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Context-relevant strategies for ICT integration in teaching and learning science subjects in Tanzania secondary schools

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Abstract. Information and Communication Technology (ICT) can improve science teaching and learning. However, understanding the contexts in which ICT is intended to be integrated for its effectiveness is limited. Therefore, the current study explored context-relevant strategies and challenges for ICT integration in the teaching and learning science subjects in secondary schools in Tanzania. Exploratory sequential design under mixed methods guided the study's conduct. 52 participants (45 science teachers, six heads of schools and one municipal education officer) were purposefully and conveniently involved. Data were collected in two phases: 1st phase was qualitative data through in-depth interviews, 2nd phase was quantitative data through a questionnaire. Thematic analysis guided qualitative data analysis where MS Excel in the form of pivotal charts were used to present the frequency of the responses. SPSS version 27 guided the quantitative data analysis, presenting the output descriptively. Participants presented various context-relevant strategies, including capacity building for teachers, building and equipping computer labs with ICT facilities, maintaining and repairing defective computers, deploying educational technology experts, and making ICT compulsory at all levels of education. On the other hand, participants identified a lack of ICT facilities, limited ICT training opportunities, and digital content as context-relevant challenges for ICT integration in science teaching and learning. The study recommends rigorous pre-service and in-service teacher training programmes on ICT pedagogical integration for science teaching and learning based on these findings. Again, we recommend the improvement of ICT infrastructure in schools to enhance the availability, access, and use of science teaching and learning. The study concludes that if sufficient infrastructures are available and science teachers are equipped with ICT knowledge, teaching and learning of science subjects will be effective.

Keywords: context-relevant strategies, ICT integration, teaching and learning, science subjects, Tanzania, secondary schools

1. Introduction

Information and Communication Technology (ICT) has emerged as a global game-changer in education delivery, offering multiple possibilities for teaching and learning practices for all subjects. Like other countries, Tanzania recognises the potential of ICT in improving the quality

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of education, and its use is considered a pivotal step towards preparing learners to develop skills of the 21st century. As such, the government has tried to foster the integration of ICTs in teaching and learning. Notably, the Tanzania Education and Training Policy and the ICT policy for basic education advocate for integrating ICTs at all levels of education delivery [42, 44]. Again, the government of Tanzania has adopted the ICT competence standards framework for teachers from UNESCO, which specifies the ICT pedagogical competencies that need to be possessed by teachers [43]. This has been followed by providing tablets to all primary and secondary school teachers in Tanzania for teaching and learning [23]. Despite the efforts made by the government, studies [21, 22] documented limited application of ICT in teaching and learning in secondary schools. In light of the current study, ICT refers to using ICT devices, including computers (with their associated input and output devices) and other handheld devices equipped with relevant applications for science teaching and learning.

1.1. Statement of the problem

Tanzanian secondary school education struggles with student performance in science and math, a common challenge in developing countries. For example, the analysis by the National Examinations Council of Tanzania, students' performance for cycle 2018 – 2020 reveals weak performance in science subject [35, 38, 39]. For this reason, several initiatives to address the challenge have been implemented, including ensuring the availability of materials and employment of science teachers [23]. Despite these initiatives, the performance has continued to be weak. However, Abidoye, Ahmed and Olorundare [1] suggests that the integration of ICT as a pedagogical tool is indispensable for addressing the challenge of teaching and learning science subjects in secondary schools. Manyilizu [22] supports that schools need to invest in ICT to enhance the teaching and learning of science subjects, especially practical sessions. Among the suggested ICT applications include designed science virtual laboratories and software simulations that can offer students meaningful learning of different concepts, principles and practical [6].

Following the role vested in ICT to improve the learning of science subjects, the government of Tanzania, like other nations, has invested much in applying ICT in teaching and learning. Among the initiatives include but are not limited to the provision of computers to secondary schools, training of teachers in ICT and provision of tablets to teachers [25]. While governments' efforts are remarkable, studies [21, 29] report the unfriendly use of ICT in teaching science subjects. Thus, poor performance in science subjects continues to exist. Malekani [20] and Ndume, Kisanga and Selemani [25] suggest that it is likely that teachers are faced with limited knowledge of the strategies of using ICT in teaching science subjects or are faced with structural and infrastructure challenges. In this context, the current study noted a gap in the context-relevant ICT strategies and challenges for ICT integration for science teaching and learning in secondary schools in Tanzania.

