Investigating the Integration of Information and Communication Technologies (ICT) in Mathematics Education: A Review of the Literature (2010-2020)

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Abstract

This systematic review examines the integration and use of Information and Communication Technologies (ICT) in mathematics education within sub-Saharan Africa in the period, 2010 to 2020. Aiming to identify trends and gaps, it analyzes research contexts, objectives, methodologies, and findings. The results identified 15 relevant studies and the Research primarily focused on evaluating the effectiveness of ICT tools in mathematics teaching and learning.Teachers were the most common research participants, followed by students. Whereas Quantitative research designs dominated the corpus of the reviewed study.The review provides valuable insights for Informing evidence-based decisions on ICT integration in mathematics education. Adapting pedagogical approaches to effectively leverage ICT tools and Designing impactful programs for teachers on ICT integration.In that regard, it was recommended that future research should be more focused on the qualitative or mixed method research to give a better understanding of the ICT in Mathematics education. Also, Investigation of the long-term impact of ICT integration on student learning outcomes offer great promise.

Introduction

Mathematics is one of the most important core subjects offered at the primary and secondary school levels of Nigeria educational system. It is of great usefulness to every human being and for the economic growth of many nations. As stated in the National Curriculum for secondary schools of the Federal Ministry of Education (FRN, 2013), the aims and objectives of Mathematics teaching at this level of education are to; help develop conceptual and manipulative skills and their applications; provide an intermediate course of study and meet the needs of potential mathematicians, engineers, scientists and other professionals, such as businessmen, administrator and architectures. Given the importance of ICT in society and perhaps in education in the future, identify possible perceptions of integrating these technologies into schools to improve the quality of teaching and learning. Teachers' use of ICT in basic general mathematics requires qualified teachers. Adopting information and communication technology (ICT) has become an essential tool to support innovative education and enhance the learning process . For example, Surajo (2020) reported that integrating technology in mathematics classes with appropriate pedagogy improves students' academic performance. The National Council of Teachers of Mathematics (NCTM) stated that technology is an essential tool for learning mathematics in the 21st century and advocated the need for schools to be more committed to helping all students harness the full potential of technology to advance their understanding of the subjects.

This systematic literature review is significant in the sense that it can provide teachers and educators with evidence-based insights on how to effectively integrate ICT tools into their mathematics lessons, promoting active learning, engagement, and deeper understanding of mathematical concepts. The findings can inform the design and content of professional development programs for teachers, equipping them with the skills and knowledge necessary to leverage ICT effectively in their classrooms. Furthermore, the review can provide valuable data and recommendations for policymakers to support the integration of ICT in mathematics education initiatives, ensuring equitable access to technology and promoting effective implementation strategies. The review can also identify solutions and strategies that address unique challenges in the sub-Saharan African region and Nigeria in particular such as limited

infrastructure, resource constraints, and diverse cultural contexts (Yunusa, Irfan & Bevell, 2018). Consequently, the objectives of this literature review is to identify literature on ICT integration in Mathematics instuction published in articles within the period of a decade (2010 to 2020) Based on this the following research questions were formulated:

i- What are the literature published on ICT integration in Mathematics education between 2010 to 2020?

ii- What are the Methodologies (Research designs) and Technologies utilized in these literature?

iii- What are the findings, and limitations highlighted in the literature?

iv- What are the opportunities for further research and improvements?

Based on these research question, figure 1. illustrates the steps in systematic review as recommended by

