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Integrating ICT in science lessons to promote science teachers' competencies in Tanzania

Angelina Kanyabwoya, Huruma Olofea Bwagilo and Samweli Tumaini Mugaya

Department of Psychology and Curriculum Studies, College of Education, The University of Dodoma, 1 Benjamini Mkapa Rd., 41218 Iyumbu, Dodoma, Tanzania

Abstract. The study examines the integration of ICT in science lessons to develop the competencies of science teachers in diploma teacher colleges in Tanzania. A multiple-case study research design was employed to capture the views and experiences of 66 participants. Data was analysed using thematic analysis. Results from the interview, focus group discussion, observation and documentary review revealed that the integration of ICT in science lessons is limited. The limited integration of ICT is due to inadequate skills, limited administrative support, and the inadequate delivery of ICT materials when needed, as well as improper conditions for ICT materials. The study concludes that, despite the availability and tutors' willingness to use ICT in teaching and learning science subjects, its application in classrooms is still unimpressive. Therefore, student-teachers are likely to remain incompetent in science subjects. The study recommends the use of ICT materials in science lessons, the provision of indoor training, and the timely procurement of ICT materials.

Keywords: ICT integration, science teachers, competencies

1. Introduction

The quality of teaching and learning science in the education sector is determined by the competencies that science teachers develop. Competent teachers are the key implementers of the curriculum and are responsible for ensuring that learners achieve academic success [18]. Several measures have been taken to ensure the development of science teachers' competencies, including the integration of information and communication technology (ICT) in science lessons [22]. Likewise, working with ICT in teaching and learning is seen as one of the key competencies necessary for academic success, especially in today's world, which is driven by the advancement of science and technology [26]. Based on the role of ICT in teaching and learning, most nations worldwide require assistance in incorporating ICT into their national education curricula, including science subjects [16]. This is because ICT can make teaching methods more dynamic and effective [13].

1.1. The role of ICT in teaching and learning of science subjects

The important role of ICT integration in teaching and learning science is to fulfil the world's expectations that demand ICT competencies to enhance the quality of teaching and learning in schools and education colleges, which support Sustainable Development Goal 4 that focuses on ensuring quality education for all children by 2030 [27, 33]. ICT integration enhances science lessons by making learning more interactive and engaging through simulations and virtual experiments, which can improve understanding and engagement [8]. ICT can be used to visualise abstract concepts, helping students to understand complex and abstract scientific ideas more easily [16]. Enabling students to conduct virtual experiments and explore scientific processes that may be too dangerous,

0009-0006-1326-9895 (A. Kanyabwoya); 0000-0002-8336-3370 (H. O. Bwagilo); 0000-0002-9228-9678 (S. T. Mugaya)
kanyabwoyaangel@gmail.com (A. Kanyabwoya); olofeahuruma@yahoo.com (H. O. Bwagilo); samwelimugaya84@gmail.com (S. T. Mugaya)
https://www.facebook.com/angelina.kanyabwoya/ (A. Kanyabwoya)

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expensive or time-consuming to perform in a traditional laboratory [1]. Similarly, ICT expands access to information and collaboration in science lessons, enabling science students to communicate with teachers and collaborate on projects with peers at any time and from anywhere [1]. With ICT, students can also work individually or together to create and share presentations, notes and other records of their learning progress [1]. Furthermore, integrating ICT into science lessons helps students develop crucial 21st-century skills, including technical and digital literacy, which are essential for the current labour market [16].

The need for science teachers to integrate ICT into their lessons and for instructors to possess the necessary technological competencies is vital. ICT integration enhances effective teaching and learning of science subjects [5, 37]. The integration of ICT in teaching and learning supports good practice in teaching science, enabling science tutors and teachers to achieve outcomes that could not be achieved without ICT, thereby facilitating the effective implementation of teaching and learning [26]. The availability of ICT resources, as well as the employment of ICT in teaching and learning, stimulates science teachers' learning and involves multiple learning styles, which allow students to develop competencies [7, 15, 21, 22]. Similarly, the integration of ICT in science lessons provides an opportunity for collaboration, the sharing of information among learners, and a chance for them to actively participate in learning [15, 21]. Correspondingly, tutors with knowledge and skills on how to apply ICT in their teaching enjoy using them in their classroom [22]. In addition, integrating ICT in science lessons enables learners to learn practically [15].

1.2. ICT integration in Tanzania

The literature in Tanzania extensively emphasises the key role of ICT in enhancing education, as it is evident in studies such as recognising the importance of this, the Government of the United Republic of Tanzania, through the Ministry of Education and Science and Technology (MoEST), acknowledged the vital role of ICT in education as early as 2007. This resulted in the formulation of the ICT Policy for Basic Education [36]. One of its primary objectives is to promote the use of ICT as a teaching and learning tool, including in science subjects. The policy also aims to ensure fair access to ICT resources for students and teachers in different educational institutions, and to promote the effective use of these resources in teaching and learning [36]. To ensure the integration of ICT in teaching and learning within schools and colleges. The MoEST advocated for ICT not only as a stand-alone subject but also as a pedagogical tool [36]. Then, various initiatives have been implemented to enhance teachers' skills in ICT integration and provision of ICT facilities, as demonstrated in studies by Swai et al. [32] and William and Kitta [39]. The initiatives include the National Information and Communication Technology Project (NICTP) for science and mathematics secondary school teachers in Tanzania (2010–13), the Teacher Education Support Project (TESP) and the Retooling Project. All the initiatives aimed at improving the integration of ICT in teaching science subjects in secondary schools and in diploma teacher training colleges in Tanzania.