1.2. The current state of science education in Tanzania and the need for ICT integration

In Tanzania's education system, secondary education is a critical stage for students' academic journey. At this stage, students are offered foundational knowledge, skills and attitudes in various subjects, including sciences [42]. Based on its practical nature, the science teaching and learning environments are restricted by insufficient teaching and learning materials such as equipment, apparatuses, chemicals, and other science supplies [12]. This has led to a continued lack of understanding of practical concepts in science subjects [37, 40]. In response, the government of Tanzania has tried to improve the context of science teaching and learning in secondary schools. Remarkably, there have been initiatives to build science laboratories in all community secondary schools, disbursement of capitation grants for procurement of science teaching and learning materials and a call to integrate technology in science teaching and learning [12, 23, 36]. Nonetheless, the context of science teaching and learning is improving at a slower pace.

Arguably, the current state of science education in Tanzania necessitates ICT integration in teaching and learning. It is established in the literature that the use of ICTs in science teaching and learning develops understanding and visualisation of complex science concepts among learners [8, 22]. Similarly, Papadakis et al. [30] add that well-designed educational technology interventions can maximise learning outcomes. This is critical, especially in the 21st century, where science teaching and learning must transcend the traditional teaching and learning modalities and include technology instructions as a powerful tool in fostering the exploration of complex science ideas through simulations, multimedia resources and collaborative activities [14]. Nonetheless, the move to technology-driven instruction is multifaceted and must be contextualised to fit the needs of a specific education system.

Several studies suggest various applications of ICT integration in science teaching and learning, including providing teaching and learning resources and assistance in instruction delivery, assessment, and virtual practical activities. It is also a tool for enhancing inclusiveness and equity in teaching and learning of science [18]. To harness the benefits of ICT application in science teaching and learning, studies suggest formulation of pertinent policies, allocation of funds for procurement of ICT equipment and support of teachers' professional development for the acquisition of ICT pedagogical integration skills [2, 7]. Nevertheless, the integration of ICT in science teaching and learning faces institutional challenges related to infrastructural development and limited capacity building among teachers and personal challenges associated with limited ICT pedagogical integration skills among teachers [16, 24].

1.3. The current study

Despite a body of literature analysing the benefits, strategies and challenges, the integration of ICT in science teaching and learning has remained minimal in Tanzania. This calls for exploring context-relevant strategies and challenges for ICT integration in science teaching and learning. Exploration of the context-relevant strategies and challenges facing ICT integration in teaching science subjects were considered significant for different reasons. First, it would set the contextual ICT facilities and technology that could be easily integrated into the teaching and learning of science subjects. Second, it would establish the actual needs of teachers for

successful integration of ICT teaching science subjects rather than imposed ones. Lastly, it would help the government to understand the challenges facing the implementation of ICT integration for teaching science subjects, thereby coming up with relevant strategies for improvements. Additionally, the findings add to the body of knowledge of the existing literature on the challenges and contextual strategies that can be used to enhance the teaching of science subjects through ICT. For this reason, the current study answers two research questions.

2. Research questions

The study employed the mixed methods procedures to address the following research questions:

i. What are the context-relevant strategies for ICT integration in teaching and learning science subjects in Tanzania secondary schools?
ii. What are the context-relevant challenges for ICT integration in teaching and learning science subjects in Tanzania secondary schools?

2.1. Theoretical considerations

The Diffusion of Innovation Theory (DOI), developed by Everett M. Rogers in 1962, was considered relevant in this study. According to Rogers [32], five factors account for individuals' adoption of innovation across time: relative advantage, compatibility, complexity, trialability and observability.

Categorically, Rogers [32] describe relative advantage as the understanding that the innovation is better than the practice or product that superseded it, while compatibility is the alignment of the innovation to the existing values, norms, experiences and needs of potential adopters. Similarly, complexity means the perceived difficulty of using or understanding the innovation. Trialability refers to the degree to which an innovation can be experimented, and observability is the degree to which the results of an innovation are observable to others.

