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Understanding stakeholders' perception on integrating ICT in teaching and learning science subjects: Experiences from Tanzanian secondary schools

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Abstract. This study investigated stakeholders' perceptions of the integration of ICT in teaching and learning science subjects in secondary schools. A cross-sectional survey design, using a mixed approach, guided the study. Survey questionnaires and interviews were used for data collection. A total of 221 respondents, including students, teachers, heads of schools and district education officers, were sampled. The SPSS version 24 was used for quantitative data analysis. The qualitative data from the interviews were subjected to thematic analysis. Results indicate that stakeholders had positive perceptions of the benefits of integrating ICT in teaching science subjects. However, their positive perception was hampered by the accessibility of ICT materials, insufficient pedagogical knowledge and limited support from school management. Therefore, it affects the integration of ICT in teaching and learning science subjects. The study recommends government and management support to ensure sufficient ICT materials. Further, teachers should be equipped with sufficient pedagogical knowledge for ICT integration in teaching and learning science subjects.

Keywords: ICT integration, science subjects, secondary schools, stakeholders

1. Introduction

Improving the quality of teaching and learning science subjects is the key focus of most educational leaders worldwide. Therefore, schools are striving to ensure quality teaching and learning of science subjects [9]. Several initiatives are available to guarantee quality science teaching and learning in secondary schools, including the integration of information and communication technology (ICT) [1, 18]. Therefore, most nations worldwide need help to accommodate ICT in their national education curriculum, including science subjects [20]. This is because ICT makes teaching methods more dynamic and effective [20, 27]. It further provides a range of tools for both online and traditional learning environments in the science classroom [24].

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Akram et al. [4] establish that ICT-integrated instructional practices enhance not only the quality of teaching and learning of science subjects but also enable students to develop their skills, boost their motivation, and enhance their knowledge and information efficiently. ICT-integrated learning practices in science subjects enhance the cognitive understanding and learning achievements of students in secondary schools [28]. Therefore, policymakers and software (and hardware) manufacturers are in constant pursuit of developing relevant materials and tools for teaching and learning science subjects. Despite the eagerness of policymakers and software (and hardware) manufacturers, research has not found clear evidence of a positive effect of ICT integration for learning science [5, 53].

Further, studies register different concerns on its effectiveness and use, including teachers' difficulties in making the best use of ICT in their science instructional practices due to inadequate technological competencies [19]. Other scholars report teachers' negative attitudes towards integrating ICT in teaching science subjects, while others prefer the use of traditional methods [40]. Despite the reported concerns, most of the literature still [4**?**] stress the fundamental role of ICT in teaching and learning. In the context of the conflicting debate, it may not be clear how teachers perceive ICT integration in teaching and learning science subjects. Therefore, the current study investigated the stakeholders' perceptions of integrating ICT for teaching and learning science subjects in secondary schools.

1.1. ICT in teaching and learning of science subjects

The place of integrating ICT in teaching science subjects in secondary schools cannot be overemphasised, considering its promising effect on teaching and learning. For instance, Abidoye, Ahmed and Olorundare [1] positions that ICT plays a critical role in everyday human activities and living. This facilitates the management and adoption of the demands of the environment. Therefore, if the vision of science education is to bring about human development, the role of ICT in science teaching and learning cannot be overemphasised. The sustainable development goals (SDGs) number four emphasises the provision of quality education [49]. With respect to goal number four, quality teaching of science and technology for human development is supreme. Further, UNESCO [51] stresses the need for ensuring effective science learning through advanced and technological pedagogies, specifically the use of ICT. UNESCO highlights that when teachers are trained to use ICT in science subjects, it can lead to higher-order thinking skills. Further, students become creative and are better prepared to deal with ongoing technological change in society and the workplace.

The vast literature on the role of ICT integration in science learning in developed countries such as the United States, the United Kingdom, and Germany suggests that students can use different tool applications to learn various science concepts. Jiménez et al. [23] noted several tool applications that can be used in teaching and learning science subjects, including word processing, publications and presentation software, spreadsheets, databases, multimedia, web browsers and email. For instance, word processing software can be used for organising ideas, writing homework, and project works [9]. Furthermore, McFarlane and Sakellariou [32] report that integrating ICT in teaching science as a tool or laboratory-based element has many advantages. One, it can help with theoretical and practical conceptual understanding of some topics in the science curriculum. Second, some computer simulations can be used as effectively

as the real activity in teaching science concepts [50, 57].

Baggott La Velle, McFarlane and Brawn [7] suggest that students in science classrooms with ICT support benefit from the instant feedback from experiments and the opportunity for more autonomous and self-directed learning. Additionally, Bogusevschi, Muntean and Muntean [9] developed a 3D virtual environment for teaching some physics aspects. The study suggested that using a virtual environment may help students with high spatial aptitude to acquire better conceptual understanding. Therefore, students who are exposed to learning science subjects through ICT are in the best position to understand science more easily compared to those using traditional methods.

Similarly to developed countries, developing countries also acknowledge the role of ICT in teaching and learning science education subjects. For example, Ahmad [3] and Amuko, Miheso and Ndeuthi [5] note that most countries have developed ICT policies in teaching and learning from the elementary grades to universities. For instance, in South Africa, the policy for ICT integration was adopted in 2004 [29]. In this regard, teachers are encouraged to ensure the use of ICT for effective teaching and learning, including science subjects. Likewise, Ahmad [3] in Nigeria examined the extent of ICT integration in teaching and learning physics and its impact on students' performance. Ahmad [3] concluded that students perform better in science subjects when taught through ICT. Amuko, Miheso and Ndeuthi [5] studied the Integration of ICT in teaching and learning Mathematics in secondary schools in Nairobi, Kenya and noted that teachers who used ICT had better teaching pedagogies, unlike those who did not.