Studies in the Tanzanian context have revealed the positive impact of integrating ICT in science education. For instance, Faloye and Faniran [13] conducted a study on integrating technology into teaching and learning practices, finding that the integration of ICT enhances students' competencies. Additionally, Kalyani [16], who conducted a study on the role of technology in education, found that the availability and use of ICT in teaching and learning promote learners' learning outcomes. In addition, Kalinga and Ndibalema [15] conducted a study on teachers' technological competencies in enhancing teaching and learning in secondary schools in Tanzania, and found that teachers with skills and technological competencies effectively utilise ICT in their teaching to improve teaching and learning in schools. Additionally, a study conducted by Lubuva, Ndibalema and Mbwambo [21] assessed the level of ICT competencies among tutors in teacher education in Tanzania. The study found that tutors with the skills of using ICT have confidence in using ICT materials in their teaching, which enhances students' performances. Also, Faloye and Faniran [13], who conducted a study on integrating technology in teaching and learning practices, found that the availability of technological devices in teaching and learning enhances students' competencies. Their study findings revealed

that learners performed better in science subjects in schools and colleges where ICT facilities were available and teachers and tutors were competent in their use.

Despite the importance of integrating ICT into the teaching of science subjects, empirical studies, including those by Ngodu, Ndibalema and William [26], Machumu et al. [22], and Ngao, Sang and Kihwele [25], reveal a disparity: teachers are not effectively integrating ICT into their lessons. The experience of tutors in using ICT to develop science teachers' competencies, together with the availability of ICT resources, is crucial for teaching science subjects. However, instructors' experience in using ICT in their teaching is a problem [21, 34]. Most developing countries, including Tanzania, struggle to equip instructors with the skills to integrate ICT into their science lessons, thereby enhancing the development of science teachers' competencies [21, 35]. The majority of teachers, including those who teach science subjects, lack knowledge and skills in using ICT in their teaching [15]. In Tanzania, examining the integration of ICT in science lessons to promote science teachers' competencies is crucial, especially in light of ongoing educational reforms that are characterised by numerous challenges. Despite the recognised importance of competent science teachers in enhancing learners' academic effectiveness and achievement, and the government's efforts in providing ICT resources in diploma teacher colleges in Tanzania, there is a significant gap in science tutors' experiences in integrating ICT in science lessons in diploma teacher colleges in Tanzania. The existing research has largely overlooked the specific challenges faced by science tutors in the Iringa, Dodoma, Tabora, and Tanga regions, leaving this aspect neglected in the literature; the integration of ICT in science lessons to develop science teachers' competencies is also a challenge in teaching. This study aims to fill this gap by examining the integration of ICT in science lessons to promote science teachers' competencies in diploma teacher colleges in Tanzania. Understanding these changing aspects is vital for informing policymakers, curriculum developers, and educational stakeholders who aim to enhance science teacher support and improve educational outcomes in Tanzania.

1.3. Objective

The following objective guided the study: to examine the integration of ICT in science lessons to develop science teachers' competencies for teaching science in diploma teacher colleges in Tanzania.

1.4. Theoretical framework

Many theories talk about competence-based learning in science teaching and learning. For instance, experiential learning theory, developed by Kolb [19], focuses on learning through direct experience and practical applications. The theory posits that knowledge is created through the transformation of experience, emphasising active participation, reflection and learning from doing rather than just listening and reading [19]. Another example of competence-based learning theory is connectivism and personalised paths, developed by Siemens [31], which support the idea of students learning at their own pace and accessing flexible, relevant content. The theory posits that learners are empowered to create personalised learning pathways based on their unique needs and goals, rather than following a one-size-fits-all curriculum, and can take charge of their experiences by connecting with relevant content and communities [31].

Additionally, social constructivist theory, developed by Vygotsky [38], is a competence-based learning theory that posits that learning is a result of social interaction between learners and their cultural environment. Thus, the theory emphasises the active involvement of students and the building of knowledge, as well as collaborative learning. Social constructivist theory also posits the zone of proximal development (ZPD) – the gap between what a learner can do independently and what they can achieve with guidance [38]. The theory also explains the concept of scaffolding – the temporary support provided by a "more knowledgeable other" (MKO) to help a learner with their zone of proximal development, which is defined as the gap between what a learner can do independently and what they can do with support [38]. In a college science education environment,

social constructivist theory views learning as an active and collaborative process where knowledge is constructed through social interaction and hands-on activities in ICT and science laboratories, particularly within the day-to-day experiences of the learning environment. This study employed social constructivist theory to facilitate interactions among science student teachers and with materials, including ICT devices, found in the college environment, thereby developing meaningful learning. Social constructivism also views the learning environment as a place where teachers organise and use materials, including ICT devices, to explore learners' prior knowledge and scientific enquiry [4]. It is an essentially competence-based educational theory based on observations and scientific studies of how student teachers learn and interact with ICT devices, such as projectors, computers, iPads, smartphones, smart televisions, and interactive whiteboards, which allow them to actively engage in creating knowledge to develop their competencies in their immediate learning environment. Thus, new information is interpreted through the existing mental frameworks of a student teacher, rather than simply being absorbed. This idea aligns with the focus of social constructivist theory, which asserts that students actively build new knowledge on what they already know [38]. The theory also emphasises the importance of a college environment that facilitates and supports the use of ICT materials in science lessons to develop science teachers' competencies. Integrating ICT in learning contributes to the development of learners' competencies [2–4, 22, 30]. Thus, the study focuses on examining the integration of ICT in promoting science teachers' competencies for teaching science in Tanzania.