This study extracted compatibility from DOI theory as a factor for ICT adoption to study context-relevant strategies for ICT adoption in teaching and learning science subjects in secondary schools in Tanzania. As a theory stipulates, for an innovation to be adopted appropriately, it must be customised to fit the context to which it intends to be used [32]. Conceivably, compatibility as a factor for technology adoption stresses the role of contextual strategies and challenges for ICT adoption in teaching and learning science subjects in Tanzania.

We anticipate that a thorough understanding of context-relevant strategies and challenges will act as a roadmap for future initiatives and interventions targeting the deployment of ICT in science education. Again, the outcomes of this study hold significant implications for education stakeholders such as policymakers, educators, teachers, students, and technology providers to rethink context-relevant strategies for deploying ICT in science teaching and learning.

3. Methodological approach

3.1. Approach and design

This study employed an exploratory sequential mixed methods research design combining in-depth interviews followed by a survey to gather comprehensive data regarding context-relevant strategies and challenges for ICT integration in the teaching and learning of science subjects in secondary schools in Tanzania. Qualitatively, the study sought to explore insights regarding context-relevant strategies for ICT integration in the teaching and learning of science subjects. The analysed qualitative data informed the development of questionnaire items to statistically authenticate the context-relevant strategies for ICT integration generated through in-depth interviews. The questionnaire also contained an open-ended item to explore context-relevant challenges for ICT integration in science teaching and learning.

3.2. Participants

The study was conducted in the Dar es Salaam region, focusing on six (6) secondary schools in the Ilala district. This region was chosen because the six secondary schools participated in various pilot projects related to ICT integration in science teaching and learning. Purposive sampling was used to obtain six heads of schools, one municipal education officer and three heads of science subject departments from each school based on their positions. On the other hand, total population sampling (TPS) was used to obtain all 45 science teachers (including heads of science departments) in all six secondary schools who participated in piloted ICT projects to participate in the survey. TPS entails involving in the study the entire population that meets specific criteria [9].

Generally, the study involved a total of 52 participants, of which 45 were science teachers, including heads of science subject departments (M=31, F=14), six heads of schools (M=4, F=2) and one male municipal education officer. Due to their involvement in various pilot projects, it was expected that science teachers, heads of science departments, heads of schools and municipal education officers could offer context-relevant strategies and challenges for ICT integration in science teaching and learning as experienced in the projects.

3.3. Instruments for data collection

We used in-depth interviews and questionnaire methods to collect data for this study. We started collecting qualitative data through in-depth interviews with heads of science departments, heads of schools and municipal education officers. The interview guide was designed to generate data about context-relevant strategies for ICT integration in the teaching and learning of science subjects in secondary schools in Tanzania. Thematic analysis was used to analyse the data from in-depth interviews through data familiarisation and organisation, data coding and reduction, and data interpretation and presentation [4]. This process involved repeatedly listening to audio clips recorded during the interview, using verbatim transcription, and repeatedly reading the scripts. This was followed by preparing initial codes and categorisation of the codes to generate specific themes. Finally, the findings were interpreted and presented as themes with respective

quotes. The findings from qualitative data analysis informed the development of questionnaire items, which were used at a later phase of data collection by science teachers.

Specifically, we involved science teachers to fill in a questionnaire to authenticate the qualitative findings. The questionnaire had three sections; the first section collected science teachers' demographic information such as sex, age, teaching experience and professional qualifications. The second section sought to establish science teachers' level of agreement with the pre-suggested context-relevant strategies for ICT integration in teaching and learning science subjects in Tanzania. The questionnaire contained six five-point Likert scale items defined by 5 – Strongly Agree, 4 – Agree, 3 – Undecided, 2 – Disagree and 1 – Strongly Disagree. The third section contained open-ended questions for exploring context-relevant challenges for ICT integration in the teaching and learning of science subjects. We used SPSS version 27 to analyse Likert scale items and MS Excel 2019 to create pivotal charts of open-ended questionnaire items, which sought to explore the challenges. The results were presented as descriptive statistics in frequencies, percentages, mean and standard deviation. Similarly, the open-ended questionnaire item was coded in MS Excel 2019 and analysed as pivotal charts.