While studies document the fundamental role of ICT integration in teaching science subjects, Sang et al. [46] studied the frequency of ICT usage in the classroom and found that overuse of ICT devices and ICT-based activities was not pleasing to students. Further, in a large-scale study involving science students across all levels of secondary school, Vaughan, Beers and Burnaford [54] found that about one-third of the students surveyed viewed ICT integration as not necessarily making science lessons fun, exciting and enjoyable. Similarly, in Kenya, Amuko, Miheso and Ndeuthi [5] reports a lack of teachers' confidence, thus hindering them from using ICT in their teaching of science subjects. In addition, Kuskaya-Mumcu and Koçak-Usluel [26] indicated that teachers' limited ICT knowledge makes them feel anxious about using ICT in the classroom and thus not confident to use it in their teaching science subjects. Similarly, Agyei and Voogt [2] in Ghana reported a low level of ICT integration in teaching science subjects resulting from low competencies and access to ICT materials.

Successful integration of ICT in teaching is related to teachers' competence and attitudes towards its use [22]. Therefore, positive attitudes towards ICT integration by school teachers are important to ensure effective teaching and learning of science subjects. Ifinedo, Rikala and Hämäläinen [21] report that many factors, including the availability and accessibility of ICT materials in school, influence positive attitudes. Others include the support given to teachers as well as teachers' practices on the use of ICT in teaching and learning [21]. Therefore, the availability and access to ICT materials, management support, and teacher practices are critical factors in teachers' perceptions of integrating ICT in teaching and learning science subjects.

The analysis and conclusions from most of such studies in developing countries in the South Sahara region reveal varied perspectives. The policies and government documents are very positive in integrating ICT for teaching and learning science subjects [38, 39]. However, the practice shows that most secondary school teachers perceive ICT as helpful in enhancing

teaching and learning but are not fully integrating it. It is on this perspective that the current study studied stakeholders' perceptions of integrating ICT in teaching science subjects.

1.2. ICT integration in Tanzania

The literature in Tanzania extensively underscores the pivotal role of ICT in enhancing education, as it is evident in studies such as Kafyulilo et al. [25] and Ndibalema [35]. Acknowledging this significance, the Government of the United Republic of Tanzania, through the Ministry of Education and Science and Technology (MoEST), recognised the essential role of ICT in education as early as 2007. This resulted in the formulation of the ICT Policy for Basic Education [52]. One of its primary objectives is to promote the integration of ICT as a pedagogical tool for teaching and learning, including science subjects. Additionally, the policy aims to ensure fair access to ICT resources for both students and teachers across diverse educational institutions and to facilitate effective utilisation of ICT resources in teaching and learning [52].

To ensure the integration of ICT in teaching and learning within schools, MoEST advocated for ICT not only as a standalone subject but also as a pedagogical tool [52]. Subsequently, various initiatives have been implemented to enhance teachers' skills in ICT integration, as demonstrated in studies by Daudi and Nzilano [13], Manyama and Ndibalema [30]. Among the initiatives include the Science, Mathematics and English (SME–ICT) Pilot Project (2011-13) and the National Information and Communication Technology Project (NICTP) for Science and Mathematics Secondary School Teachers in Tanzania (2010-2013). All the initiatives aimed at improving the integration of ICT in teaching science subjects in secondary schools in Tanzania. In this respect, studies in Tanzania's context reveal the positive impact of ICT integration in teaching science subjects. For instance, Beichumila, Bahati and Kafanabo [8] studied the use of chemistry-computer-based simulations and animation instructional activities for supporting students' learning and indicated that more than 70% of the students were able to perform well. Likewise,

Fidelis and Oduor Onyango [16] examined the role of ICT in teaching science subjects in Ngara district. Their study findings established that in schools where ICT facilities were available and teachers were competent in their use, students performed better in science subjects.

Despite the initiatives and importance of integrating ICT in teaching science subjects, empirical studies, including those by Ndume, Kisanga and Selemani [36] and Ngao, Sang and Kihwele [37] reveal a disparity: teachers are not effectively integrating ICT into their instructional practices. Furthermore, evidence suggests that the predominant use of ICT by teachers is non-pedagogical, encompassing tasks such as exam typing, letter writing, and the processing and storage of student records and grades [36]. In support of this idea, although technology in education, particularly in the classroom environment, is significant, its application in Tanzania science subjects is too scarce in most contexts [31]. The challenges facing it are accessibility of digital technologies, ICT facilities and teachers' attitudes towards its use [25, 37]. It is of this essence that the current study investigated the stakeholders' perceptions of its use and current status.

1.3. Purpose of the study

This study examined stakeholders' perceptions of integrating ICT in teaching and learning science subjects in secondary schools in Tanzania. Precisely, the study was guided by two research objectives in order to assess their perception towards ICT integration:

1. What is the stakeholders' perception of ICT integration in teaching and learning science subjects in Tanzanian secondary schools?
2. What is the current status of ICT integration in teaching and learning science subjects in Tanzanian secondary schools?

1.4. Theoretical underpinning

This study employed Rogers' Diffusion of Innovation Theory, which aims to explain the process of innovation adoption within a given population [42]. According to Rusek et al. [44], innovation in this theory is used to refer to technology. This study focuses on the adoption of ICT as an innovation in the teaching and learning of science subjects in Tanzania secondary schools. As presented by Rogers [43], the theory conceptualises adoption as the act of individuals deviating from their previous practices and diffusion as the systematic communication of innovation through specific practices over time within a social system. The theory presents four situations in which ICT can be adopted in teaching/learning contexts [55]. One is the perceived relative advantage of an innovation. This entails the degree to which it is perceived better compared to the previous ones [33]. The second focuses on compatibility with existing values, norms, and practices. Thus, compatible innovation may be acceptable easily, while non-compatible innovation may not easily be accessible [33]. The third factor involves simplicity, which adopters can implement. The last one is whether the innovation can yield observable results. The integration of ICT in teaching and learning science subjects in Tanzania is relatively innovative. In relation to this study, the adoption analysis was raised by examining the perceived benefits of ICT integration in teaching and learning science subjects. Further, diffusion analysis was gauged by exploring the status of ICT integration in teaching and learning science subjects.