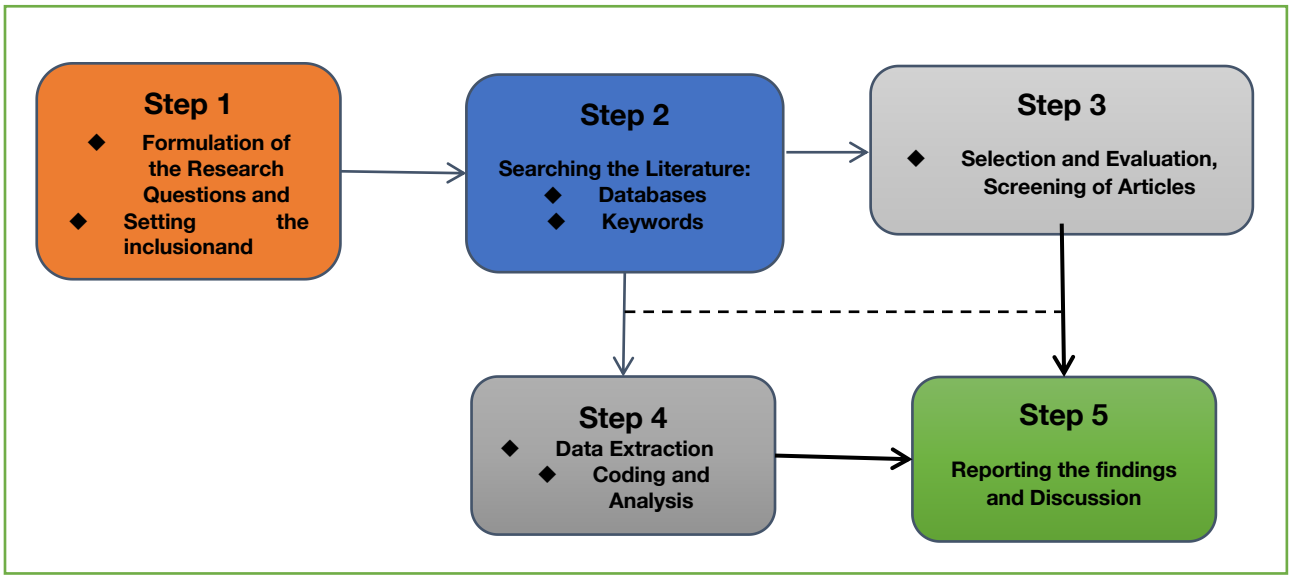

Figure 1. The systematic review process as developed by the authors

Criteria for inclusion and exclusion in the review of literature

The criteria for inclusion and exclusion of literature in the review will include:

✓ Articles published in the English Language in sub-Saharan African and Nigerian Contexts

- ✓ Articles published between 2010 and 2020
- ✓ Articles on Teaching and learning of Mathematics
- ✓ Articles focused on literature at Secondary School level

Exclusion criteria

- ✓ Articles not published in the English Language
- ✓ Articles not published within the time frame of the review
- ✓ Articles not focused on Secondary School Context
- ✓ Articles not focused on Mathematics education at Secondary School context

Review of related Literature

There have been several studies which have specifically focused on ICT integration in secondary Mathematics teaching.

Onasanya, Shehu, Ogunlade and Adefuye (2011) in their study of teacher's awareness and extent of utilization of information communication technologies for effective science and health education in Oyo state, Nigeria. Their findings show that the level of their utilization of ICT resources for teaching science and health education was found to be very low and there exists a significant difference between the male and female science teachers in their level of utilization of ICTs, with the male out-performing their female counterparts with higher mean scores. This implies that there is low utilization of ICTs resources for teaching science and health education in Oyo state, Nigeria.

Information and Communication Technology is not just regarded as a tool, which can be added to or used as a replacement of existing teaching methods, but seen as an important instrument used to support new ways of teaching and learning Nwili (2019) .In the area of education, a growing body of evidence demonstrates that ICT is an effective means for addressing education goals and requirements. A study conducted by Agyei and Voogt (2011) in Ghana among pre-service and in-service Mathematics teachers, reported low levels of ICT integration levels as a result of low competencies and access levels of ICT. Successful integration of ICT in teaching is related to teachers' competence and also their attitudes towards the use of modern technology in their teaching and learning Ayub, Bakar and Ismail (2012). Positive attitudes towards computer

use by school teachers are important to ensure the integration of the technology if effectively carried out in the school curriculum and also during teaching and learning

