Integration of Digital Technologies into Primary School Science Education: Exploring Challenges and Craved Initiatives

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Abstract

The study explored the challenges and craved initiatives for adoption to enhance the integration of digital technologies into science education in Tanzanian rural primary schools. It employed interviews, documentary reviews, and observations to generate data. Data were analysed thematically. The findings show that limited technological facilities, little knowledge of integrating digital technologies, lack of priority to teach science and technology subjects practically, and teachers' negative attitudes impeded a successful integration of digital technologies. The study further revealed the establishment of e-resource centres, science curriculum content digitalisation, the introduction of digital technology science labs, and the digitalisation of teacher education as desired initiatives for adoption to enhance the integration of digital technologies. The study recommends a collaborative partnership between the government and interested local and international digital technology agencies for technical and financial support to address the challenges and implement the desired initiatives.

Keywords: *challenges, craved initiatives, digital technologies, science education, rural primary schools*

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Introduction

As we approach the third decade of the 21st century, the debate is on supporting the integration of digital technologies into science education. As such, the importance of integrating digital technologies into science education, particularly in primary schools in today's digital era, cannot be underestimated. Primary education is an integral part of basic education responsible for raising children for the forthcoming generation. Indeed, the youth with requisite digital literacy skills pertinent to bridging the global digital divide and helping them to navigate through the education system and socio-economic life are in high demand (Shehaj, 2022). The term digital technology is used in this study to mean diverse software and gadgets

such as smart boards, laptops, tablets, e-simulations, and virtual labs integrated into the teaching and learning of primary school science education to empower pupils with digital technology literacy skills (Haleem et al., 2022).

Empirical evidence shows that digital technologies are inadequately integrated and used in science education in many rural primary schools across sub-Saharan African countries. As a result, the lion's share of primary school levers is less equipped with digital literacy skills that could enable them to interact meaningfully in an increasingly digital technology-led world (Delgado, 2023; John, 2024). This inadequacy calls for exploring the challenges and craved initiatives to be adopted to enhance the integration of digital technologies into Tanzanian rural primary schools. A plethora of research on integrating and using digital technologies into primary school science education has been conducted in high-income country contexts (See, e.g., de Vicente, 2024; Sandoval-Henriquez et al., 2024; Shvardak et al., 2024).

Studies in high-income countries have indicated promising integration of digital technologies into primary school science education due to various factors. These range from the availability of digital infrastructure and resources to teachers' training and attitudes, socio-economic stability, and successful implementation of Information and Communication Technology (ICT) policies. For example, a study by de Vicente (2024) on the level of digital technology integration into Spanish pre-primary and primary schools revealed that digital infrastructure was adequately available and integrated into science teaching and curriculum. The study also reported that there was no significant difference in terms of digital integration between urban and rural schools. The experience of high-income countries offers invaluable insights and ambition to improve schools' digital technology environment in low-income countries.

Empirical studies conducted in the Tanzanian context have mainly investigated the assessment of ICT integration as a pedagogical tool in secondary education, context-based approaches for ICT integration into secondary science subjects teaching and learning, preparedness of pre-primary teachers in integrating ICT in teaching and learning, integrating the use of tablets into secondary school teaching and learning, and challenges and opportunities for implementing ICT subject in primary education (Alihaji, at el., 2024; Bakari & Ali, 2023; Kassim, 2024; Ngodu at el., 2024; Tandika & Ndijuye, 2019). A few other studies that have focused on the integration of digital technologies into education have largely focused on secondary and university levels (Bitegeko et al., 2024; Bulugu & Nkebukwa, 2024; Peter, 2023).