2. Methodology

2.1. Research approach and design

The study employed a qualitative approach to examine the integration of ICT in science lessons to promote science teachers' competencies. The study used the approach to explore respondents' views in natural social settings. Creswell [10] claims that qualitative studies explore how people make meaning of the problem investigated in a natural social setting. The study used interviews and focus group discussions to explore participants' views on how the integration of ICT in science lessons develops science teachers ' competencies. Correspondingly, the study employed a multiple-case study research design to collect data through qualitative methods, including interviews, focus group discussions, observation, and documentary review, in order to gain an in-depth understanding of the integration of ICT in science lessons and promote science teachers' competencies for teaching science.

2.2. Participants

The study involved 4 college principals, 4 academic deans, 4 college internal quality assurers, 12 science tutors, 4 ICT and computer science tutors and 38 science student teachers, making a total of 66 participants who were selected purposively to seek information on the integration of ICT in science lessons to promote science teachers' competencies for teaching science.

2.3. Research instruments

The study employed an interview guide to gather information from college principals, academic deans, internal quality assurers, science tutors, and ICT and computer science tutors, aiming to elicit their views on the integration of ICT in science lessons and promote science teachers' competencies for teaching science. Additionally, the study utilised focus group discussions to gather the opinions of science teachers. It employed a non-participant observation guide sheet to observe teaching and learning activities taking place during science lessons for both science tutors and science teachers. Furthermore, the study reviewed various academic documents, such as schemes of work and lesson

plans, to have an in-depth understanding of the integration of ICT in science lessons to promote science teachers' competencies for teaching science.

2.4. Data analysis procedure

This study employed the Miles and Huberman [23] framework for qualitative data analysis to organise the data [29]. The technique was employed to analyse data collected through interviews with college principals, academic deans, college internal quality assurers, science tutors and ICT and computer science tutors. The technique was also used to analyse data collected through focus group discussions conducted with science student teachers in the studied colleges, as well as data from reviewed documents and classroom observations. The three stages of Miles and Huberman's [23] framework are described as follows.

The first stage is data reduction, which occurs continually throughout the analysis [23, 24, 29]. In the early stages of data reduction, data collected from college principals, academic deans, internal quality assurers, science tutors, ICT and computer science tutors, and science student teachers through interviews and focus group discussions were transcribed, edited, segmented and summarised. The data also obtained from document reviews and classroom observations were edited, segmented and summarised. In the middle stages, the transcribed interviews and focus group discussions, together with the reviewed documents and observed data, were coded using themes, clusters, and patterns. Coding is the stage at which data are reduced by condensing them [23, 29]. In the later stages of data reduction, the coded data obtained from college principals, academic deans, internal quality assurers, science tutors, ICT and computer science tutors, and science student teachers, as well as data from documents reviewed and classroom observations, were conceptualised and explained.

The second stage is data display [24, 29]. At this stage, the researcher organised the data collected from college principals, academic deans, internal quality assurers, science tutors, ICT and computer science tutors, and science student teachers, and that from documents reviewed and classroom observations in order to identify recurring patterns; that is, grouping related themes and labelling them, in order to highlight the most distinctive features. This labelling process clarifies the qualitative differences between categories, explaining how the integration of ICT in science lessons promotes science teachers' competencies in diploma teacher training colleges.

The third stage involves drawing and verifying conclusions [24, 29]. At this stage, the reduced and displayed data from college principals, academic deans, internal quality assurers, science tutors, ICT and computer science tutors, and science student teachers, as well as data from reviewed documents and classroom observations, were used to inform the conclusion. Themes that had been organised and labelled were in the form of propositions and were used to conclude [24]. The analysis procedures were performed on data collected within and between cases, as well as within and between the four selected diploma teacher colleges. The data collected from participants were compared within and between colleges to inform the discussion and conclusion on the integration of ICT in science lessons, promoting science teachers' competencies for teaching science.

2.5. Trustworthiness

Credibility, dependability, confirmability and transferability are key issues to guarantee the study findings [6, 12, 14, 20]. The study established credibility through prolonged engagement in the field during data collection, which enabled the collection of essential information on the integration of ICT in science lessons to promote science teachers' competencies for teaching science. Credibility was also confirmed through the use of the member check technique during proposal development, which verified the data collection tools and the collected data, ensuring that the findings align with the study's intended objectives. Dependability was ensured by describing the research methods used during data collection and consulting with the supervisor and other research experts during the development of the research proposal and instruments, which provided the necessary information on integrating ICT in science lessons to promote science teachers' competencies for teaching science.

Confirmability, here, the study kept detailed notes of procedures used during data collection and analysis throughout the study. To enhance transferability, the study described the context, location, participants, and the study problem, informing readers about the integration of ICT in science lessons to promote science teachers' competencies in teaching science.

2.6. Ethical considerations

The study considered five ethical responsibilities, including the voluntary participation of respondents, obtaining a research permit, avoiding harm and bias to the respondents, maintaining confidentiality and anonymity during research conduct [28, 29]. Considering the above ethical considerations, the study briefly explained its purpose and value to society, the educational sector, and its stakeholders. The researcher also asked participants about their willingness to participate in the study and stated that the findings were not biased. Additionally, the study ensured the confidentiality of the information provided by the respondents, using it only where necessary. Similarly, the researcher labelled the selected diploma teacher colleges by letter and assigned numbers to the participants. Furthermore, the study requested a research permit from the Vice Chancellor of the University of Dodoma.