UNESCO (2011) also submitted that teachers need to use teaching methods which are appropriate for acquiring needed knowledge in particular societies. Students were not only to acquire an in-depth knowledge of their school subjects but also to understand how they can generate new knowledge, using information and communication technology (ICT) as a tool ICT is a tool that supports the learning process and holds the promise of new solutions to all the challenges that education is facing (Oduma & Ile, 2014). Teachers' use of ICT in basic general mathematics requires qualified teachers and visionary school leadership. Teachers and school leaders need to recognize the potential of ICT in teaching and learning, especially in basic general mathematics. Lack of knowledge, government policy, and investment to introduce ICT in schools often misses opportunities to implement desirable school reforms (Foluke2017). The use of ICT in Nigeria and African countries, in general, is growing and increasing dramatically. However, while there is much knowledge about the use of ICT in developed countries, there is not much information about the introduction of ICT in schools in developing countries.

It is very beneficial for teachers to use ICT to teach their students. This is because using ICT allows the teacher to demonstrate their understanding of the possibilities and implications of ICT for learning and teaching. Plan, implement and manage learning and teaching in an open and flexible learning environment. ICT integration can significantly impact a teacher's work, especially if their ICT is conceived as a tool to support changes in educational approaches. Teachers will need to change their roles and the organization of their classrooms, but they will also need to invest energy in themselves and their students, especially in preparing them to introduce and manage new learning arrangements. ICT plays a unique but complementary role in each of these approaches, as new technologies require new teachers' roles, new teaching methods, and new elements of teacher education.

The success of ICT integration will depend on teachers' ability to combine technology with new teaching methods. In teaching and learning of Mathematics, teachers' beliefs about Mathematics learning with or without using technology are considered to be important because it could influence teaching and learning, and curriculum reform. At the classroom level, teachers' beliefs can accelerate or slow down curriculum reforms as teachers' beliefs are resistant to change and

play a role in teaching practice. Findings from a study done in Kenya by S. Amuko, M. Miheso and S. Ndeuthy (2015) has shown that teachers who begin using ICT in their teaching, initially believe that technologies creates more work for them. The success of ICT integration will depend on teachers' ability to combine technology with new teaching methods. To achieve this, teachers need adequate preparation, time, and ongoing support to ensure they have the knowledge, skills, and confidence to teach using ICT. The need to provide teacher training programs and professional development facilities for current and future teachers cannot be overemphasized. Undoubtedly, the main challenges in integrating ICT into the classroom are its educational impact, its impact on curriculum structure and content, classroom organization and practice, and the changing role of teachers.

Methodology

The review highlights research studies conducted in the field of mathematics highlighting the application of ICT in teaching and learning of mathematics. Several databases (Google Scholar, Sci Direct and Sci Hub) were explored, using keywords such as: *Integration of ICT in teaching and learning of mathematics* and *ICT in mathematics teaching, 'ICT in mathematics education' AND 'Sub-Saharan Africa'*. The literature chosen was in English languages that can be understood by the researcher. In addition, the search was limited to studies published between 2010 until 2020 related to ICT in mathematics education. More than 80 studies were found. However, only 15 studies from Nigeria and sub-Saharan African region were selected based on the research focus on ICT in teaching and learning of mathematics in secondary schools as well as the study's inclusion and exclusion criteria. The selected studies were chosen based on the context of studies, and the scope. The selection of literature was based on the need to answer the research questions. In addition, content analysis was carried out in order to ensure that the selected align with the core objectives and focus of the paper.