These studies have generally demonstrated that digital technologies have not been satisfactorily integrated and used across education levels. However, across the urban and rural primary school settings, overall, these studies indicate that rural primary schools are more underserved in terms of digital technologies (See, e.g., Bakari & Ali, 2023; Delgado, 2023). This situation, therefore, calls for the need to examine the challenges and desired initiatives to be adopted to enhance the successful integration of digital technologies into primary school science education in the rural context of Tanzania. Nevertheless, little is known about the challenges facing the integration of digital technologies into science education, particularly in rural primary schools in Tanzania. The study explored the challenges and desired initiatives for adoption to enhance the integration of digital technologies into science education in the context of rural Tanzanian primary schools to address the knowledge gap.

This study contributes to the understanding of the challenges and craved initiatives for adoption to enhance the integration of digital technologies into science education in rural primary schools in Tanzania. This understanding may spur education policy and decision-makers in Tanzania to revisit the current approaches and strategies used to integrate digital technologies into primary school science education. Two research questions guided the inquiry:

i. What are the challenges facing the integration of digital technologies into science education in rural primary schools in Tanzanian?

ii. What initiatives should be adopted to enhance the integration of digital technologies into science education in rural primary schools in Tanzania?

Theoretical Framework

The study was guided by Activity Theory proposed by Engestron (2008). Originally, this theory was developed by Soviet Union-era researchers in the 1990s. Later, in 2008, Engestron advanced the Activity Theory (Keijo, 2014). Activity theory was considered suitable for this study for two reasons. First, it seems to be an effective lens for understanding the integration of digital technologies into educational systems. It is because several scholars researching technology integration into education have relied on this theory, which does not appear baffled by time (See, e.g., Dai et al., 2024; Keijo, 2014).

Second, it presents a framework for understanding the integration of digital technologies into primary school science education in the interconnectedness of six components: subject, object, tools, community, rules, and division of labour at systemic and individual levels (Gyasi et al., 2021). The theory argues that the

integration of digital technologies into the activity system may result in contradictions that act as craved initiatives and catalysts for systemic change. The theory focuses on processing an object/objective (integration of digital technologies into primary school science education) to transform it into a desired outcome. The process requires a subject; an individual, or a group of people linked to a given activity.

Tools are the mediating artefacts from the external environment essential for achieving the activity outcomes. The community involves one or several individuals who divvy the objective with the subject. Rules represent challenges that constrain the integration of digital technologies into the context of the activity system. Division of labour delimitates how tasks, power, and status are divided among members of the community. Thus, *Activity Theory* offers a socio-cultural perspective that considers the fact that digital technology integration in primary school science education must be studied within the broader context and the teaching and learning settings in which it is located (Keijo, 2014).

The study adapts the basic elements of the Activity Theory to explore challenges and desired initiatives for adoption to enhance the integration of digital technology into primary school science education in terms of *subject* – primary school teachers and head teachers (their experience in teaching science subjects, instructional use of digital technologies, necessity of pedagogical competence and skills in digital technology). *Object* – integrating digital technology into primary school science education. *Tools* – digital technology facilities, availability, and associated problems. *Rules* – challenges, desired initiatives, and expectations. *Community* – government, digital technology agencies and partners at the local and international levels, teachers, school leadership, students, and ICT personnel. *Division of labour* – roles of government, teachers, students, and the support of school leadership. *Outcome* – successful integration of digital technologies into primary school science education.

Methodology

Approach and design

The study employed a qualitative research approach to capture the participants' perspectives through interaction in their natural environments. The researcher used the bracketing technique to reduce the limitations of this approach, such as the possibility of attaching researchers' bias to the findings and conclusions (Cohen et al., 2018). The study employed a case study design with schools as the main cases and participants as units of analysis. The choice of this design stemmed from the fact that data collected from multiple cases is considered more reliable and richer

when compared with data from a single case. It also allowed the researcher to employ multiple sites to equate different perspectives on the study object (Yin, 208).