3. Results

The study aimed to examine the integration of ICT in science lessons to promote science teachers' competencies for teaching science in diploma teacher colleges in Tanzania. One research objective guided the study; therefore, the study results are presented with reference to this objective.

The study investigated the integration of ICT in science lessons to promote science teachers' competencies. Qualitative data collected from college principals, academic deans, college internal quality assurers, science tutors, ICT and computer science tutors, and science student teachers concerning with integration of ICT in science lessons for promoting science teachers' competencies revealed three key issues such as availability of ICT resources in diploma teacher colleges, practice on the use of ICT for teaching science subjects and administrative support on the use of ICT for teaching and learning science subjects as presented in table 1.

3.1. Availability of ICT resources in diploma teacher colleges

The study sought to gather respondents' opinions on the availability of ICT resources in diploma teacher colleges as one of the factors influencing the integration of ICT in the teaching and learning of science subjects. The interview with respondents revealed that all diploma teacher colleges have the necessary ICT resources, though the environment and ICT resources found in colleges differ from one college to another. On this aspect of ICT resources availability, one science tutor from selected diploma teacher colleges said:

> Our college has an ICT laboratory and resources like computers, projectors, projector screens, iPads, smart television and whiteboards, as well as internet access and various software that support teaching and learning of science subjects. I feel secure and happy, especially when I teach my chemistry students. Additionally, I mostly use a computer to prepare lesson notes, lesson plans, scheme of work and PowerPoint slides for my subject presentation. Not only that, but I also provide online assignments that require my students to surf materials and perform their tasks, which in turn develop their competencies. (Interview with science tutor, college B, 2024)

Likewise, one of the FGDs developed said:

> Our college has all the necessary ICT devices like computers, white boards, iPads, projectors, just to mention a few, as well as internet access for us to access when given online tasks, when surfing materials. Additionally, we do learn science using ICT resources in

Table 1
Integration of ICT and science teachers' competencies [17].

Themes	Findings from participants' responses in colleges A, B, C and D	Reasons from participants findings in colleges A, B, C and D
Availability of ICT resources	• ICT materials are available in diploma teacher colleges, though the availability differs from one college to another. • Some colleges have adequate ICT resources, while others have limited resources.	• Presence of projectors and their screens, smart TV, iPads, computers, smart phones, white boards and internet sources in diploma teacher training colleges
The use of ICT in science lessons	• 4 science tutors used ICT in their teachings due to adequate skills, flexibility, adequate ICT resources and support from administrators.	• Teaching science using simulations, animations and PowerPoint presentations. • Providing online assignments and soft copy notes • Tutors use a computer to prepare lesson notes, lesson plans, scheme of works and PowerPoint slides for the subject presentations.
	• 8 out of 12 science tutors did not use ICT in their teachings due to lack of skills, inadequate ICT resources, rigidity and limited administrative support.	• Science tutors teach using chalk and a board. • Providing written quizzes and assignments.
Administrative support on the use of ICT in science lessons	• Few administrators support the use of ICT in science lessons.	• Availability of ICT devices such as projectors and their screens, smart TV, iPads, computers, smart phones, white boards and internet sources, which are in good condition in colleges
	• Majority face challenges to support the use of ICT in science lessons when requested.	• Inadequate ICT materials and some of them being in bad conditions due to limited budget and the delays and inadequate funds administrators receive from the government.

> some of our science subjects. Furthermore, the use of ICT during science lessons makes lessons attractive and enhances creativity in both tutors and science student teachers. (FGD, college C, 2024)

In the line of thinking, the responses from college pricipals in college A, B, C nad D reported the presence of ICT resources by explainig that the government of Tanzania through various programs including Teacher Education Support Project (TESP) provide support to diploma teacher colleges by doing rehabilitation of buldings including ICT laboratories and provision of ICT resources such as projectors, projector screens, computers, iPads and smart television which are necessary for teaching and learning science. In addition, the responses from academic deans in colleges A, B, C, and D reported the presence of materials such as projectors, whiteboards, computers and internet sources within their colleges. Also, data obtained from document reviews, such as schemes of work and lesson plans of some science tutors in colleges, showed the suggested teaching and learning materials, like projectors, smart phones, iPads, computers, and data from classroom observations showed that

some science tutors used the ICT resources as suggested in their lesson plans.

The responses from participants and data from classroom observations indicate that diploma teacher training colleges have ICT resources; however, the environment and availability of these resources vary from one college to another due to several factors, including class size and administrative support. Thus, some colleges have limited ICT resources, while others have adequate resources. The availability of ICT resources has a positive impact on the teaching and learning of science, as well as the development of science teachers' competencies. This is because the availability of ICT resources creates an environment that stimulates tutors to use ICT when teaching their student teachers. Through the use of ICT in their teaching, science student teachers can learn practically, which in turn promotes the development of their competencies. This study's findings align with those of Kalyani [16], who conducted a study on the role of technology in education, enhancing learning outcomes and 21st-century skills, and found that the availability of ICT resources improves learning outcomes.