2. Methods and procedures

2.1. Research approach and design

The current study is grounded on a cross-sectional survey design where both quantitative and qualitative paradigms were used to allow the collection of data through interviews and questionnaires to the selected sample [12]. The current study believes that sound information could be collected if surveys are done correctly. Thus, the cross-sectional survey design was seen as the most appropriate one for exploring stakeholders' perceptions of the integration of ICT in teaching and learning science subjects. According to Mohamed [34], a cross-sectional survey design enables the researcher to examine the way in which individuals think about issues (perceptions) and their actual behaviour (practice). In this regard, the collected data aimed to establish stakeholders' existing perceptions of the integration of ICT in teaching and learning science subjects.

2.2. Location and study population

The study was carried out in two districts, Dodoma City and Ilala Municipal Council. It was selected because these districts had secondary schools participating in the implementation of various pilot programmes related to ICT integration in teaching and learning science subjects. Six government-owned schools teaching Information and Computer Studies (ICS) subjects that were involved in ICT pilot projects were purposefully selected to participate in the study.

2.3. Sampling procedures

A total of 221 participants were involved in the study. These included 45 teachers teaching science subjects (biology, chemistry, and physics), 168 students, six head teachers (HTs) and two District education officers (DEOs). These participants are key implementers of ICT integration teaching and learning in secondary schools. In this study, 18 teachers in the capacity of head of departments were purposefully subjected to semi-structured interviews. Likewise, head teachers and DEOs were purposefully selected because they are instructional leaders in the school and the district, respectively. Due to this, they could share teachers' perceptions and status of integrating ICT in teaching science subjects in schools under their capacity. Systematic random sampling was used to select students to be involved in the study with respect to gender and class. Students were involved because they are the consumers of science learning through the integration of ICT in teaching and learning.

2.4. Data collection methods

Data collection included both quantitative and qualitative measures. For this reason, three data collection methods – interviews, questionnaires, and observation – were used. The use of three methods was for triangulation and complementation reasons [17]. A semi-structured interview guided by interview guides was used to collect qualitative data from teachers, heads of schools, and DEOs. The data collection process involved systematic recording and documenting of responses using digital voice recorders and notebooks. Quantitative data were collected by administering questionnaires to teachers and students. Students and teachers filled out the questionnaire to gauge their perception towards integrating ICT in teaching and learning science subjects, as well as examining the status of ICT integration in teaching and learning. Specifically, the study used a closed-ended Likert scale questionnaire for teachers and students in order to assess their perception of the integration of ICT in teaching and learning science subjects. Likewise, the observation rubric was used to assess teachers' use and status of ICT integration in teaching science subjects in secondary schools. This served to establish a comparison between what was revealed by stakeholders and the actual practices for validation of the data.

2.5. Validity and reliability

To address issues of reliability and validity of instruments for credible findings, a pilot study was conducted in the Dodoma region at one secondary school which was not involved in the main study. The results from the pilot study were used to determine the internal consistency reliability of the variables in the questionnaire using Cronbach's alpha's reliability coefficient indicating the

inter-item correlation [11]. The reliability value for teachers' perception towards the effective use of ICT in teaching and learning science subjects was (α = 0.785, n = 9), availability and accessibility of ICT facilities for teaching and learning sciences subjects (α = 0.909, n = 14), administrative support on the use of ICT for teaching and learning science subjects (α = 0.672, n = 5) and effective use of ICT for teaching and learning science subjects (α = 0.846, n = 9). The total inter-item reliability value was which is generally acceptable [11]. Further, the interview data were coded individually by the researcher and given to an expert in ICT in order to find out the inter-rater reliability. The inter-rater reliability was calculated by percentage among the four experts, where 94% was reached as a consensus agreement. For the interview guide and observation guide, the results obtained from the pilot study were used to amend the items that appeared to be ambiguous or could not produce the required information. Additionally, the study observed all ethical issues governing the research activity involving seeking the research ethical clearance, permission from all relevant authorities, the participants' consent, and confidentiality.

2.6. Data analysis

Data were qualitatively and quantitatively analysed. Quantitative data were analysed by using descriptive statistics using Statistical Product and Service Solutions (SPSS) version 24.0. Basic descriptive statistics such as frequency, percentages, and mean were used to describe teachers' and students' perceptions of the integration of ICT in teaching and learning science subjects. The qualitative data collected through semi-structured interviews (individuals with teachers and heads of schools and DEOs) were processed thematically [10]. The process involved transcribing the audio recordings into text for analysis procedures and reporting. After transcription, the researcher thoroughly read the data to understand its meaning. Then, a codebook was developed based on field data, i.e. inductive coding [45]. Then, inter-rater coder reliability was assessed to validate the codes. After coding, all codes were extracted and exported to an Excel spreadsheet for analysis, and the recurring codes were merged to create frequencies of responses. This process enabled easy creation of themes. Finally, all data (quantitative and qualitative) were presented in percentages in terms of tables and charts for easy report writing.

3. Results

The study aimed to investigate the stakeholders' perceptions of ICT integration in teaching and learning science subjects in secondary schools in Tanzania. Two research questions guided the study, and therefore, the study results are presented with reference to the research questions.