Study area

The study was conducted in six public primary schools purposefully sampled from three rural districts in Tanzania: Ileje, Momba, and Songwe. Before the study time from July to September 2024, the integrated rural development organisation and the education officer-SIDA integrated project report in Songwe region indicated that these districts were relatively the most destitute regarding digital technology integration in primary schools (EOSIP, 2023; IRDO, 2024). Two primary schools were sampled purposefully from each district. Each of these schools had teachers who had attended an in-service seminar on integrating digital technology into primary school science teaching and learning. The researcher believed that these teachers could offer rich information pertinent to the study problem. The district education officers assisted the researcher in identifying the schools in each district. As such, the selected study sites and participants provided rich data that could not be gained from other choices (Maxwell, 2013).

Sampling

The study used a criterion purposive sampling technique to recruit 18 participants. This sample size enabled the researcher to reach a saturation point at which further information became repetitive. Criterion purposive sampling helped to identify participants with rich and relevant data for the study (Creswell & Creswell, 2018). Study participants included six head teachers and 12 teachers. One head teacher was sampled from each school based on their administrative and leadership roles. Headteachers were also involved in the study as they were overseers of the implementation of ICT policy at the school level.

Two teachers were recruited from each sampled school to make a total of 12. Two criteria were used to select teachers. First, having attended an in-service training on the integration of technology into primary school science teaching and learning, as hinted earlier. Second, having at least 10 years of experience in teaching primary school science subjects. Teachers with this work experience offered insightful perspectives on the challenges facing the integration of digital technologies into primary school science education. They were well-positioned to envision and share the craved initiatives that could be adopted to enhance the integration of digital technologies into science education in the studied rural primary schools.

Ethical considerations

The researcher observed all the necessary ethical concerns as per the national guidelines for research ethics that are in line with in-country researchers and associates of the University of Dar es Salaam (UDSM). The researcher sought research clearance from the UDSM. Research clearance enabled the researcher to get research permits from the regional, district, and institutional authorities. With the help of research permits, participants' consent to be involved in the study was sought. The researcher upheld confidentiality throughout the study to conceal the participants' and schools' identities. As such, when presenting the findings, participants were anonymised using titles such as headteacher and teacher. Schools' names were masked using letters A, B, C, D, E, and F.

Data collection methods

Data were mainly generated through interviews corroborated with documentary analysis and observations. These methods helped to cross-validate the information collected from each data collection method. Therefore, any flaw in one method was addressed by the strengths of the other method (Yin, 2018).

Interviews

The interview method helped the researcher to delve into participants' experiences and perspectives on the challenges facing the integration of digital technologies into primary school science education. It also enabled access to information about the desired initiatives for adoption to enhance the integration of digital technologies. Their insights could not be captured through documentary review and observation (Cohen et al., 2018). A face-to-face semi-structured interview technique was adopted because of its flexibility in varying the order of questions and clarifying them when required. It also enabled the researcher to be focused. Interviews were guided by an interview schedule containing open-ended questions on the challenges and craved initiatives. This interview protocol was useful for probing and navigating from the planned questions to unplanned emerging issues (Creswell & Creswell, 2018). Interviews were conducted with head teachers and teachers in their offices to keep them relaxed. Each interview session took between 40 and 60 minutes. Interviewees' consent was obtained to tape-record the interviews to add on manual note-taking.

Documentary analysis

Documentary analysis was used to capture data related to current government efforts geared toward the integration of digital technologies into primary school

science education. A documentary review schedule was used to facilitate the analysis of relevant documents that included the new draft of the 2023 national ICT policy in Tanzania, the primary school science and technology syllabus for standard III-VII of 2019 (STSPSE-STD III-VII), and the 2016 curriculum for pre-primary education (CPPE).

Observations

The observation method enabled the researcher to verify the self-reported data from interviews. The researcher employed the non-participant, semi-structured observation strategy to be present in the studied schools as an unobtrusive observer (Bryman, 2016). An observation schedule was used to guide the observations. It focused on context-related challenges facing the integration of digital technologies into primary school science education in the studied schools. Observations were carefully conducted to avoid interrupting schools' instructional activities. Before data gathering, senior academics from the department where the researcher works were asked to check the data collection instruments for validation purposes.