Additionally, the study's findings are supported by those of Faloye and Faniran [13], who conducted a study on integrating technology in teaching and learning practices, and found that the availability of technological devices in teaching and learning enhances students' competencies. In addition, social constructivist theory posits the presence of a teaching and learning environment that is well-equipped with resources, allowing learners to interact with these materials to produce meaningful learning. Some colleges studied had ICT resources that allowed science tutors to integrate them into their teaching, and student teachers were able to interact with these ICT resources during their learning through material surfing, using animations, and completing online assignments. However, in some colleges, their ICT resources were limited, as indicated in table 1. This finding hurts the teaching and learning of science subjects in diploma teacher colleges in Tanzania. Inadequate ICT resources hinder the integration of these resources in science lessons, as science tutors use alternative methods that they have found most effective in the absence of ICT resources. This study's findings were supported by those of Ngodu, Ndibalema and William [26], who conducted a study on understanding stakeholders' perceptions of integrating ICT in teaching and learning science subjects, based on experiences from Tanzanian secondary schools. The study found that inadequate ICT resources negatively affect the teaching and learning of science subjects in schools.

3.2. Practice on the use of ICT for teaching and learning science subjects

This section presents tutors' practices on the use of ICT for teaching and learning science subjects in diploma teacher colleges. Data for this facet were collected from college principals, academic deans, college internal quality assurance officers, science tutors, ICT and computer science tutors, and science student teachers. The results from participants on integrating ICT in science lessons produce different responses, as presented in table 1. Few science tutors used ICT in their teaching, and the majority did not use ICT resources in their teaching due to several factors, including tutors' skills, availability of ICT resources, rigidity, and lack of administrative support. Based on the aspect of using ICT in science lessons, one of the science tutors in selected diploma teacher colleges argued:

> I do use ICT to teach my biology student teachers because I have the skills to use a projector and a computer. Moreover, I do prepare PowerPoint presentations, lesson plans and schemes of work as well as online assignments to simplify my teaching and make biology lessons attractive and well understood by student teachers. Not only that, but I also use animations in some topics for more clarification. (Interview with science tutor, college D, 2024)

In addition, FGD developed reported that:

> In our college, chemistry and biology tutors do use ICT during lessons, they usually provide us with online assignments, and sometimes they request us to surf materials, and they sometimes teach us using a PowerPoint presentation. Additionally, on our side,

> as science student teachers, we do use ICT like smartphones and iPads to search for materials and perform assignments given by our tutors. (FGD, college D, 2024)

In addition, the responses from Internal quality assurers in colleges A, B, C and D testify to the use of ICT by a few science tutors. They reported that during their classroom monitoring process, they observed some science tutors using PowerPoint presentations and animations to teach science concepts. Additionally, academic deans from colleges A, B, C, and D reported the use of projectors, iPads, and computers in science lessons. Likewise, college principals from colleges A, B, C and D reported the use of ICT by some of the science tutors in their colleges. In addition, data from the reviewed science tutors' lesson plans and classroom observations indicate that few of them included ICT resources in their lesson plans and effectively incorporated them into their teaching.

The responses from participants, combined with data from the document review and classroom observations, indicate that few science tutors utilised ICT in their science lessons. The use of ICT in science lessons enhances the teaching and learning of science subjects, promoting the competencies of science teachers. Integrating ICT into science lessons enables tutors to cover a wide range of topics and concretely teach abstract concepts. Science student teachers can also surf teaching and learning materials, complete online assignments and capture abstract concepts using animations and simulations. This positively impacts the teaching and learning of science subjects, promoting the competencies of science teachers in their teaching of these subjects. This study's findings are supported by those of Faloye and Faniran [13], who conducted a study on integrating technology in teaching and learning practices and found that integrating ICT enhances students' competencies.

Additionally, this study's findings align with those of Kalyani [16], who investigated the role of technology in education, focusing on its impact on learning outcomes and 21st-century skills. The study found that the use of ICT in teaching and learning promotes learners' learning outcomes. In addition, the study findings align with those of Kalinga and Ndibalema [15], who conducted a study on teachers' technological competencies in enhancing teaching and learning in secondary schools in Tanzania. The study found that teachers with skills and technological competencies utilise ICT in their teaching to enhance teaching and learning in schools. This study's findings are also supported by the results of a study conducted by Lubuva, Ndibalema and Mbwambo [21] on the assessment of tutors' level of ICT competencies in teacher education in Tanzania. The study found that tutors with the skills of using ICT have confidence in using ICT materials in their teaching.

Nevertheless, participants' responses showed that the majority of science tutors did not use ICT in their science lessons due to several factors, including inadequate skills among science tutors, insufficient ICT resources, rigidity, and limited administrative support, as presented in table 1. Illustrating this phenomenon, one of the science tutors in one of the selected diploma teacher colleges said:

> Despite the fact that our college is well equipped with all necessary ICT resources like computers, projectors, iPads and whiteboards, I do face challenges and difficulties in using them because I don't have enough skills to integrate ICT in my physics lessons. Additionally, I don't use ICT because I feel like I'm not competent enough to use it in my presentation. (Interview with science tutor, college C, 2024)

In addition, one of the FGDs developed argued:

> Being the fact that the use of ICT during science lessons makes lessons attractive, enhance creativity and develop competencies to both tutors and science student teachers, some science tutors in our college never use ICT during class lessons instead they just explain to us various csience concepts and giving us written assignments to work on them and some of the science tutors use ICT in a wrong way during their teachings. (FGD, college A, 2024)

In addition, responses from college internal quality assurers in Colleges A, B, C, and D reported that the majority of science tutors in these colleges do not use ICT in their teaching; instead, they simply explain and write science concepts on the blackboard and give their students written assignments to complete. Additionally, the responses from the academic deans of colleges A, B, C, and D, who were responsible for monitoring the teaching and learning process, revealed that some tutors do not utilise ICT in their teaching. The academic deans further reported that when science tutors were asked why they did not use ICT in their lessons, some said they lacked the necessary skills, while others cited insufficient ICT materials, meaning they had to fight for resources with other tutors. Some also mentioned a lack of administrative support, while others simply preferred their teaching style. In addition, science tutors' lesson plans reviewed in colleges showed that the majority of them did not suggest ICT materials for the lessons, and this was supported by classroom observations, which show that the majority of science student teachers did not use ICT resources in their teachings; they just taught using chalk and board and written quizzes and assignments.