3.1. ICT integration in teaching and learning in science subjects

Data to this research question aimed at investigating stakeholders' perception of ICT integration in teaching and learning science subjects. Qualitative and quantitative data were collected simultaneously. Data were collected from students, teachers, heads of schools and DEOs. Regarding quantitative data, the participants were required to rate on a 5-point Likert scale to determine their level of perceptions on ICT integration for science teaching. Different

perception-based statements were given of which the respondents were required to show their level of agreement based on 1 – Strongly Disagree (SD); 2 – Disagree (D); 3 – Undecided (UD); 4 – Agree (A); 5 – Strongly Agree (SA). The table 1 presents students' perception towards ICT integration in teaching and learning science subjects.

Table 1
Students' perception towards the perceived benefits of ICT in teaching and learning science subjects (N = 168).

Perception statement	SD		D		UD		A		SA		Mean
	N	***%***	***N***	***%***	***N***	***%***	***N***	***%***	***N***	***%***	
ICT improves students' academic performance and achievements	6	3.6	3	1.8	15	8.9	55	32.7	89	53.0	4.3
ICT increases students' learning motivation and commitment	23	13.7	12	7.1	15	8.9	45	26.8	73	43.5	3.8
ICT helps to assess students' learning through tests/quizzes	21	12.5	5	3.0	23	13.7	47	28.0	72	42.9	3.9
ICT helps students to engage in practical learning	14	8.3	4	2.4	28	16.7	44	26.2	78	46.4	4.0
ICT helps to access and store teaching and learning materials	9	5.4	3	1.8	8	4.8	49	29.2	99	58.9	4.3
ICT enhances teacher and student interaction as well as among students during teaching and learning processes	28	16.7	7	4.2	31	18.5	40	23.8	62	36.9	3.6
ICT facilities learning to students with varied disabilities	24	14.3	7	4.2	15	8.9	55	32.7	67	39.9	3.8
ICT helps a teacher to organise and prepare the lessons	26	15.5	10	6.0	7	4.2	42	25.0	83	49.4	3.9
ICT helps to design and produce learning resources	26	15.5	4	2.4	14	8.3	44	26.2	80	47.6	3.9
Overall perceptions	20	11.9	6	3.6	17	10.1	47	28.0	78	46.4	3.9

As indicated in table 1, students had a positive perception towards ICT integration in teaching and learning science subjects. Based on the study findings, students rated the perception-based statements between 3.6 and 4.3 in a 5-point Likert scale. This signifies that students' perceptions towards the integration of ICT in teaching and learning science lie on the same side. Categorically, students highly perceived that ICT improves students' academic performance and achievements at a mean score of 4.3 and lower in the aspect which suggested that ICT enhances teacher and student interaction rated at a mean score of 3.6 on a 5-point scale. Overall, students rated their perception at 3.9 on a 5-point Likert scale. This implies that, although most respondents had a positive perception of ICT integration, quite a number of students still either did not see or did not know the benefits of using ICT in teaching and learning science subjects. In the same regard, table 2 also presents similar findings from the teacher's side.

Table 2
Teachers' perceptions towards ICT integration in teaching and learning science subjects (N = 45).

Perception statement	SD		D		UD		A		SA		Mean
	N	***%***	***N***	***%***	***N***	***%***	***N***	***%***	***N***	***%***	
ICT improves students' academic performance and achievements	2	4.4	1	2.2	0	0.0	13	28.9	29	64.4	4.5
ICT increases students' learning motivation and commitment	2	4.4	1	2.2	4	8.9	20	44.4	18	40.0	4.1
ICT helps to assess students' learning through tests/quizzes	2	4.4	1	2.2	13	28.9	6	13.3	23	51.1	4.0
ICT helps students to engage in practical learning	2	4.4	1	2.2	2	4.4	10	22.2	30	66.7	4.4
ICT helps to access and store teaching and learning materials	1	2.2	1	2.2	1	2.2	12	26.7	30	66.7	4.5
ICT enhances teacher and student interaction as well as interaction among students during teaching and learning processes	1	2.2	2	4.4	0	0.0	17	37.8	25	55.6	4.4
ICT facilities learning to students with varied disabilities	1	2.2	2	4.4	3	6.7	24	53.3	15	33.3	4.1
ICT helps a teacher to organise and prepare the lessons	0	0.0	3	6.7	0	0.0	17	37.8	25	55.6	4.4
ICT helps to design and produce learning resources	0	0.0	2	4.4	0	0.0	18	40.0	25	55.6	4.5
Overall perception	1	2.2	2	4.4	3	6.7	15	33.3	24	24.0	4.3

As presented in table 2, the data collected from teachers revealed shared and differing perceptions of the data collected from students. For instance, teachers' perceptions regarding the integration of ICT in science teaching and learning range between 4.0 (Agree) and 4.5 (Strongly Agree) on a 5-point Likert scale numerically different from the perceptions of students. In the same vein, teachers had high perceptions that ICT improves students' academic performance and achievements, which was rated at 4.5 (Strongly Agree), while the utility of ICT to assess students' learning through tests/quizzes was rated low at 4.0 (Agree) on a Likert scale. This implies that teachers were aware of the benefits of integrating ICT in teaching science subjects, although several factors might impact them.

Apart from quantitative data, the qualitative data were elicited from teachers, heads of schools and DEOs through semi-structured interviews. Similar to quantitative data, the informants, through qualitative data, had positive perceptions towards ICT integration in teaching and learning science subjects. Table 3 presents the qualitative data from the informants.

Data as presented in table 3 reveal that four themes, including improved students' performance in science subjects, increased motivation in teaching and learning science subjects, access to the Internet for teaching and learning resources and effective lesson plan preparation delivery, were reported.

Table 3
Participants' perception on ICT integration in teaching and learning science subjects.