Data analysis methods

Documentary and observation data were analysed using the qualitative content analysis method. This method involved the categorisation of data and analysing qualitatively the frequencies of the data categories appearing in national ICT policy and curriculum texts. Interview data were analysed thematically following six steps by Braun and Clarke (2006). The thematic analysis enabled the researcher to produce, analyse, and report recurring patterns from the dataset. Data familiarisation involved transcribing verbatim all interviews and reading repeatedly interview transcripts and observation notes. A copy of the transcript was then sent through email to each participant to review and give feedback within one week. However, no changes were proposed by study participants.

Re-reading the transcripts enabled the researcher to capture initial concepts regarding the challenges and desired initiatives that could be adopted to enhance the integration of digital technologies into primary school science education. The next stage was to generate initial codes/nodes, which involved two cycles. In the first cycle, free nodes useful for exploring the dataset were generated. Initial nodes were generated deductively where the researcher used predetermined headings generated from the research questions. The first cycle was useful for organising data into two major topics, namely, challenges and desired initiatives that were generated manually. The major topics became the starting free nodes through which related data chunks were attached to produce relevant data extracts for analysis.

Since the initial free nodes could not inform the data meaning, the second cycle of coding was conducted to generate meaningful codes. Data extracts were read critically several times to capture their meaning. Recurring ideas meaningful to the study were noted. A word, sentence, or paragraph was used as a primary unit for the identification of codes that were labelled with a few words.

This process led to the third stage of searching for themes, which was done inductively. Codes and their data excerpts were re-read critically to identify ones with more unified concepts. The researcher grouped and merged them to generate a theme. The next step involved counterchecking and revising the themes against the whole dataset to determine whether all the information related to the study had been extracted completely and meanings captured accurately. Two researchers' colleagues were requested to countercheck whether or not each theme represented participants' voices correctly. Even though colleagues were satisfied with the developed themes, they advised the researcher to reduce and merge some of the quotations supporting the themes. Defining and naming themes involved describing and refining each theme to answer the research question. For each research question, four major themes were derived from data analysis. Finally, the researcher produced a report with key participants' voices in block quotations to illustrate the themes.

Findings and Discussion

Findings are presented according to the two research questions and main themes that emerged from the analysis of data. The major findings are discussed in relation to the theory that guided the study and other relevant literature and empirical studies.

Challenges facing the integration of digital technologies into primary school science education

Data analysis generated four main themes, namely limited technological facilities, little knowledge of integrating digital technologies as a pedagogical tool, lack of priority to teach science and technology subjects practically, and teachers' negative attitudes towards integrating digital technologies at lower education levels.

Limited technological facilities

Findings revealed that limited technological facilities were one of the challenges facing the integration of digital technologies into primary school science education. Participants explained that one could not find facilities such as tablets, digital science labs, and computers in the rural primary school context. One of the teachers said:

> Limited technological facilities constrain the integration of digital technologies into primary school science education. In my view, the

> successful integration of digital technologies needs facilities such as computers, tablets, digital science labs, and reliable power. It is very rare to find these tools for learning and teaching science in our rural primary schools. How can you integrate digital technologies into the teaching and learning of primary school science if you do not have these facilities? It is not easy *(Interview, Teacher 1, School A)*.

The above quotation shows that the lack of adequate supply of digital facilities was a barrier to the integration of digital technologies into teaching and learning science in the studied rural primary schools. Findings from observations corroborated the findings from interviews. It was observed that none of the participating schools had, for example, digital science labs. Three desktop computers, one in each head teacher's office were found at schools A, C, and F. At school D, the researcher observed one tablet possessed by a teacher. However, on the one hand, head teachers whose offices had computers said that those computers were for administrative purposes. On the other hand, a teacher who had a tablet reported that she used that tablet for personal matters. It means that available computers and tablets were not for science teaching and learning. Rather, they were for office and personal use, respectively.