Participants' responses, as well as data from the document review and classroom observations, indicate that the majority of science tutors did not integrate ICT into their science lessons. This can hinder science student teachers' understanding of abstract concepts through visualisation, limit their access to massive information resources, prevent the development of 21st-century digital skills and reduce engagement and motivation in learning science. Thus, the lack of ICT use in science lessons negatively affects the development of science teachers' competencies in colleges. This study's findings align with those of Ngodu, Ndibalema and William [26], who conducted a study on understanding stakeholders' perceptions of integrating ICT in teaching and learning science subjects. The study found that there was minimal use of ICT in science lessons in schools due to inadequate skills among science teachers and insufficient ICT materials. Additionally, this study's findings align with those of Machumu et al. [22], who conducted a study on instructors' experiences with using ICT in facilitating student teachers' learning. The study found that instructors lack the skills necessary for using ICT in their teaching, which hinders the integration of ICT in teaching and learning.

3.3. Administrative support on the use of ICT for teaching and learning science subjects

The study assessed the extent to which administrative support enhances ICT integration in the teaching and learning of science subjects in diploma teacher colleges. Referring to participants' views on administrative support for the use of ICT in teaching and learning, participants' responses varied, as presented in table 1. Some participants stated that a few administrators support the use of ICT in science lessons, while others responded that the majority of administrators face challenges in supporting the use of ICT in science lessons when requested. Thus, the results revealed minimal administrative support. With regard to administrators supporting the use of ICT in science lessons, one of the science tutors from one of the selected colleges said:

> For me, I can say that college administrators support teaching and learning by ensuring that the internet is available for us and our student teachers to seek information about science subjects. Additionally, they also make sure the devices, like projectors and computers, are in good maintenance and ready for use. To me, integrating ICT in my chemistry lessons in each period is not an issue because of the support I get from the college principal and academic dean. (Interview with science tutor, college D, 2024)

In addition, one of the college principals had this to say:

> The college is full of ICT resources such as computers, projectors and iPads to support tutors' teaching of science. My duty as Principal is to make sure that they are in good order and doing maintenance when required. Not only that, but also insisting that science tutors use ICT in their lessons. However, for science tutors who face challenges in using ICT, I usually conduct indoor training for capacity building. (Interview with principal, college C, 2024)

In line with this thinking, academic deans in colleges A, B, C, and D reported that college administrators support the use of ICT in science lessons. Thus, they ensure that ICT resources are available and in good condition to be integrated into science lessons and provide in-house training to equip science tutors with knowledge and skills about the integration of ICT. In support of this, focus group discussions (FGDs) conducted in colleges indicate the availability of ICT resources, such as computers, projectors, iPads, and smart televisions, as well as internet sources, which are in good working order. Additionally, classroom observations revealed the availability of ICT resources in classrooms and laboratories that science tutors and student teachers utilised during science lessons.

Participants' responses and data from classroom observations indicate that administrative support for the use of ICT in science lessons is available in some colleges. The availability of administrative support enables the availability of ICT resources and the maintenance of those materials that are not in good order. This motivates science tutors to use ICT resources in their teaching. The use of ICT in science lessons enhances science teaching and learning, promoting science teachers' competencies by enabling science student teachers to understand abstract concepts through visualisation, providing access to massive information resources, fostering the development of 21st-century digital skills, and increasing engagement and motivation in learning science subjects. This study's findings relate to those of Binsaleh and Binsaleh [9], who conducted a study on the teaching and learning process through ICT integration in private Islamic schools in Thailand. The study found that administrative support is important in enabling ICT integration in the teaching and learning process in schools.

Nevertheless, the participants' views in some colleges indicate that administrative support is minimal due to the limited budget colleges receive from the government, as well as inadequate and delayed funding, as presented in table 1. Illustrating this aspect, one of the science tutors from one of the selected colleges argued:

> I see that the administrative system is not well implemented in our college. For instance, when I want to use ICT, I face the challenge of ICT materials not being in good condition, and when I request a solution, the administrators claim a limited budget. Additionally, internet access is also a problem for our college; all these hinder me from integrating ICT into my lessons. Not only that, but also inadequate ICT resources in our college are also a case, and the ICT resources we have cannot accommodate the large number of students enrolled in the college. Generally, the administrative support for the use of ICT in teaching and learning science in our college is low. (Interview with science tutor, college B, 2024)

Aligned with the response above, some college principals in colleges B, C, and D reported that they wish to support the use of ICT in science lessons at the standard level; however, they face challenges when it comes to purchasing and maintaining ICT resources. Thus, a lack of sufficient funds and delays in budgeting make them fail to meet the demands of their subordinates. Likewise, the FGD conducted in colleges B and D revealed that science student teachers face challenges in accessing ICT resources during learning; some computers and iPads were not functioning, and there was sometimes no internet access. When they requested support from administrators, they often received incorrect support. In addition, classroom observations revealed inadequate ICT resources in some colleges and the presence of ICT resources that need maintenance.