Table 1. Summary of the reviewed articles

SN	Author & Year	Title	Objectives	Subjects/Sample	Methods/Methodology	Findings
1.	Eddie M M and Jose M M **(2018)** **Zambia**	Teachers ICT skills, Belief and Attitude towards ICT integration in teaching and learning of mathematics in Zambia *(journal of global research in in education and science)vol 11(4)*	(1) To determine the level of ict skill ,belief and attitude of mathematics teachers in Kebwe district in Zambia 2 To establish the relationship between the teachers' ICT skills, belief and attitude in the integration of ICT in the class room	Teachers	Descriptive survey research	The teachers' attitude towards computer use were positive and at moderate level Most of mathematics teachers have the confidence they are able to integrate a number of ICT software in there teaching and learning of mathematics
2.	Bature, B. **(2016)** **Nigeria**	The impact of information and communication technology(ICT) as a tools for effective teaching and learning mathematics. (J*ournal of Applied Computational Mathematics*)	(1) To find out whether the use of ICT tools in teaching and learning mathematics improve student performance and achievement (2)To find out whether the use of ICT tools enhances teaching and learning of mathematics while improve student problem solving skills (2)Find out whether the use of ICT tools motivate and make student interested in learning mathematics	students and teachers	Survey research design	Effective use of ICT tools enhance teaching and learning of mathematics and improve students' problem solving skill Effective use of ICT tools motivates and makes students interested in learning mathematics
3	Dele-Rotimi, Adejoke Olumide **[2018]** **Nigeria**	The role of Information and Communication Technology in Teaching and Learning of Mathematics for Educational Development	1 The use of ICT influences teaching and learning mathematics 2 The influence of teachers' attitude on the use of ICT for teaching and learning of mathematics	Teachers,	Descriptive survey design	the use of ICT significantly influence teaching and learning of mathematics ICT significantly influence teachers

		in Nigeria	3 The use of ICT in teaching and learning mathematics improve educational development			attitude for teaching and learning mathematics
4	Mbah C. N; Uchegbulem A .N. P and Edugbe I . E **[2017]** **Nigeria**	The Impact of Modern Technology in Understanding Mathematical Concepts in Nigerian secondary school, a case study of Imo state secondary schools *[International journal of education and evaluation] vol3[5]*	1 To ascertain the adoption of technological devices in teaching and learning makes impact in understanding mathematical concepts 2 To what extend has the use of modern technologies changes the orientation of student in showing details of solving mathematical problems	Teachers	Descriptive and inferential design	Adoption of modern technology devices in both teaching and learning impact in students understanding of mathematical concept
5	Nwoke B I and Ikwuanusi E N **(2016)** **Nigeria**	Impediments to integration of ICT in teaching and learning of mathematics in secondary school.	1 to determine the impediments to integration of ICT into teaching and learning of mathematics in secondary schools in Imo state	Teachers	Descriptive survey research design	Inadequate ICT facilities Lack of teachers confidence and competence Negative attitude among teachers
6	Sheila Amuko, Marguerine Miheso and Sophie Ndeuthy **(2015)** **Kenya**	Opportunities and Challenges: Integration of ICT in Teaching and Learning Mathematics in Secondary Schools, Nairobi Kenya (*journals of education and practices) vol 6; no 24, 2015*	To examine the challenge and opportunities to ICT use in teaching and learning mathematics in secondary schools	Teachers	Description survey design	Lack of technical support with regards to ICT integration Current mathematics curriculum does not allow enough time to integrate ICT in teaching

7	Ameen, S.K Adeniyi,M.S., & AbdulahI **(2019). Nigeria**	Teacher and student level of utilization of ICT tools for teaching and learning mathematics in Ilorin Nigeria (*African journals of education studies in mathematics and science) vol 15, 2019*	To investigate the assessment of teacher and student level of utilization of ICT tools for teaching and learning mathematics	Teachers and Students	Description research of survey type	Mathematics teachers and students are not skilled in utilizing ICT tools Gender does not have any effect on the teachers and students on the use of ICT tools for teaching and learning
8	Onasanya, Shehu, Ogunlade and Adefuye (2011) **Oyo, Nigeria**	Teachers awareness and extend of utilization of ICT for effective science education in Nigeria	To find the level of computer literacy of secondary school science teachers To find the teachrs level of ICT urtilization	Teachers	Ex-Post factor research	Low level of computer literacy Serving science teachers should be required and supported in in- service training on the use of computers
9	Prospery Mwili, (2018) Tanzania	Assessing the attitude of sec. sch. teachers towards the integration of ICT in teaching process in Kilimanjaro region in Tanzania	To assess the extent of ICT integration into the teaching process To describe the attitude of teachers towards integration of ICT in the teaching process	Teaches	Quantitative and Qualitative research	The teachers lack competence to integrate ICT into the classroom Need technical support
10	Agyei and Voogt (2011) **Ghana**	ICT use in the teaching of mathematics : Implication for professional development of pre- service teachers in Ghana	To explore the feasibility of ICT use in mathematics classroom in Ghana for pre- service teachers	Teachers ans Administrators	survy design and Interview	Lack of confidence among teachers during integration Lack of access to resources Lack of effective training Lack of time for the