These findings can be attributable to various factors, such as the meagre implementation of the Tanzanian ICT policy for basic education, little government commitment, stumpy political will, and insufficient engagement of ICT stakeholders (Bitegeko et al., 2024; Delgado, 2023). Activity theory emphasises that there should be a constant supply of digital technology facilities to realise the successful integration of digital technologies into primary school science education. Regarding this, the government should develop a sense of political will to influence the availability of digital facilities in rural primary schools by engaging different ICT stakeholders and the private sector (Engestrom, 2008). The finding echoes that of Kafanabo (2024), who found that unreliable power supply was one of the challenges for using technology during school closure caused by COVID-19 in Tanzania.

The finding also aligns with the newly drafted Tanzanian national ICT policy of 2023, which acknowledges that "*Despite the achievements made by the country to develop the digital infrastructures, they are not adequate to provide efficient and affordable digital services*" (MoICIT, 2023, p. 31). However, the finding is contrary to UNESCO (2018), which emphasises that the availability of facilities for digital technology integration should be leveraged to speed up the achievement of the goals of the Education 2030 agenda. The finding implies that unless concerted efforts are made to ensure digital technology facilities are available in rural primary schools, the digital divide among primary school pupils will persist.

Little knowledge of integrating digital technologies into teaching

Findings indicated that despite the limited digital technology facilities in the studied primary schools, primary school teachers and head teachers reported having limited knowledge of integrating digital technologies as a pedagogical tool. For example, one of the head teachers commented:

> Apart from the insufficient supply of facilities, another challenge I see is related to our little knowledge of how to integrate digital technology as a pedagogical tool. I think it is because teacher training colleges in Tanzania where we are trained have not yet prioritised digital technology use in primary school science education pedagogy. *(Interview, Head Teacher 2, School B).*

The quote above suggests that inadequate training of head teachers and primary school teachers on how to integrate digital technologies into the delivery of primary school science education is a critical barrier facing the use of digital technologies in primary school science delivery. Participants associated this finding with their preparation in teachers' training colleges. The finding disputes the Activity Theory belief that underscores the importance of digital technology pedagogical competence as a prerequisite condition for the successful integration of digital technologies into primary school science teaching (Engestrom, 2008). The finding is also contrary to the study by de Vicente (2024) conducted in the Spanish context. De Vicente's study found a strong correlation between teachers' digital pedagogical competence and the use of digital technological tools. This finding suggests the need for strengthening primary school teachers' training in terms of the applications of digital technologies.

Lack of priority to teach science and technology subjects practically

Findings showed that practical teaching of science and technology subjects in the studied rural primary schools had not been given priority. Participants expressed that despite commendable government efforts to introduce a subject called 'science and technology,' which is taught from class three to six, this subject is taught theoretically. Another head teacher was captured saying:

> There is a lack of priority to teach science and technology subjects practically. The government did a good thing to introduce this subject in primary schools. Pupils learn science and technology subjects from standard three to seven. Even in pre-primary classes, pupils are taught the theoretical fundamentals of science and technology. But unfortunately, we teach this subject theoretically. We just teach

> pupils the basic parts of a computer and their functions theoretically *(Interview, Head Teacher 5, School E)*.

The quotation above implies that the drive to teach science and technology subjects practically is low in the studied rural primary schools. Instead of pupils interacting and using real computers to develop digital technology literacy skills, they ended up developing imaginations on the way computers' hard and soft components, such as keyboard, monitor, Microsoft Word, and Microsoft Excel programmes, look like.

Findings from a review of the primary school curriculum and observation supported the interview findings. It was revealed that there was a science and technology subject that was taught in classes three through seven. This finding is demonstrated in the following extract captured from the primary school science and technology curriculum for standard III-VII: "*The science and technology syllabus for primary school education standard III-VII consists of technological skills, information and communication technology, experiments, and [...]. Using this syllabus, the pupil will develop [...] creative scientific and technological skills*" (STSPSE-STD III-VII, pp. iv & 1).