Response	Quote
Improved students' performance	When teachers use ICT, students understand easily, so they also perform well in exams
Increased motivation in teaching and learning science subjects	When we use ICT, we are motivated to teach because we can teach practically Teachers like to teach using ICT because it reduces the burden of writing on the board
Access to the Internet for teaching and learning resources	Sometimes the books are few, but when we use the internet, we get teaching materials
Effective lesson plan preparation delivery	ICT helps me teach well because students can see what I am teaching Teachers can use simulations in teaching and make their lesson presentation effective

3.1.1. Improved students' performance in science subjects

The interview with respondents revealed that all of them shared their views regarding the role of ICT in improving students' performance. Respondents argued that by comparing students' performance between ICT users and non-ICT users, one can identify a significant difference. It was informed that when teachers integrate ICT in science subject teaching, students get to learn practically. In contrast, when teachers do not integrate ICT, students learn theoretically. Specifically, teachers said that teaching science subjects through videos helped students learn all aspects of the concept visually and through hearing. Therefore, using more than one sense organ. On this aspect, one teacher said:

> When I am teaching the major groups of organisms, such as Monera, Protista, and Fungi, I don't have physical specimens, so using a video becomes a necessary means. Students can easily observe them with their features rather than through drawings or giving explanations only. (Interview with the teacher, school B)

In the same line of thinking, the head teachers reported that the integration of ICT in teaching and learning subjects enables learners to develop permanent memory. Thus, students would view what was being taught and, therefore, could not forget them easily. Such arguments from teachers and heads of schools could be reflected in the teachers' questionnaire as well as the students' questionnaire. The findings through the questionnaire showed that 95.33% of the teachers and 85.73% of the students had a positive belief that ICT improves students' academic performance and achievements. This indicates that when ICT is integrated well into teaching and learning, students can perform better in science subjects as they get an opportunity to learn practically.

3.1.2. Increased motivation in teaching and learning science subjects

The analysis of the findings showed that informants raised three things regarding motivation in teaching and learning science through ICT. These involved increased autonomy and ownership, access to updated information and real-world applications. With regard to increased autonomy, respondents, especially DEOs, argued that through the use of ICT, teachers and students could assume more responsibility in their teaching and learning. Focusing on students, it was explained that students could follow their interests, study on their own and develop into more self-directed learners. Likewise, one of the heads of schools shared the same feelings; however, they cautioned that in order to ensure self-directed learning, schools needed to ensure students had access to internet resources. Again, in the same regard, the DEO notified:

> The good thing about ICT is that curious students can learn by themselves. For instance, teachers can provide learning areas and ask students to read materials online. If students get them, they become motivated to learn more without much assistance and feel happy. (Interview with DEO A)

The DEO's expression implies that the integration of ICT can be used to scaffold students' learning processes. However, as pointed out by the head teachers, what is necessary is to provide them with the necessary guidance. Thus, the guidance may be in ensuring resource availability or giving directions on the reading materials.

Additionally, the respondents argued that when the morale for learning and teaching science subjects increases, both teachers and students may get access to updated information on science subjects. Specifically, teachers argued that in order to teach science subjects well, they needed to be up-to-date. Therefore, when they integrated ICT into teaching and learning, they could get the current readings for teaching science, which would motivate them more in teaching. During the interview with teachers, it was observed that updated information was beneficial not only to them but also to students. In relation to this, one teacher exemplified:

> The world of science is changing every day. Therefore, teachers and students must be current in their ICT knowledge all the time. When students have access to current online science materials, that may motivate them, thus triggering further investigation and learning for them. (Interview with the teacher, school D)

While teachers held the view that integration of ICT enabled them to have more access to updated information, heads of schools did not give it much priority. It was revealed that most of them focused on the use of ICT as a pedagogy, which is mainly used for teaching and learning science subjects. On this aspect, the heads of schools were of the view that teachers needed to prepare the lesson plan and design the activities that could be facilitated through ICT. This implies that the head of schools had limited knowledge of the integration of ICT in teaching and learning as the process was not confined only to using it as a pedagogical tool. Such limited understanding was likely to affect their contribution to the supervision of ICT integration in science subjects by their subordinates (teachers).

Generally, there seems to be no significant difference between data collected through interviews and questionnaires. This is because most of the aspects were ranked highly in the

questionnaire. Likewise, the same views were held positively during the interviews. In this regard, one might conclude that stakeholders had positive perceptions of ICT integration for promoting students' and teachers' motivation in learning and teaching science subjects.

3.1.3. Access to teaching and learning resources

Furthermore, respondents viewed that when ICT is integrated into teaching science subjects, both students and teachers will have an opportunity to access online resources. In this aspect, three issues were raised: access to e-books, virtual laboratories and simulations, and the application of educational websites. Specifically, teachers were of the opinion that most of the schools did not have sufficient science books and other books were expensive. Therefore, they suggested that using ICT could enable them to get access to electronic or digital books that could help them in teaching and learning. However, teachers noted that the lack of internet bundles for downloading and searching for such books was a challenge. In this regard, one of the teachers testified:

> Physics books such as Lambert are very expensive and not sufficient at school, but when you have internet access, you can download them and have enough of them. Nevertheless, the problem is that sometimes our phones do not have the capacity to store such a large number of books. Also, you may find you don't have sufficient money to buy an internet bundle. (Interview with the teacher, school B)

The explanations in the quote above, as given by the teacher, denote that teachers had positive perceptions and were knowledgeable about using ICT to access reading materials but were facing some challenges. Therefore, working on such challenges may enable them to apply ICT in teaching and learning effectively.

Additionally, DEOs were of the view that if teachers were more knowledgeable, they could use ICT in preparing the virtual laboratories. Such laboratories could be supportive in situations where there was a shortage of labs as well as facilities. Despite that fact, the DEOs suggested virtual laboratories of which the discussion with teachers rarely acknowledged their use. As it was revealed, most of them appeared to be unaware of the virtual laboratories, and some of them reported that they were expensive. Thus, the limited understanding of teachers in virtual laboratories and simulations for teaching science subjects can be exemplified as inadequacy in integrating ICT in teaching and learning science subjects. This is because virtual laboratories are essential in teaching science subjects, especially in environments with limited facilities like Tanzania.