						integration
11	Umar A and Musa S (2020). **Nigeria**	ICTand learning of mathematics in Nigeria	To examine ICTs effect on learning of mathematics in Nigeria	Teachers	Systematic literature empirical review	Need for effective human resource development in ICT for teachers Teachers attitude and belief about the use of ICT are obstacle to teachers practical adoption and effective use of ICT
12	Julius U Ukah & Samuel Odey(2018) **Nigeria**	Teachers* attitude ICT Facilities Urtilization and teaching effectiveness of mathematics teachers in public secondary schools in Cross Rivers state	To find the influence of mathematics teachers* attitude toward ICT facilities on their effectiveness in public sec school The influence of ICT facilities utilization on the teaching effectiveness of mathematics teachers in public sec school	Teachers and Students	Inferential research design	Teachers attitude towards ICT facilities and its utilization does not influence teachers teaching effectiveness in mathematics Pedagogy and environmental variable have vital role in determine math's teachers effectiveness
13	Kere Osman Daud& Abu Suleman (2015). Ghana	junior high school teachers knowled and attitude towards the teaching ICT technology	To assess teachers knowledge in teaching ICT To determine mesures to improve current of teachers ICT skills	teachers	Cross-sectional descriptive survey	Inadequate provision of ICT equipment professional training for teachers in the use of ICT is needed

14	Wachira, P., & Keengwe, J. (2010). Kenya	Technology Integration Barriers: urban school mathematics teachers perspectives	To find out available technology for teaching mathematics To find out why teachers do not use technology in their classrooms	Teachers	mixed methodology quantitative and qualitative	availability of technology Unreliability of technology Lack of time
15	Surajo and etal (2020) Nigeria	Level of utilization of ICT tools for teaching and learning mathematics in senior secondary schools in Kano	to asses mathematics teachers utilization of ICT tools students level of the use of ICT tools in learning Teachers level of utilization of ICT tools in teaching mathematics	Teachers and Students	survey design	Teachers have not utilized the ICT tools for their teaching Lack of competence in the use of ICT tools for teaching

Results / Analysis

This review seeks to examine and understand the methodology used by researchers to study the impact of ICT on mathematics education in sub-Saharan African context. The findings from these research studies will shed more light onthe effectivenessof ICT integratio on students' learning outcomes. And to highlight implications for education and further research. Most of the studies reviewed are limited to Nigeria and the sub-Sahara region. Figure 1 shows the distribution of the reviewed articles according to context

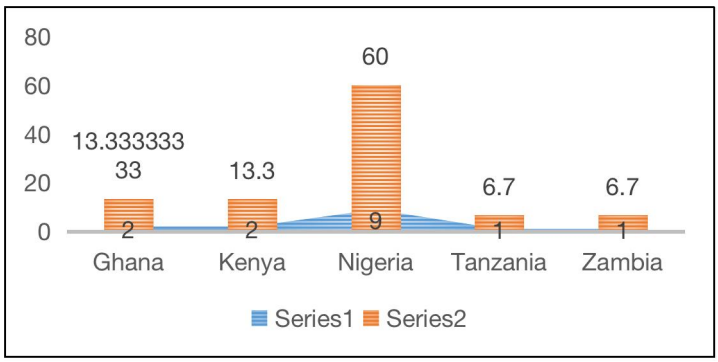

Figure 1. Distribution of articles in the literature review based on Context

From Figure 1., the most productive context in research within the review was Nigeria with nine articles (n-9, 60%), two articles each (n-2, 13.3%) are affilliated to Ghana and Kenya, while Tanzania and Zambia produced only one article each from the research corpus. (n-1, 6.7%).