The curriculum further states, "*The teaching and learning of science and technology subject is based on [...] practical [...] aimed at helping the pupil acquire the target competencies. The teacher is expected to assess the pupil's ability to perform practical [...]* (STSPSE-STD III-VII, p. 4). Moreover, analysis of the pre-primary education curriculum also revealed that science and technology were emphasised in pre-primary classes. The curriculum states, "*In order to cope with advances in science and technology, especially in Information and Communication Technology (ICT), the curriculum should emphasise [...] and the use of ICT in the teaching and learning process* (CPPE, p. 2.).

However, the researcher observed that all of the studied primary schools did not have computer labs to facilitate the practical teaching of science and technology subjects. It means that teaching science and technology subjects practically was accorded less priority in the studied schools. However, if this situation is sustained, it may widen the digital literacy divide among primary school pupils (Sandoval-Henriquez et al., 2024). The finding is contrary to previous studies (See, e.g., Shvardak et al., 2024; Tandika & Ndijuye, 2019) that emphasise prioritising practice-base teaching and learning of digital technologies to empower pupils with digital literacy skills needed in the current digital age. This empowerment is vital not only for work-related skills and life at large but also for their continuing science and technology education through secondary and tertiary education levels (Shehaj, 2022). Similar findings were reported by David (2018), who found that

several countries in Africa, such as Comoros, Burkina Faso, Niger Guinea, and Madagascar, do not have computer labs in primary schools to offer practical computer skills to pupils. The establishment of computer labs seems to be given priority in lower and upper secondary and higher education institutions.

Teachers' negative attitudes on integrating digital technologies at lower education level

Findings demonstrated teachers' unwelcome attitudes toward digital technology integration into rural primary schools. Their unwelcome attitudes were another barrier to the successful integration of digital technologies into primary school science education. Most teachers explained that their fear of integrating digital technologies was based on their worry that children's good morals would be spoiled through their exposure to digital technologies. One of the teachers commented:

> Many of us teachers as parents in rural areas are still not comfortable with our young children interacting with digital technologies not only in schools but also at home. We believe that if children start engaging with technological tools at an early age, it may expose them to immoral behaviours that may endanger their good moral standing (Interview, Teacher 11, School F).

The expression above suggests that teachers teaching science in rural areas appear to be laggards in terms of accepting the positive side of using digital technology for children in schools and at home. Nonetheless, despite the huge benefits of digital technology integration into primary school science education, it is still debatable about the proper ways primary school children can use the technology to minimise the resultant negative effects that can spoil their good morals. It is because the excerpt above presents some reservations against the integration of digital technologies into primary school science education. Such suspicion means that exposing children to digital technology may lead them to read inappropriate or immoral content that might be harmful to their behaviours. This finding echoes previous studies by Alcardo et al. (2019) and Ndibalema (2014). For instance, Alcardo et al. found that teachers' negative attitudes and beliefs were among the barriers to integrating and using digital technologies in teaching and learning. Similarly, Ndibalema, examining the teachers' attitudes towards using digital technologies as a tool of pedagogy, found that teachers had a low awareness of the potential of digital technologies in the teaching and learning process over its drawbacks. The finding implies a need to create awareness among primary school teachers in rural areas on the importance of digital literacy in the current digital-driven education.

Initiatives for adoption to enhance the integration of digital technologies into primary school science education in Tanzania

Data related to desired initiatives were analysed, giving four key themes: the establishment of e-resource centres, the digitalisation of science curriculum content, the introduction of digital technology science labs in primary schools, and the digitalisation of teacher education.