3.1.4. Effective lesson plan preparation delivery

Of particular note was that the desire or perception for having an effective lesson was seen to motivate teachers to use ICT for teaching and learning science subjects. The interview with the informants revealed that teachers felt that ICT could enliven a lesson, thus making it realistic. Also, some of the teachers were of the view that lesson delivery became smooth when they used ICT compared to the traditional way of teaching where ICT was non-existent. It was also found

that some teachers preferred to use ICT, bearing in mind that it made students more engaged in the lesson. On this matter, during the interview, it was clearly revealed that:

> When a teacher uses ICT, the lesson becomes live – easier to understand and draws the attention of learners. (Interview with the Commissioner for Education)

Additionally, heads of schools pointed out that ICT can help the teacher present the lesson effectively. They further urged that through ICT integration, students can investigate practical applications of scientific concepts taught by the teacher. This can be realistic if the teacher uses video films, role-playing, and virtual field trips. Furthermore, one of the DEOs suggested that through ICT, if teachers demonstrate the application of science to real-world situations, this connection might facilitate good presentations and motivate students' learning of science subjects.

Generally, the study findings presented positive stakeholders' perceptions towards ICT integration in teaching science subjects. Neither the qualitative data nor the quantitative data revealed a significant negative perception towards integrating ICT in teaching and learning science subjects. However, some concerns regarding the challenges that may hinder the perceived benefits were reported mostly by teachers and heads of schools. This alarming note is that despite the fact that teachers and other stakeholders had positive beliefs, the government needs to improve the situation for effective learning of science subjects.

3.2. Current status of ICT integration in teaching and learning science subjects

The study focused on three aspects to determine the current status of ICT integration in teaching science subjects in secondary schools. The first aspect focused on material availability and accessibility, the second on teachers' practices, and the last on support provided by the school management.

3.2.1. Availability of ICT materials for teaching science subjects

Further, the study sought teachers' responses on the availability and accessibility of ICT facilities as determinants of ICT integration in the teaching and learning of science subjects. This was done by giving an opportunity to teachers to rate their level of agreement with a statement showing the availability of ICT gadgets on a 3-point Likert scale (1 – Not available; 2 – Available; 3 – Not sure). The results on the availability of ICT facilities for science teaching and learning in secondary schools are shown in figure 1.

The results, as presented in figure 1, reveal that most teachers, 39 (86.7%), perceived that desktop computers were highly available, followed by photocopy machines, scanners and printers, which 37 (82.2%) science teachers reported. The high availability of such ICT facilities in secondary schools is attributed to the fact that the study schools participated in ICT pilot projects for science teaching and learning. These results, however, contradicted the interview with the heads of schools who reported a shortage of ICT materials for teaching science subjects. The heads of schools reported that science materials were more expensive and were not in

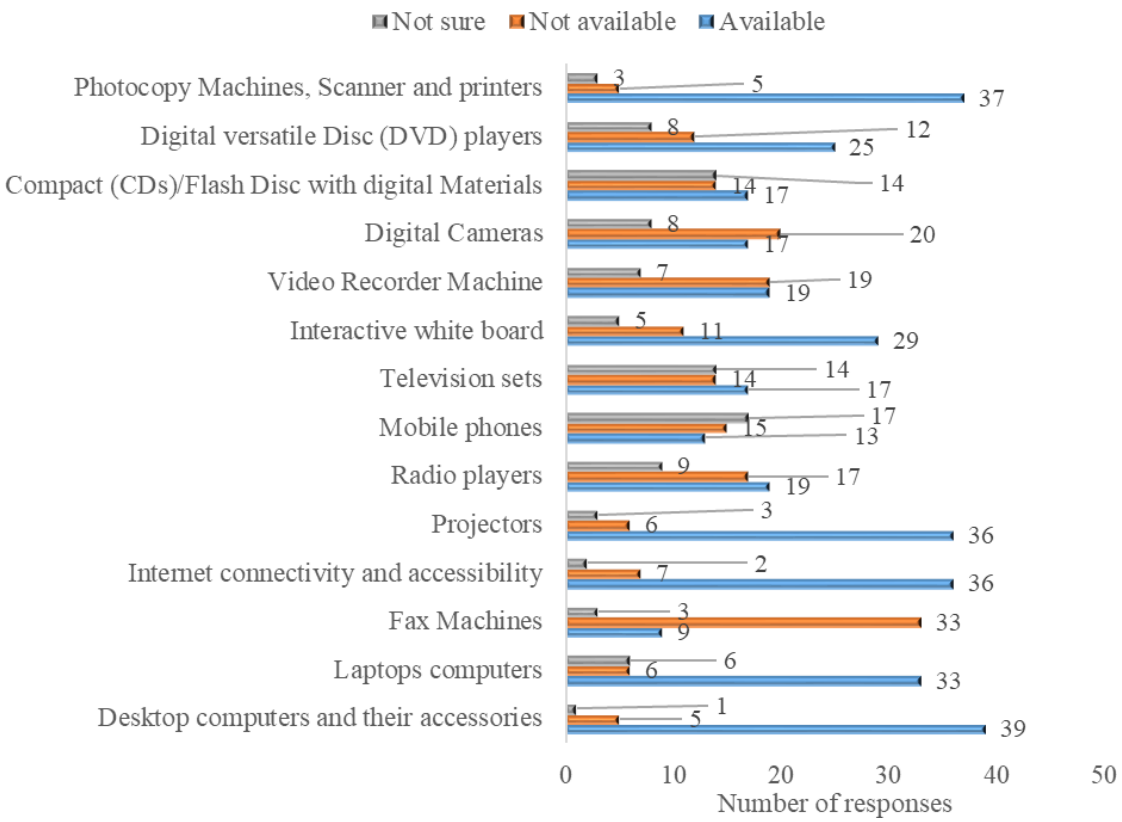


Figure 1: Availability of ICT facilities for science teaching and learning.