In terms of Research Design, the most prominent resaerch method adopted within the reviewed literature is the Quantitative resaeerch approach. Predominated by the descriptive survey research design, this is having a total of twelve articles (n-12, 80%) followed closely by the mixed method research design at three articles (n-3,20%) There are articles was found relating to the use of qualitative research approach in ICT integration in mathematics education study.Figure 2. shows the distribution of the articles based on research design.

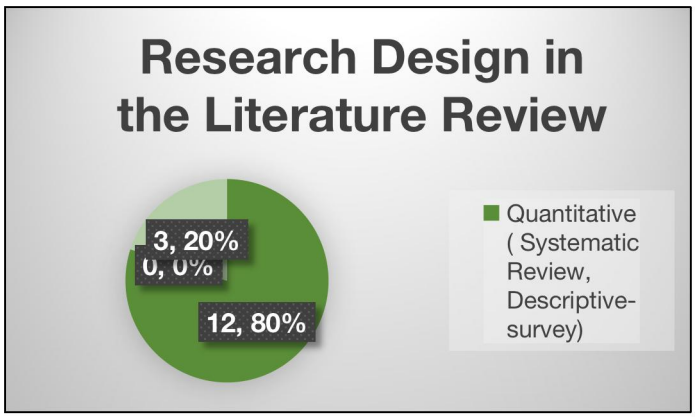

Figure 2. Distribution of articles based on research design

In regard to the samples within the research corpus, Figure 3 illustrates the distribution of the samples in terms of students only (n-0), teachers and students (n-4, 27%); teachers only (n-10, 57%), teachers and administrators (n-1, 6%) and other stakeholders zero.

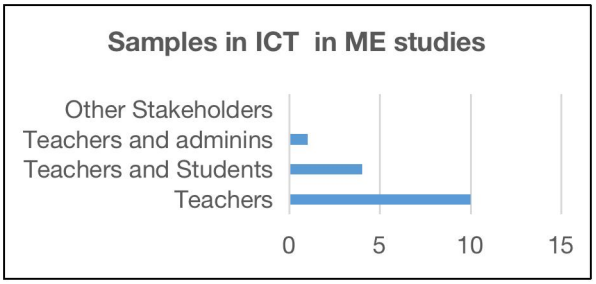

Figure 3. distribution of sample in the literature reviewed.

Major Findings: Integration of ICT in Mathematics Education

This review of literature on ICT integration in mathematics education identified several key findings. Studies by Bature (2016) and Rotimi (2018) reported that the effective use of ICT tools positively impacted student performance, achievement, and problem-solving skills in mathematics. However, Mbah et al. (2017) and Surajo et al. (2020) highlighted that despite such potential benefits, the adoption of ICT practices remains low in many settings. This is often attributed to limited teacher capacity in utilizing ICT tools, as identified by Amoku et al. (2015) and Ameen et al. (2019). These studies further suggest that teachers face challenges such as lack of technical support and confidence in using ICT for mathematics instruction. Regarding demographic factors, Ameen et al. (2019) found no significant influence of gender on ICT

integration. However, Netsianda and Ramaila (2020) emphasize the critical role of professional development and dependable internet access in overcoming barriers to successful ICT integration in education.

Discussion

The number of the reviewed studies on integration of information and communication technologies ICT in mathematics education in sub-Saharan Africa indicated that western African contributed more studies The outcome was because nine studies were from Nigeria two from Ghana two from Kenya while Tanzania and Zambia has one study each this sub regions southern and western regions has more papers published on the integration of ICT in teaching and learning of mathematics. Another probable reason for interest in research on integration of ICT in teaching and learning of mathematics in sub-Saharan Africa is that ICT is seen as a tool that will be able to help students with problem solving as majority of the students has always perceived mathematics as a difficult subject however the use of ICT is promising to change the perspective of both students and teachers towards learning and teaching of mathematics Nwoke and Ndidi (2016). The result presented in this study may not be sufficient, against the background that sub-saharan africa comprises of 48 countries out of which only 4 countries produced the number of reviewed articles (15 articles) this supposed indicate the low level of integration of information and communication technologies in teaching and learning of mathematics.