Establishment of e-resource centres

Findings indicated that one of the initiatives for adoption to enhance the integration of digital technologies into primary school science education is introducing e-resource centres. Participants argued that e-resource centres are useful for providing technical support and training for science subjects teachers and headteachers on matters related to the integration of digital technologies into primary school science education. One of the teachers said:

> In my view, establishing e-resource centres to support technically the integration of digital technologies into primary school science education is an important initiative that can be adopted. Such centres are also essential for providing digital technology integration training for head teachers and teachers (Interview, Teacher 3, School C).

The quotation above indicates that establishing e-resource centres can facilitate the smooth integration of digital technologies into primary school science education. Indeed, e-resource centres might contribute significantly to supporting the integration of digital technologies into primary school science education. This finding is in line with Marasinghe et al. (2024), who maintain that e-resource centres are a rich source of digital information for teachers and students who search for digital learning materials on top of the traditional teaching and learning of science. The finding also agrees with the Activity Theory that posits that e-resource centres serve as mediating artefacts solicited from the external environment to achieve the learning goals in primary school science education (Engestrom, 2008; Marasinghe et al., 2024).

Primary school science curriculum content digitalisation

It was revealed that the digitalisation of primary school science curriculum content was another desired initiative that can be adopted to enhance the integration of digital technologies into primary school science education. Participants explained that a digitalised primary school science curriculum is essential for addressing the pupils' current digital challenges. One of the teachers commented:

> One of the best strategies to promote the integration of digital technologies into primary school science education is to digitalise primary school science curriculum content. Digitalised curriculum content is critical for addressing diverse science learning needs and increasing primary school pupils' digital literacy skills needed in the current digital era (Interview, Teacher 12, School D).

The above excerpt suggests that a digitalised curriculum content for primary school science education could be suitable not only for attending to pupils' science learning needs but also for promoting digital literacy among them. This finding can be attributable to the aspiration of transforming Tanzanian education from a knowledge-driven society to an information and digital-driven society. The finding is in line with the 2024-2034 Digital Economy Strategic Framework (DESF) for Tanzania (MoICIT, 2024). The DESF notes that digital technologies have infused all facets of our socio-economic setting, including education. It is because the digital age is being embraced across the world, and there is also a dedication in Tanzania to adapt to the digital sphere. Adapting to the digital sphere can be achieved by capitalising on the desirable initiatives towards new horizons; our nation aspires to guarantee that the benefits of the digital age are reachable by all equally (MoICIT, 2024). It means that digitalising primary school science curricula content would enhance accessibility to the advantages of the digital era for primary school pupils in underserved rural settings.

Introduction of digital technology science labs in primary schools

The introduction of digital technology science labs in primary schools could create an opportunity to enhance the integration of digital technologies into primary school science education. Participants argued that digital technology science labs could make the learning of science at the primary education level more meaningful and inspire pupils to love science in the Tanzanian context. This view was captured by one of the head teachers when she said:

> In my view, the integration of digital technologies into primary school science education can be enhanced through the introduction of digital technology science labs in primary schools. Digital science labs have the potential to make the learning of science subjects at the primary school level more concrete, meaningful, and enjoyable. It is because they contain exciting simulations, images, videos, and other digital media formats available on disks or the internet. As such, they can attract more pupils to love science starting from primary through secondary education (Interview, Head teacher 6, School F).

The quote above implies that the government needs to mobilise joint efforts from different education stakeholders, partners, and the private sector both at national and international levels to ensure that digital technology science labs are introduced in primary schools. This initiative seems to be necessary in Tanzania because many students dislike science subjects, particularly when they join secondary education, claiming that such subjects are difficult (Fussy et al., 2023; Francis, 2024). Findings from the documentary review substantiated the findings from interviews. Analysis of the new draft of the 2023 National ICT policy in Tanzania showed that the policy recognises the introduction of digitalised simulation labs as one of the ventures that can be adopted to enhance the applications of digital technologies in education. These findings agree with Nieveen (2024), who argues that digital technology science labs have become a prerequisite for advancement in Science, Technology, Engineering, and Mathematics (STEM) education. They are imperative for empowering children with digital literacy and the high-level digital skills they require to succeed in their future scientific inquiries.