school budgets. Therefore, they failed to purchase them to enable easy learning of science subjects through ICT. Regarding this, one of the heads of the school exemplified:

> Unless you get some sponsors or a certain project, you cannot get sufficient ICT materials to teach science subjects. Our school budget is very small; thus we cannot get money to buy all the materials we need. We can only afford to buy a few science materials rather than ICT materials. (Interview with the head of school, school F)

3.2.2. Practices on the use ICT for teaching and learning sciences subjects

This part presents teachers' practices on the use of ICT for teaching and learning science subjects. The results show that teachers' practices on integrating ICT in teaching science subjects were minimal. This may indicate that teachers' competencies may also be low or were affected by other factors (e.g., material accessibility). Data for this aspect were collected from teachers, heads of schools and DEOs. Teachers filled in the questionnaire on practices-based statements to show their level of agreement on a 5-point Likert scale defined by 1 – Strongly Disagree (SD); 2 – Disagree (D); 3 – Undecided (UD); 4 – Agree (A); 5 – Strongly Agree (SA). Table 4 presents teachers' practices on the use of ICT for teaching and learning of science subjects.

Table 4
Teachers' practices on the use of ICT for teaching and learning science subjects (N = 45).

Teachers' ICT use practices	SD		D		UD		A		SA		Mean
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	
Use a word processing programmes to produce a text	3	6.7	2	4.4	2	4.4	12	26.7	26	57.8	4.2
Able to create folders, move files, rename files	2	4.4	4	8.9	0	0.0	12	26.7	27	60.0	4.3
Use the internet/emails to communicate with others	1	2.2	5	11.1	2	4.4	22	48.9	15	33.3	4.0
Use a spreadsheet programs	3	6.7	4	8.9	3	6.7	12	26.7	23	51.1	4.1
Create PowerPoint presentations linked with animation, video or audio clips	2	4.4	3	6.7	2	4.4	26	57.8	12	26.7	4.0
Use social networks to communicate	2	4.4	2	4.4	6	13.3	19	42.2	16	35.6	4.0
Download and install software on a computer	3	6.7	2	4.4	2	4.4	28	62.2	10	22.2	3.9
Obtain learning materials from websites, YouTube and Google	2	4.4	0	0.0	2	4.4	19	42.2	22	48.9	4.3
Using the projector in teaching and learning	3	6.7	0	0.0	2	4.4	26	57.8	14	31.1	4.1
Overall teachers' practices on the use of ICT	1	2.2	1	2.2	7	15.6	24	53.3	12	26.7	4.0

The results presented in table 4 show that teachers' responses regarding ICT use practices range between 3.9 and 4.3, implying that teachers agreed to integrate ICT in their teaching and learning. Overall, teachers' practices on the use of ICT for teaching and learning at 4.0 on a 5-point Likert scale imply satisfactory practices on the use of ICTs in teaching and learning. Based on the findings, it can be argued that the status of ICT integration in teachers' practices is convincing.

Nonetheless, the quantitative views diverged from the views collected through interviews with stakeholders. For instance, the heads of schools showed that most of the teachers were not competent enough to integrate ICT into teaching and learning science subjects. Regarding this, the heads of schools pointed out that ICT competence among teachers was one of the major determinants of teachers practising ICT for teaching and learning. The informants argued that when teachers are competent in using ICT as a pedagogical tool, they get motivated to use the same in their daily teaching. Illustrating this phenomenon, one of the informants said:

> I am of the view that having competent teachers who can use ICT properly cultivates the motivation for the ongoing use of ICT. However, teachers are not that well prepared to use ICT for teaching, which is why they find no need to do so. (Interview with the acting headmistress, school E)

Such clarification shows that teachers were not integrating ICT to the required standards.

This is because they lacked the necessary skills to do so. Therefore, there is a need to ensure that teachers are equipped with the necessary competence for effective integration.

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

The study determined the level to which administrative support accounts for ICT integration in the teaching and learning of science subjects. In this regard, the participants shared their views on the administrative support for ICT teaching and learning. This was done by prompting participants to rate some statements showing some administrative roles in supporting the use of ICT in science teaching. Respondents were required to rate their level of agreement with the statements on a 5-point Likert scale defined by 1 – Strongly Disagree (SD); 2 – Disagree (D); 3 – Undecided (UD); 4 – Agree (A); 5 – Strongly Agree (SA). Table 5 presents teachers' views on the provided administrative support for the integration of ICT in science teaching and learning.

Table 5
Teacher's responses on administrative support on the use of ICT for teaching and learning science subjects (N = 45).

Variable	SD		D		UD		A		SA		Mean
	N	***%***	***N***	***%***	***N***	***%***	***N***	***%***	***N***	***%***	
Provides professional development opportunities on ICT training reprogramme/seminar/workshop	8	17.8	2	4.4	10	22.2	16	35.6	9	20.0	3.4
Makes ICT facilities and software accessible to teachers and students	13	28.9	2	4.4	15	33.3	4	8.9	11	24.4	3.0
Provides financial support for procuring ICT facilities and their utilisation	10	22.2	7	15.6	8	17.8	12	26.7	8	17.8	3.0
Maintains classrooms with the necessary facilities to support ICT use	13	28.9	8	17.8	3	6.7	7	15.6	14	31.1	3.0
Offers sufficient electric power supply	17	37.8	4	8.9	7	15.6	7	15.6	10	22.2	2.8
Motivates and encourages teachers to use ICT in teaching and learning activities	3	6.7	1	2.2	9	20.0	11	24.4	21	46.7	4.0
Overall administrative support	11	24.4	4	8.9	7	15.6	10	22.2	12	26.7	3.1

As it is noted from table 5, teachers' responses regarding administrative support for ICT integration in science teaching and learning ranged between 2.8 and 3.4, implying that teachers were undecided on that aspect. On average, the average mean score of the responses regarding administrative support towards ICT integration was found to be 3.1 (undecided). This implies that most of the teachers were not satisfied with the support given by the administration in

supporting the use of ICT in teaching and learning science subjects.