3.4. Validity and reliability of the study

To ensure internal validity, we spent less time interval between qualitative and quantitative data collection. This was done to control the effects of extraneous variables such as history and maturation from interfering with the study's findings [15]. Again, we used total population and purposive sampling to ensure external validity and avoid selection biases. We also subjected the data collection tools to five peers and three educational technology experts for the review process. Then, we made relevant improvements based on the comments given. We also ensured the validity of the findings through methods and participant triangulation.

For the internal consistency reliability of the questionnaire items, we computed the internal consistency reliability using Cronbach's alpha reliability test. The Cronbach's Alpha Coefficient result for six items measuring context-relevant strategies for ICT integration in teaching and learning science subjects was 0.844. The reliability value $\alpha > 0.7$ was considered the minimum acceptable reliability measure [11]. Therefore, there is a high internal consistency among items measuring context-relevant strategies for ICT integration in teaching and learning science subjects.

4. Findings

This study explored context-relevant strategies and challenges for science teaching and learning in secondary schools in Tanzania. The findings are therefore organised based on the two research questions that were focused on in this study: (1) context-relevant strategies and (2) challenges of ICT integration in teaching and learning of science subjects in Tanzania secondary schools.

4.1. Context-relevant strategies for ICT integration in teaching and learning of science subjects

In this aspect, participants mentioned six context-relevant strategies: capacity building for teachers, building and equipping computer labs with ICT facilities, maintenance and repairing of defective computers, hiring educational technology experts, creating partnerships with content creators or educational technology organisations, and making ICT a compulsory subject at all levels of education.

Capacity building for teachers

The informants' views revealed that using ICTs for science teaching and learning requires relevant ICT pedagogical integration skills. As such, science teachers need to be equipped with the required knowledge, skills, and attitudes for ICT integration in science teaching and learning. On this, heads of science departments, heads of schools and municipal education officers had similar views regarding the role of capacity-building programmes towards equipping teachers with skills for ICT use in science teaching and learning:

> Given the advancements in science and technology, teachers in my department are eager to use ICTs in science teaching and learning. To be able to do that effectively, I think we should have programmes to capacitate teachers in ICT pedagogical integration skills (Head of Physics department, School A, November 2020)

From another viewpoint, one participant had similar ideas related to capacity building for teachers on ICT integrations but added that both pre-service and in-service teachers should be capacitated on ICT pedagogical skills. Commenting on this aspect, the municipal education officer argued that:

> … as we think about capacitating teachers on ICT pedagogical integration skills, we must also think of teacher education programmes. In my view, teacher education should be ICT-driven for effective ICT integration in teaching and learning science subjects in secondary schools (Municipal Education Officer, November 2020)

Although the informants suggested the capacity building programmes as a strategy to integrate ICTs in science teaching and learning at different levels of magnitude, they still had a converging point. Science teachers should be trained in using ICTs for science teaching and learning through pre-service and in-service training programmes.

Building and equipping computer labs with ICT facilities

Effective integration of ICTs in science teaching and learning requires the presence and accessibility of relevant ICT hardware and software. Thus, participants voiced the role of the government and other education stakeholders in building ICT laboratories and equipping them with relevant computer hardware and software for science teaching and learning:

> … to enhance the use of ICTs for science teaching and learning among teachers and students in this school, I think the government should designate a computer lab and equip it with ICT facilities with internet accessibility. This will reinforce ICT use in science teaching and learning (Head of School, School B, November 2020)

Similarly, informants believed teachers could be acquainted with knowledge, skills, and attitudes regarding ICT use in science teaching and learning through Teacher Resource Centers (TRC), available nationwide. However, this should be preceded by equipping the TRCs with relevant ICT facilities:

> Teacher resource centres lack ICT tools, as well. In this situation, I do not expect a miracle for teachers to develop a culture of ICT use. I think we need to ensure that our teachers' resource centres are equipped with ICT tools (Head of Chemistry Department, school C, November 2020)

While more informants raised a concern about lacking relevant ICT facilities in their schools, they were concerned that some schools had been supported with computers but had locked them in some rooms, and thus, nobody was using them. Although this is associated with a lack of computer laboratories on one side, on the other side, it resonates with a lack of relevant expertise on the installation and use of the ICT facilities:

> Shockingly, some schools have many computers, but they are locked inside, and no one uses them. I think the head of schools should be creative to ensure that a special room is designated for use as a computer lab when we are waiting for other initiatives to build computer labs (Head of Biology Department, School F, November 2020)

Notably, informants stressed the role of having relevant ICT facilities and infrastructure as a strategy for ICT integration in science teaching and learning in secondary schools in Tanzania. Categorically, their views were centred around two specific support areas: building computer labs and equipping them with ICT facilities and supplying ICT facilities to TRCs to make them functional regarding ICT usage.