The responses from participants and data from classroom observations show that there is limited administrative support for the use of ICT in science lessons in diploma teacher colleges in Tanzania. The majority of administrators fail to support the use of ICT resources, maintain some resources, and also fail to conduct in-house training for their subordinates. Science tutors struggle to integrate ICT into their teaching, with some not using it at all. This hurts the teaching and learning of science subjects, as well as the development of science teachers' competencies. This study's findings relate to the study by Ngodu, Ndibalema and William [26], which investigated stakeholders' perceptions of integrating ICT in teaching and learning science subjects. The study found that minimal administrative support hinders the use of ICT in science lessons, which in turn limits the development of students' competencies.

4. Discussion

The study examines the integration of ICT in science lessons to promote science teachers' competencies for teaching science in diploma teacher colleges in Tanzania. The study is based explicitly on science tutors' use of ICT in teaching and learning science to develop science teachers' competencies for teaching science.

4.1. Availability of ICT resources in diploma teacher colleges

The responses from participants and data from classroom observations indicate that diploma teacher training colleges have ICT resources; however, the environment and availability of these resources vary from one college to another due to several factors, including class size and administrative support. Thus, some colleges have limited ICT resources, while others have adequate resources. The availability of ICT resources has a positive effect on the teaching and learning of science, as well as on the development of science teachers' competencies. This is because the availability of ICT resources creates an environment that encourages science tutors to incorporate ICT into their teaching of student teachers. Through the use of ICT in their teaching, science student teachers are able to learn practically, which in turn promotes the development of their competencies. This study's findings relate to those of Kalyani [16], who conducted a study on the role of technology in education, enhancing learning outcomes and 21st-century skills. The study found that the availability of ICT resources enhances students' learning outcomes. Additionally, the study's findings are supported by those of Faloye and Faniran [13], who conducted a study on integrating technology in teaching and learning practices, and found that the availability of technological devices in teaching and learning enhances students' competencies.

However, some colleges had limited ICT resources. This negatively affects the teaching and learning of science subjects at diploma teacher training colleges in Tanzania. Inadequate ICT resources hinder the integration of ICT into science lessons, as science tutors often resort to alternative methods when ICT resources are unavailable. This study's findings were supported by those of Ngodu, Ndibalema and William [26], who conducted a study on understanding stakeholders' perceptions of integrating ICT in teaching and learning science subjects. The study found that inadequate ICT resources negatively affect the teaching and learning of science subjects in schools.

4.2. The integration of ICT in science lessons in diploma teacher colleges

The results from participants on integrating ICT in science lessons revealed that few science tutors used ICT in their teaching, while the majority did not utilise ICT resources in their teaching due to several factors, including tutors' skills, availability of ICT resources, rigidity, and lack of administrative support. The responses from participants, combined with data from the document review and classroom observations, indicate that few science tutors utilised ICT in their science lessons. The use of ICT in science lessons enhances the teaching and learning of science subjects and promotes the competencies of science teachers. Integrating ICT into science lessons enables tutors to cover a wide range of topics and concretely teach abstract concepts. Science student teachers can also surf learning materials, complete online assignments and capture abstract concepts using animations and simulations. This has a positive impact on the teaching and learning of science subjects, promoting the competencies of science teachers. This study's findings are supported by those of Faloye and Faniran [13], who conducted a study on integrating technology in teaching and learning practices and found that integrating ICT enhances students' competencies.

Additionally, this study's findings align with those of Kalyani [16], who investigated the role of technology in education, focusing on its impact on learning outcomes and 21st-century skills. The study found that the use of ICT in teaching and learning promotes learners' learning outcomes. In addition, the study findings align with those of Kalinga and Ndibalema [15], who conducted a study on teachers' technological competencies in enhancing teaching and learning in secondary schools in

Tanzania. The study found that teachers with skills and technological competencies utilise ICT in their teaching to enhance teaching and learning in schools. This study's findings are also supported by the results of a study conducted by Lubuva, Ndibalema and Mbwambo [21] on the assessment of tutors' level of ICT competencies in teacher education in Tanzania. The study found that tutors with the skills of using ICT have confidence in using ICT materials in their teaching.

However, participants' responses and data from the reviewed documents and classroom observations show that the majority of science tutors did not integrate ICT into their science lessons due to several factors, including inadequate skills among science tutors, inadequate ICT resources, rigidity, and limited administrative support. This can hinder science student teachers' understanding of abstract concepts through visualisation, limit their access to massive information resources, prevent the development of 21st-century digital skills and reduce engagement and motivation in learning science. Therefore, not using ICT in science lessons hurts the development of science teachers' competencies at college. This study's findings relate to the findings of Ngodu, Ndibalema and William [26], who conducted a study on understanding stakeholders' perception on integrating ICT in teaching and learning science subjects: Experiences from Tanzanian secondary schools and found that there was minimal use of ICT in science lessons in schools due to inadequate skills of science teachers and inadequate ICT materials. Additionally, this study's findings align with those of Machumu et al. [22], who conducted a study on instructors' experiences with using ICT in facilitating student teachers' learning. The study found that Instructors lack the skills necessary for using ICT in their teaching, which hinders the integration of ICT in teaching and learning.