Likewise, the qualitative data from the DEOs and heads of the schools show an indirect situation. The interviews with the heads of schools and DEOs show that schools had limited budgets for buying ICT facilities. Therefore, there were times when teachers were interested in integrating ICT into teaching science subjects, but they lacked materials. On this, teachers were of the belief that the school administration was responsible for ensuring the availability of such materials. Therefore, when they requested these materials in the absence of the school heads, they reported limited support. With this context, it can be argued that most of the teachers were receiving less support from the school administration. As a result, this affects teachers' integration of teaching science subjects through ICT integration.

4. Discussion

The study investigated teachers' perceptions of ICT integration for teaching and learning science subjects in secondary schools. Specifically, the study focused on stakeholders' perceived benefits and the status of ICT integration in teaching and learning science subjects. The findings revealed that participants had a positive perception towards the use/integration of ICT in teaching and learning science subjects. However, the majority of these participants had a very low level of ICT use for educational purposes. This result relates to the findings of Eickelmann and Vennemann [15], who surveyed how science teachers were using computers in teaching and learning. Further Pelgrum [41] investigated the extent and availability of computers in schools as well as the nature of instructions used by teachers through computers [15, 41] where he found that most of the teachers were ready to use computers; however, only a small number of teachers were using ICT as an integral part of teaching science.

In line with other studies [16, 25], the current study findings showed that science teachers tended to integrate ICT software wares and resources such as the Internet, video presentations and word processes in teaching and learning. However, simulations and games, virtual laboratories and spreadsheet programs appeared to be rarely used by science teachers in teaching science subjects [31]. These findings are not surprising as Rogers' theory of diffusion [42] stresses that teachers are more likely to integrate ICT in their classroom if they see its relevance to their instruction and are convinced that it is compatible with educational goals and easily accessible [56]. In support of these findings Manyilizu [31] notes that for effective use of ICT in teaching science subjects, teachers must be knowledgeable about its specific use. In the current study, teachers also revealed limited knowledge of different aspects of ICT integration in teaching and learning science, such as virtual labs and simulations.

There is evidence to show that poor access to ICT materials has far-reaching adverse implications for teachers' integration of ICT in teaching and learning science subjects. Shortage of ICT materials lowers teachers' integration of ICT in teaching and learning [19]. Further, Singhavi and Basargekar [48] conducted a study on the relationship between material accessibility and teacher use and found that teachers whose schools had sufficient ICT materials were likely to integrate ICT in teaching and learning. In this research, teachers in Tanzania felt that there was a shortage of ICT materials for teaching and learning science subjects. They, as a result, developed limited integration of ICT because they felt that they could not access ICT materials

for teaching and learning science subjects. This has implications for the government of Tanzania in the sense that along with emphasising the importance of integrating ICT in teaching science subjects, the availability and accessibility of ICT materials should be ensured.

Along with issues around ICT materials accessibility, the support from the management was also limited and, in turn, impacted teachers' ability to integrate ICT in teaching and learning science subjects. On this aspect, Setiawan, Satori and Munir [47] assert that teachers become effective when the school management supports them in executing their duties. In the context of this study, the interviewed teachers were unable to integrate ICT in teaching science subjects because they lacked material and academic support from the school management. The assumption here is that because of the lack of relevant support from the management, teachers lost confidence in their ability to integrate ICT in teaching science subjects, thus negatively affecting the learning of science subjects. Atyang, Gathumbi and Babusa [6] and David, Tanui and Oruta [14] recommend that the school management should be on the frontline to ensure that teachers are supported in different aspects such as materials and academic mentorship. This would help them to be able to integrate ICT in teaching and learning. The findings, however, suggest that since head teachers also reported lacking sufficient budget for ICT materials, the government should ensure that schools are either provided with ICT materials or allocated with budgets.

5. Conclusions and recommendations

The analysis of the findings shows that most of the stakeholders had a positive view of integrating ICT in the teaching and learning of science subjects. Despite the positive perception revealed by stakeholders, there is limited integration of ICT in teaching and learning science subjects. The constrained integration of ICT in teaching and learning science subjects stems from teachers' limited understanding of how to incorporate it effectively, a shortage of ICT teaching and learning resources due to a limited budget, and insufficient support from the school management. With these remarks, one can conclude that, despite the positive stakeholders' understanding, perception, and readiness to integrate ICT in teaching and learning science subjects, its implementation in the classroom discourse is still unconvincing. Therefore, students are likely to continue to perform poorly in science subjects. Further, the data reveal that the structural and process organisation to ensure effective implementation of ICT is still challenging. This results in the unfriendly execution of ICT in teaching science subjects in secondary schools.

In this regard, the study recommends that the government and school administration take some initiatives to ensure the availability of ICT materials for effective teachers' integration of ICT in teaching and learning. This could be done by allocating a sufficient budget for buying ICT materials. Furthermore, in-service training (in-school and out-of-school) remains fundamental to teachers when it comes to enabling them to develop effective ICT pedagogical integration in teaching science subjects. Further, the study recommends further study to investigate on the structural and process factors that impact the integration of ICT for effective teaching and learning of science subjects in secondary schools.

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