Maintaining and repairing defective computers

This was a critical aspect of ICT integration in science teaching and learning. The informants acknowledged the support they received from the ICT facilities by participating in the ICT pilot project. However, a lack of maintenance culture lowered such efforts:

> Our school has computers that we received in the ICT pilot project. However, most computers are currently not functional due to hardware and software problems. I think our schools should have maintenance policies for sustainable use of the facilities (Head of Chemistry Department, School D, November 2020)

Another viewpoint related to this cemented the role of school-based initiatives to repair the ICT facilities supported by different education stakeholders as a strategy for sustainable use of ICTs in science teaching and learning. To them, maintenance culture should ensure the careful handling and use of ICT facilities.

> … the schools that already have ICT facilities should have strategies to repair the facilities regularly. This should go with having some rules and guidelines to ensure proper handling and use of the ICT facilities (Head of Physics Department, School B, November 2020)

Arguably, informants' views set the ground for schools with ICT facilities to consider maintaining and repairing defective or malfunctioning ICT facilities. This will help the school overcome the challenge of lacking ICT tools, making ICT integration in teaching and learning science subjects promising.

Deploying educational technology experts

Informants were anxious that educational technology experts should be deployed in each school or the TRCs to offer technical support to teachers and students on using ICTs for science teaching and learning. It was noted that technical support would improve teachers' and students' practices on the use of ICTs in their teaching and learning:

> Among the strategies to ensure the use of ICT in schools is the presence of sufficient experts to support teachers and students. In fact, teachers or students need to be supported in case they get stuck in the use of ICT for teaching and learning. If experts to support teachers are lacking, then people find no value in using ICT in schools (Head of School, School C, November 2020)

Based on the informants' narratives, it is evident that teachers were willing to integrate ICTs into teaching science subjects. However, they felt that deploying ICT experts in their schools was a strategy to motivate science teachers to use ICTs for teaching and learning science subjects.

Creating partnership with digital content creators or educational technology organisations

Concerning this aspect, informants pointed out the need for secondary schools to partner with digital content creators or educational technology organisations to receive technical and pedagogical support on using ICTs for science teaching and learning. In their narrations, it was clear that there was a need for support to ease the acquisition of digital content for science subjects and the acquisition of relevant ICT pedagogical integration skills. On this, one head of school had these to say:

> We are lucky that our school is located in Tanzania's largest city, where ICT industries and organisations are abundantly available. It is a great time now for

> us to form a kind of partnership with these industries for more support on digital content and other kinds of technical support (Head of School, School F, November 2020)

On the same matter, the municipal education officer spelt out his role as an educational leader to find assistance from organisations nearby the schools to support these schools in terms of ICT facilities, content and skill development among teachers and students to seamline ICT integration for science teaching and learning:

> … I think we, as educational leaders, are responsible for seeking partnerships with government and non-government organisations to support us in terms of improving ICT infrastructure in our schools (Municipal Education officer, November 2020)

It is worthwhile noting that partnership with other organisations or ICT industries is essential in several ways. These organisations can support the schools regarding ICT facilities, digital content, and technical support for ICT integration in science teaching and learning.