Regarding research design and instruments used in integration of information and communication technologies research in sub-sahara africa most of the reviewed studies applied the quantitative research design. Although the quantitative design is a standard measure and an excellent way of computing result in scientific field it is limited. However, a quantitative design was used in ten of the studies, while mixed method was used in five of the studies, the authors are of the view that mixed method research approach offers better ways to explain and understand scientific phenomenon

The study further underscores the significance of considering all stakeholders in education sector as a critical success factor in the implementation of any technology integration in education..

The significant determinant of integration of information and communication technologies in teaching and learning of mathematics is lack of appropriate professional training and competence on the use of digital technologies.

Conclusion

In order to generate an informed idea of trends in technology-enhanced mathematics education, a review of literature (2010-2020) was carried ou in this study. Analysis of relevant studies was conducted through the lens of a classification system developed specifically for this purpose.The literature review identified the main trends in the integration of ICT in mathematics education. . The review of literature revealed that although there is great diversity in the empirical research into the use of technology in mathematics education, the outcomes of its utilization do notmeasure up to the potentials of the transformative power of ICT on the learning experiences in different settings. The study further showed that the focus of most of the research on ICT integration in mathematics education is focused more on the teachers than the students and the other stakeholders in the secondary school stettings with quantitative research design of the survey strategy dominating the in the trends.Thus, more research grounded in the qualitative paradigm is needed to understand more authentically the tracjectory and magnitude of ICT integration in mathematics education in sub-Saharan African context.

Recommendation

Based on the findings from the review of literature the following recommendations aim to address the identified challenges and leverage the potential benefits of ICT integration in enhancing the teaching and learning of mathematics.

1. Need to enhance mathematics' teachers capacity:

- The ministry of education needed to develop and implement comprehensive professional development programs specifically designed to equip teachers with the necessary knowledge and skills to effectively use ICT tools in their mathematics classrooms.
- Institutional administrators and managers needed to provide ongoing technical support to teachers, including assistance with troubleshooting, utilizing specific software, and integrating ICT into lesson plans.

2. Fostering supportive learning environment in school settings:

- The authority concerned in different contexts should address infrastructure limitations by increasing access to reliable internet connectivity and providing necessary technological resources within schools.
- There should be programs and policies that encourage a collaborative learning environment where teachers can share best practices, troubleshoot challenges, and learn from each other's experiences in using ICT for mathematics education.

3. Addressing gender and regional disparities in ICT adoption and Use:

- More research is needed to investigate factors beyond gender that might influence teachers' and students' engagement with ICT in mathematics education.
- Development of targeted interventions addressing specific needs and challenges faced by different regions and demographics, such as providing additional support to schools with limited resources or addressing potential regional cultural factors impacting ICT adoption.

4. Monitoring and Evaluation of the long-term impactof ICT in Mathematics Education:

- Implement systematic data collection and evaluation measures to track the long-term impact of ICT integration on student learning outcomes, teacher behavior, and overall educational effectiveness.
- Utilize the collected data to refine and adapt ICT integration strategies and ensure their continued effectiveness in improving mathematics education.

Limitation of the review

This review has limitations. Firstly, the focus on sub-Saharan Africa restricts the generalizability of findings to other African regions. Secondly, the study investigates only secondary school settings, potentially overlooking valuable insights from higher education contexts. Finally, the review excludes French-language literature, potentially missing relevant research from Africa's diverse linguistic landscape. Future studies could address these limitations by:

(i) Expanding the scope geographically to encompass all African regions.

(ii) Including both secondary and higher education contexts.

(iii) Considering research published in multiple languages, including French.

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