The digitalisation of teacher education

Findings revealed that the digitalisation of teacher education was another craved initiative for enhancing the integration of digital technologies into primary school science education. Participants believed that the digital divide among primary school teachers could be bridged when the teachers' training programmes are digitalised. As a result, all primary school teachers graduating from these programmes would be empowered with the requisite knowledge and skills for integrating digital technologies into their teaching. One of the teachers explained:

> There is a need to digitalise teacher education to bridge the digital divide among primary school teachers. Digitalised training programmes are critical for empowering student teachers with the necessary skills for integrating effectively and responsibly digital technologies in the teaching and learning process. Such programmes are also important for preparing pupils for the digital society (Interview, Teacher 8, School E).

The extract above implies that the digitalisation of teacher education programmes is one of the untapped initiatives that can be adopted to enhance the integration of digital technologies into primary school science education. It has the potential to empower the pool of future primary school teachers with the requisite digital competencies. The finding implies that unless primary school teachers' training is digitalised, the digital divide among primary school teachers may persist. This finding is attributable to the fact that primary school teachers have little knowledge of how to use digital technologies as a pedagogical tool, as reported in this study.

The finding echoes the Activity Theory that emphasises the need for pedagogical competence in digital technology as a precondition for instructional use of digital technologies. The finding is also in line with a study by Oreku (2022), who found insufficient teacher preparation for the development of digital-related skills was one of the barriers to the integration of digital technology into the teaching and learning of science. Similarly, Shvardak et al. (2024) argue that the increasing importance of digital technologies in education systems intensifies the demand to integrate these technologies into the professional preparation of teachers. It means that there should be concerted efforts dedicated to prioritising the incorporation of digital technology skills development in primary school teachers' training programmes.

Limitations and opportunities for future research

Although the findings may be plausible, the following limitations to this study suggest further research. First, the study examined the integration of digital technologies into primary school science education but with a major focus on challenges and craved initiatives. Studies that can investigate the root causes of the identified challenges are recommended. Second, the study revealed negative attitudes among teachers serving in rural contexts on the integration of digital technologies into primary school science education. However, it did not document the pervasiveness of this attitude across Tanzanian rural contexts. Future research should consider establishing the prevalence of this attitude across rural settings in Tanzania by expanding the sample beyond the one used in the present study.

Conclusions and Recommendations

The study explored the challenges and desired initiatives that can be adopted to enhance the integration of digital technologies into primary school science education in the context of Tanzanian rural primary schools. Findings show that the integration of digital technologies into primary school science education in the studied schools is faced with several challenges. They include inadequate technological facilities to support the integration of digital technologies into primary school science education and, petite knowledge among primary school teachers on how to integrate digital technologies into teaching science. Other challenges were a lack of priority to teach science and technology subjects practically and teachers' negative attitudes towards integrating digital technologies at lower education levels. Furthermore, the study has established that establishing e-resource centres, digitalisation of primary school science curriculum content, the introduction of digital technology science labs in primary schools, and digitalisation of teacher education are desirable initiatives, which, when adopted, could enhance the integration of digital technologies into primary school science education in the context of the studied primary schools.

Based on the findings, the study recommends the following for improved policy and practice. First, the Tanzanian government, through the Ministry of Education, Science, and Technology, should mobilise financial resources to ensure an adequate supply of digital technological facilities such as computers, tablets, and digital science labs in rural primary schools. Second, there is a need to digitalise primary school teacher education to bridge the digital skill gap existing among primary school teachers in Tanzania. Third, the local government authorities must prioritise regular conduct of awareness creation campaigns in rural areas on the importance of digital technologies for pupils in the current digital-driven era. Fourth, through outsourcing educational digital integration experts, head teachers in the studied schools should regularly organise school-based workshops on how to integrate technology into the teaching and learning of science using facilities available in schools.

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