Making ICT a compulsory subject at all levels of education

During interviews, it appeared that ineffective ICT integration in teaching and learning science subjects results from fear of technology due to limited skills in ICT use. Thus, one of the strategies to foster ICT use would be to teach ICT subjects at all levels of education. This would improve ICT use among teachers and students and remove their fear of technology use:

> … my views on that question are that ICT should have been made compulsory at all levels of education, including teacher education. This would help alleviate technophobia among teacher trainees. To me, it is at the college where these teachers would be well prepared for ICT use in schools (Head of School, School A, November 2020)

Similarly, informants were mindful that ICT was being taught in all teacher education programmes, but it was taught theoretically rather than practically. As such, to ensure the proper acquisition of ICT skills, practical teaching and learning of ICTs should be encouraged at all levels of education:

> … I think it is ample time now to ensure that ICTs are taught practically from primary school to other levels of schooling. This will equip teachers and students with skills in ICT use for science teaching and learning (Head of Biology Department, School E, November 2020)

Furthermore, we quantitatively sought science teachers' views regarding the context-relevant strategies for teaching and learning science subjects in secondary schools in Tanzania. Science teachers were prompted to rate their agreement or disagreement with the context-relevant strategies identified during the interview. This was done using a five-point Likert scale defined by 5 – Strongly Agree, 4 – Agree, 3 – Undecided, 2 – Disagree, and 1 – Strongly Disagree. The responses of science teachers are presented in table 1 underneath.

Table 1
Context-relevant strategies for ICT integration as perceived by science teachers (N=45).

Strategies	Strongly Disagree *N* (%)	Disagree *N* (%)	Undecided *N* (%)	Agree *N* (%)	Strongly Agree *N* (%)	Mean±std
Maintaining and repairing defective computers	0 (0.00)	3 (6.67)	3 (6.67)	21 (46.67)	18 (40.00)	4.20±0.84
Capacity building for teachers on ICT integration	2 (4.44)	1 (2.22)	3 (6.67)	10 (22.22)	29 (64.44)	4.40±1.03
ICT to be a compulsory subject at all levels of education	0 (0.00)	1 (2.22)	6 (13.33)	14 (31.11)	24 (53.33)	4.36±0.80
Build computer labs and supply relevant facilities	1 (2.22)	1 (2.22)	0 (0.00)	15 (33.33)	28 (62.22)	4.51±0.82
Establish partnerships with digital content organisations	1 (2.22)	0 (0.00)	3 (6.67)	16 (35.56)	25 (55.56)	4.42±0.81
Deploy educational technology experts	0 (0.00)	0 (0.00)	1 (2.22)	10 (22.22)	34 (75.56)	4.73±0.50

To a large extent, the responses of science teachers regarding the context-relevant strategies for ICT integration in the teaching and learning of science subjects resonate with the views found during the in-depth interviews. The mean scores of science teachers regarding various context-relevant strategies range between 4.73 (strongly agree) and 4.20 (agree). The highly rated context-relevant strategies were "*Deploy educational technology experts*" and "*Build computer labs and supply relevant facilities*", which had the mean scores of 4.73 and 4.51, respectively. Most science teachers strongly agree with effective ICT integration in science teaching and learning. The two most appealing context-based strategies are building computer laboratories, equipping them with relevant ICT facilities, and deploying educational technology experts in all secondary schools.

4.2. Context-relevant challenges on ICT integration in teaching and learning of science subjects

The responses from science teachers in an open-ended questionnaire yielded five context-relevant challenges for ICT pedagogical integration in the teaching and learning of science subjects. Details of the responses are presented in figure 1 below.

As seen in figure 1, most (30) responses from science teachers suggested that one of the overriding context-relevant challenges of ICT integration in teaching and learning science subjects in Tanzania was inadequate ICT infrastructure and facilities. Responses from other science teachers (27) considered the cost of internet bundles for their private devices as another challenge limiting them to "*access online resources for teaching and learning*". Also, a good number of science teachers (25) believed that limited ICT training opportunities were denying them the chance to update their skills in ICT use for science teaching and learning. On the other hand, few science teachers (7) considered that the limited accessibility of digital content for science teaching and learning was limiting their abilities to integrate ICTs for science teaching.

