, the current status of the incorporation of ICT in mathematics education seems to be low compared to other economies.

Innovative Teaching Methods: ICT opens up possibilities for innovative teaching methods, and enhances student engagement and learning outcomes. Interactive software, virtual labs, and online resources provide diverse and dynamic ways to teach mathematical concepts. These tools can cater to different learning styles and help to make learning more interactive and enjoyable for students (Adejoh, 2021).

CHALLENGES OF ICT IN TEACHING MATHEMATICS IN NIGERIA

The challenges of implementing ICT in mathematics education in Nigeria are numerous. Scholars have highlighted some of the major areas of challenges. These include:

Resource Allocation: One of the primary challenges in integrating Information and Communication Technology (ICT) in teaching mathematics in Nigeria is the inadequate allocation of resources. Inadequate allocation of resources refers to limited funding that affects the quality and availability of ICT tools and learning materials for mathematics. Many schools lack funding which hampers the necessary technological tools and materials. This results in a significant disparity in educational quality between urban and rural schools (Adejoh, 2021).

Digital Divide: The digital divide remains a significant barrier to effective ICT in education. There is a gap between students who access digital tools and those who do not, influenced by socioeconomic factors. There is also a significant disparity in ICT access between urban and rural areas, leading to unequal educational opportunities. According to Business Day NG (2023), schools in cities are more likely to have computer labs and internet access. There is also the issue of the skill gap in teacher training in ICT. Warschauer et al. (2004) highlight the digital divide in ICT access, which can lead to unequal educational opportunities, particularly in under-resourced schools. This divide affects access to resources and impacts students' ability to engage with and benefit from ICT-enhanced learning environments (Ogunleye, 2020).

Teacher Competence: The competence of teachers in ICT for teaching mathematics is another crucial challenge. Many teachers lack the training and skills to incorporate ICT into their teaching methods. The absence of continuous professional development programs focused on ICT integration compounded the issue (Nwosu & Chikwendu, 2019). Bingimlas (2009) points out that while ICT has potential benefits, inadequate

teacher training and support can hinder its implementation in mathematics education. Many teachers lack adequate training in ICT and modern teaching methods for mathematics, thereby impacting the quality of education. Though there are initiatives to train teachers in ICT skills and effective mathematics teaching methods, there is a gap in the required number of trained personnel, especially in rural areas.

Infrastructural Issues: Inadequate infrastructure, including unreliable electricity supply and poor internet connectivity, severely limits the effective ICT in Nigerian schools. These infrastructure issues are particularly acute in rural areas, where schools often operate without basic amenities; implementing ICT-based teaching methods becomes difficult (Adebayo, 2018). According to Business Day NG (2023), the availability of ICT infrastructure in Nigerian schools is currently inadequate and uneven, with significant gaps between urban and rural areas.

Slow Curriculum Integration: Another challenge is the slow or incomplete integration of Information and Communication Technology (ICT) in the curriculum. There were several efforts to update and align the curriculum with global standards. There is a need to redesign the curriculum and incorporate ICT tools and methodologies. Without a well-structured curriculum that leverages ICT, the potential benefits of technology in teaching mathematics cannot be fully realized (Akinyemi & Okafor, 2021).

Poor funding and policy implementation: It is pertinent to submit that the disparity is due to insufficient funding, poor policy implementation, and the high cost of digital devices. While there are government initiatives to improve ICT infrastructure, their impact has been limited, leaving many schools under-resourced and unable to fully integrate ICT into education(Business Day NG, 2023). Government efforts are limited or weakened by poor funding, policy inconsistency and higher cost of ICT infrastructures (Yusuf & Afolabi, 2010; Adomi, 2010). For instance, programs like the National Policy on Education and the Nigerian Education Sector ICT4E Strategic Plan aim at improving ICT and mathematics education, suffer implementation challenges.

PROSPECTS OF ICT IN TEACHING MATHEMATICS IN NIGERIA

Despite the challenges, the prospect of using Information and Communication Technology (ICT) in teaching mathematics in Nigeria is promising. Some of the prospects reported by various scholars are:

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Increasing Availability of Affordable Technology: The rapid advancement in technology has led to the production of affordable and accessible digital tools, and providing opportunities. The increasing availability of cheap technology and the growing awareness of the importance of education provide a foundation for future improvements. Additionally, international collaborations and partnerships can provide the necessary support and resources to bridge the existing gaps (Babalola & Adeoye, 2022). This makes it easier for schools and individuals to acquire ICT equipment, even with limited budgets. The proliferation of low-cost tablets and laptops provides an opportunity to integrate technology into classrooms more widely (Babalola & Adeoye, 2022).

Growing Awareness and Support: There is a growing recognition of the importance of ICT in education among stakeholders, including government, educators, and parents. This increased awareness is driving efforts to improve ICT integration in schools. Policies and initiatives promoting ICT use in education are being developed and implemented at various levels (Akinyemi & Okafor, 2021).

Government Initiatives and Policies: The Nigerian government is increasingly committed to enhancing Information and Communication Technology in schools. Initiatives such as the National Information Technology Development Agency (NITDA) and various state-level programs aim to provide support and resources for schools to adopt ICT. These efforts include improving internet connectivity and providing ICT training for teachers (Adebayo, 2018).

Teacher Training Programs: There are ongoing efforts to enhance teacher competence in ICT through professional development programs. These programs aim to equip teachers with the skills and knowledge to integrate technology into their teaching practices. Enhanced teacher competence is crucial for maximizing the benefits of ICT in the classroom (Nwosu & Chikwendu, 2019).

International Collaborations and Partnerships: International organizations and development partners play a significant role in supporting ICT integration in Nigerian education. Partnerships with global technology companies and educational institutions provide access to resources, expertise, and funding. These collaborations can help bridge the existing gaps and promote sustainable ICT use in education (Ogunleye, 2020).

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CONCLUSION AND RECOMMENDATIONS

The paper reviewed the challenges and prospects of ICT tools in mathematics teaching in the Nigerian educational system. It shows that ICT in teaching mathematics is validated by several learning theories. Nigeria is still struggling with the integration of ICT in mathematics education due to curriculum integration, teacher competence, infrastructure deficits, and the digital divide. The paper also highlighted the prospect of ICT in mathematics education in Nigeria.

The integration of ICT in teaching mathematics in Nigeria requires a multifaceted approach, addressing infrastructural, training, and resource challenges. With concerted efforts from the Government, private sector, and communities, the educational landscape can be transformed to better prepare students for the future. To enhance the integration of ICT tools in mathematics education in Nigeria, it recommends that:

1) The Government should ensure consistent implementation of ICT policies across schools.
2) Government should allocate more resources to improve ICT infrastructure, especially in rural areas.
3) Government should provide ongoing professional development for teachers in the use of ICT in their teaching.
4) Government should deliberately facilitate public-private partnerships to foster collaborations to support ICT initiatives in education...
5) There should be regular monitoring and evaluation of all ICT integration initiatives, programmes, policy implementation, and resources.

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