4.3. Administrative supports on the use of ICT in science lessons in teacher colleges

Participants' responses regarding administrative support for the use of ICT in teaching and learning revealed minimal support. Some participants reported that few administrators support the use of ICT in science lessons, while others responded that the majority of administrators struggle to provide this support when requested. Participants' responses and data from classroom observations indicate that administrative support for the use of ICT in science lessons is available in some colleges. The availability of administrative support enables the provision and maintenance of ICT resources that are not in good order. This motivates science tutors to use ICT resources in their teaching. Using ICT in science lessons enhances teaching and learning, promoting the competencies of science teachers and the understanding of abstract concepts among science student teachers through visualisation. It also provides access to vast information resources and promotes the development of 21st-century digital skills, while increasing engagement and motivation in the study of science subjects. This study's findings relate to those of David, Tanui and Oruta [11], who conducted a study on the role of school administration in the implementation of ICT in human resources administration in public secondary schools. They found that administrators who are supportive promote the implementation of ICT in secondary schools. Additionally, this study's findings relate to those of Binsaleh and Binsaleh [9], who conducted a study on the teaching and learning process through ICT integration in private Islamic schools in Thailand. They found that administrative support is crucial in enabling ICT integration in the teaching and learning process in schools.

However, some participants' views indicate that administrative support is minimal due to the limited budget colleges receive from the government, as well as inadequate and delayed funding. The majority of administrators fail to support the use of ICT resources, maintain some ICT resources, and conduct in-house training for their subordinates. Science tutors struggle to integrate ICT into their teaching, with some of them not using it at all. This hurts the teaching and learning of science subjects, as well as the development of science teachers' competencies. This study's findings relate to the study by Ngodu, Ndibalema and William [26], who found that minimal administrative support hinders the use of ICT in science lessons, which in turn limits the development of students' competencies.

4.4. Challenges facing teaching and learning of science in diploma teacher colleges

The participants' responses, which addressed the question of what the challenges are in the teaching and learning of science subjects, revealed that a lack of adequate skills in using ICT in science subjects during lessons, as well as inadequate ICT materials such as projectors, computers, iPads, smartphones, and smart televisions, are among the challenges. Additionally, the delay in ICT materials when needed, especially during teaching and learning science subjects, and some science tutors' resistance to changing the way they teach, thus clinging to outdated teaching methods and failing to keep up with scientific and technological developments, were also challenges. These findings relate to the study conducted by Agyei [3] on integrating ICT into schools in sub-Saharan Africa, which found that a lack of teachers' skills and inadequate resources hinder the integration of ICT in classrooms.

4.5. Suggestions to improve teaching and learning of science subjects in teacher colleges

The responses from participants regarding suggestions to improve the teaching and learning of science subjects revealed that conducting several in-service training sessions, providing internet access, and having adequate ICT materials such as projectors, computers, smart televisions, and whiteboards on time may improve the teaching and learning of science subjects. The study findings align with those of Ngao, Sang and Kihwele [25], who conducted a study on understanding teacher educators' perceptions and practices regarding the integration of ICT in teacher education programs. The study found that the availability of teaching and learning materials, as well as in-service training, improves teaching and learning in schools. Additionally, the findings align with those of Abidoye, Ahmed and Olorundare [1], who conducted a study on the effectiveness of ICT on teachers' science teaching, and found that the availability of ICT facilities and in-house training will improve the teaching and learning of science. The findings, however, suggest that college principals reported delays in funding and inadequate budgets for ICT resources. The government of Tanzania should ensure that diploma teacher colleges are either provided with ICT materials or allocated sufficient budgets in a timely manner.

5. Conclusions and recommendations

The analysis of the study findings indicates that all diploma teacher colleges have ICT resources; however, the availability of ICT materials varies from one college to another. Despite the availability of ICT materials shown by participants, the integration of ICT in teaching and learning science subjects is minimal. The limited integration of ICT in science lessons is due to inadequate skills in using ICT, inadequate ICT materials resulting from an insufficient budget, a lack of support from management, delays in ICT materials, especially when needed, and poor conditions of ICT materials. With these notes, the study can conclude that, despite the availability and willingness to use ICT in teaching and learning science subjects, its application in classrooms is still unimpressive. Therefore, student-teachers are likely to remain incompetent in science subjects. Furthermore, the study findings reveal that the administrative system responsible for guaranteeing the effective implementation of ICT in diploma colleges remains challenging.

The unfavorable results revealed about integration of ICT in teaching science subjects in diploma teacher colleges trigger recommendations to science tutors to use ICT such as projectors, computers, smart phones, iPads, animations, simulations and internet access in their science lessons to make lesson attractive by using them to explain abstract concepts and difficult topics and enable student teachers acquire the 21st century digital skills. Likewise, the college management team is required to be innovative enough to create other sources of income by initiating projects that would generate fund to support the college in affording some of the costs such as organising seminars and indoor trainings for building capacity to science tutors and buying ICT materials such as computers, projectors iPads and projector screens to allow integration of ICT in teaching and learning science. Similarly, the government needs to ensure the availability of education projects that enable them to have

adequate funds for the education sectors and institutions, which will help in running diploma teacher colleges, including the construction of ventilated classrooms with electric power, ICT laboratories and buying computers, projectors, iPads and whiteboards to support teaching and learning of science. In addition, the study recommends further study to examine the administrative factors that influence the integration of ICT for effective teaching and learning of science subjects in diploma teacher colleges.

Data availability statement

Data will be available for use in the public portal after publication.

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Declaration on Generative AI

During the preparation of this work, the authors used DeepL Translate and ChatGPT to check grammar and spelling.

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