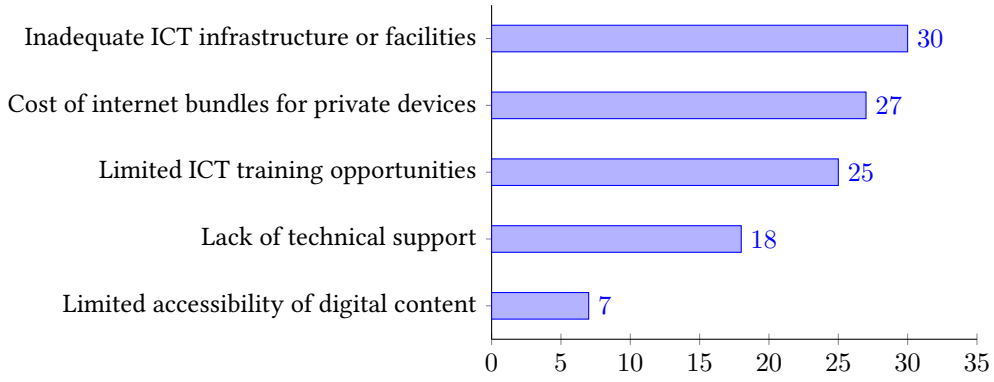

Figure 1: Context-relevant challenges on ICT pedagogical integration.

5. Discussion

This study explored context-relevant strategies for ICT integration in teaching and learning science subjects in Tanzania secondary schools, focusing specifically on context-relevant strategies and challenges for ICT integration in science teaching and learning.

5.1. Context-relevant strategies for ICT integration in teaching and learning science subjects in Tanzania secondary schools

The findings from the participants suggest various context-relevant strategies for ICT integration in the teaching and learning of science subjects. Broadly, the suggested strategies target enhancing teachers' ICT pedagogical competencies, improving ICT infrastructures in schools, and creating partnerships between schools and other ICT-based organisations based on ICT pedagogical integration. These findings relate to previous studies which considered access to ICT facilities and perceived competency among teachers as prerequisites for ICT integration in teaching and learning [28, 31]. On this, Ferede et al. [10] clarify that educational institutions must have supportive policies to enhance teachers' ICT skills, build relevant ICT infrastructure and provide the required ICT support for ICT integration in teaching and learning. Recently, the government of Tanzania has supported all secondary school teachers with tablets for teaching and learning [23]. This marks a milestone regarding the availability of ICT equipment in schools. However, further strategies, such as improving internet services, are needed to improve the accessibility of digital teaching and learning materials.

Furthermore, previous studies such as by Ferede et al. [10] and Karkouti [17] support the current study on the importance of training on ICT pedagogical skills for science teaching and learning. However, the current study emphasises two important strategies for the development of ICT pedagogical skills among teachers. These are strengthening pre-service and in-service teacher preparation on ICT skills and making policy adjustments to allow ICT to be taught at all levels of education delivery. The latter impliedly means that developing ICT competencies is a lifelong process. Thus, it should be encouraged at all levels of schooling as the policy stipulates [42]. While the current study insists on the provision of training to teachers, studies

investigating teachers' readiness for ICT integration reveal other interesting findings. For example, a study by Ndume, Kisanga and Selemani [25] shows that teachers may be equipped with relevant training but have poor readiness towards using ICT in teaching and learning. Other researchers present that some teachers are too traditional and resist change. This implies that apart from training teachers on ICT skills, they must be coached on the potential benefits of using ICT for teaching science subjects.

The current study's findings have also stressed the role of collaboration with digital content developers and educational technology organisations. One study by Lomos, Luyten and Tieck [19], considers school-based collaboration among teachers as an important aspect to improve ICT use among teachers. The current study has, however, suggested collaboration between schools and outsider organisations such as digital content developers and educational technology institutions. The current study and previous studies commonly address the role of collaboration for effective ICT pedagogical integration, although the difference exists in the scope of collaboration. This is a call to educational managers to create environments for schools to collaborate with ICT organisations on issues related to digital content and the development of ICT skills and infrastructure for teaching and learning. The difference from other studies is that the current study has revealed the need for teachers to be equipped with the capacity to create content by themselves instead of being the rubber stamp for implementing the ICT content developed somewhere by someone else. This may result in teachers' confidence in using ICT content and materials. On this note, some action studies may be done to equip teachers with the knowledge of ICT content creation for teaching and learning science subjects.

5.2. Context-relevant challenges on ICT integration in teaching and learning of science subjects

Participants presented various context-relevant challenges for ICT integration. Generally, the context-relevant challenges were related to inadequate ICT infrastructure such as ICT equipment, cost of internet services and limited access to digital content. These findings support the views of Mohammadi, Mohibbi and Hedayati [24], who consider the availability of relevant ICT infrastructure, facilities and digital content as important attributes for effective ICT integration in teaching and learning. Again, the cost of internet service and accessibility to digital content for teaching and learning are negatively related. Similar to the current study findings, the study by Ngeze [26] revealed a remarkable number of secondary schools with limited ICT materials for effective integration. It was noted that the ratio of students per computer r ranged from 20:1 to 110:1, implying that the pupils' actual learning demands cannot be met by the ICT facilities that are currently available. Likewise, Hennessy et al. [13] and Wallet and Melgar [45] report that this challenge exists across many African countries. While the current study aligns with some literature, other scholars noted the difference. For instance, Sedoyeka and Gafufeen [33] report that despite the shortage of ICT infrastructures, ICT adoption in some schools was very low as some secondary schools supplied with computers could not even switch on. This implies that despite the findings revealing the absence of ICT materials, teachers' readiness and adoption may still be challenging in its use.

Similarly, the views that inadequate ICT skills due to limited training opportunities and technical support on ICT integration limit teachers ICT integration in teaching and learning

of science subjects are supported by previous studies [3, 41]. Equally, Banele [5] reported the limited number of trained ICT teachers and lack of computer technicians as the factors hindering the effective integration of ICT in teaching science subjects in most secondary schools. Of different note from the current study, Banele [5], remarks that even for the few schools with computer-trained teachers, they are constrained by restrictions, school bureaucratic procedures and lack of technical support in computer laboratories, thus resulting in inadequate use of ICT in classrooms. This indicates that despite the inadequate number of teachers and technicians with relevant ICT skills to feed the growing number of secondary schools with ICT materials, school management should make ICT easy and accessible for teaching and learning science subjects. Arguably, in-service and pre-service training is needed to equip teachers with the required ICT pedagogical integration skills. Likewise, the school management needs to be capacitated on the role of ICT in teaching and learning science subjects.

While the major study findings revealed a shortage of ICT materials and limited training, the literature reports other challenges not explicitly revealed in the current study. For instance, the study by [27] presents the challenge of power supply in most African countries. Like Tanzania, the lack of access to energy greatly hinders the use of ICT in teaching and learning in secondary schools [34]. Thus, with limited electricity, teachers may be unable to effectively use ICT devices in activities such as producing learning materials or connecting to the internet for further learning. Therefore, other studies may investigate the use of ICT in a limited electricity supply and its impacts on learning and teaching through ICT.

6. Conclusion and recommendations

In the 21st century, ICT is an integral part of the classroom teaching and learning process. Consequently, various education systems are finding ways to effectively integrate it into the teaching and learning of science subjects. Even though there is great variability in context across the educational systems, integrating ICT in the teaching and learning of sciences must be preceded by understanding context-relevant strategies and challenges for effective integration. Based on the context of the current study, the integration of ICT in the teaching and learning of science subjects must consider three key issues: the development of science teachers' ICT pedagogical skills, building relevant ICT infrastructure and supplying the required ICT equipment and services, and putting in place technical support mechanisms for ICT pedagogical integration. Teachers commonly face challenges of insufficient ICT facilities and services, limited ICT skills, and a lack of technical support for ICT integration in teaching and learning sciences.

In view of the findings of the current study, it is recommended that pre-service and in-service training programmes should be improved to equip teachers with relevant ICT pedagogical skills. Again, schools must be equipped with relevant ICT equipment and services and technical personnel to assist teachers with ICT pedagogical integration in science teaching and learning. Furthermore, the current study recommends that intervention studies be conducted on the need to supply ICT equipment in schools, thus enhancing teachers' ICT pedagogical integration skills. It makes sense to note that the current research relied on self-report survey questionnaires and interviews, of which the participants' responses may be subjected to some social desirability biases. Further research may be carried out employing other methods, such as observations, to

validate participants' responses and the actual practices in the classroom context. Likewise, the design allowed the establishment of causal relationships between ICT integration strategies and student learning outcomes. Further research may be conducted employing experimental design to establish the predictive power of ICT integration and learning outcomes among students.

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