An examination of the physical proximity of learning in shaping students' mastery of technology-enhanced mathematics and science concepts.

Onyancha V Moragwa[1], Evode Mukama[2]

[1,2] University of Rwanda, College of Education

***Corresponding Author: moragwavalentine@gmail.com**

Abstract

The fast-paced advancements in the technological space and its application have influenced greatly its usage in teaching especially in science and mathematics subjects. The overall objective of this study was to examine the physical proximity of learning in shaping students' mastery of technology-enhanced mathematics and science concepts. Consequently, the study investigates how technology can promote teaching presence toward the mastery of mathematics and science concepts and how the latter can be grasped by the learners using physical proximity strategies. This research study used a mixed-method research design and was conducted in Kayonza District (Eastern Province) and Gasabo District (Kigali), Rwanda. The participants were postgraduate students at the University of Rwanda, College of Education undertaking a master degree in chemistry education, mathematics education, physics education and biology education under the Africa Centre of Excellence for Innovative Teaching and Learning Mathematics and Science. A sample size of 88 students was selected from both Remera and Rukara campuses. Participants were in a range of 21-40 years old. The study used both interviews and questionnaires to collect empirical data. Qualitative data was analyzed using thematic analysis while quantitative data was analyzed using R software. The study reveals that a virtual lab is a vital tool in promoting teaching presence regarding the mastery of mathematics and science concepts. The use of virtual labs seems to foster instructional design and organization from teachers. Moreover, virtual labs seem to facilitate meaningful discourses, interactions between learners and between the learners and the teacher. The findings show also that virtual visualizing seems also to play a role in direct instruction where the teacher offers guidance and direction to learners on various subjects or issues of contention that may need the clarity. Thus 87.6% of the respondents affirm that technology integration in learning is efficient in bridging the gap of physical proximity among learners and teachers through various virtual instruments and platforms. The study also demonstrates that various forms of technology that can be used to bring mathematics and science concepts to the learners' physical proximity including WhatsApp, Microsoft Teams, Google Meet, Zoom and Webex. The study therefore recommends that visualization should be integrated in the curricula, training of teachers and students to maximize physical proximity components and sharing of best practices among teachers and students.

Introduction

Many authors have defined science and technology in a variety of versions (Heinich et. al., 2002; **Hensicke, 2009; Abdullahi,2007**). However, what is important is to understand these two terminologies (science and technology) and how they interact with each other. Science gives an individual a conceptual framework of his physical and social world, while technology equips someone with the devices, knowledge, skills, techniques, and attitudes of mind that are used to solve problems in our daily lives **(**Heinich et al, 200**2).**

Hensicke (2009) sees technology as the application of acquired knowledge and skills in solving practical problems, for example, the knowledge and skills applied in using artifacts and processes. Therefore, the use of modern technological advancement in today's classroom cannot be underestimated. The modern classroom demands the integration of swift approaches such as visual aids (animation and video clips), audio resource, pictures, diagrams (Jesse, Twoli, Maundu, & Twoli, 2014). These soft skill techniques make learning very meaningful to the students as it unlocks their talents in the world of science(Jesse, Twoli, Maundu, & Twoli, 2014).

Computers are advanced devices that have applications in teaching, management, and information communication that make them special other than the other learning devices (Heinich et al, 2002). In technology-enhanced concepts, computers are integrated into teaching and learning in order to strengthen students' attainment, motivation, and the education process at large. This is considered so because it can easily use text, graphs, video, pictures, films, and even animations to deliver the message needed during the learning process hence mastery of the content becomes very high which is depicted in the performance of the student (Heinich et al, 2002).

Abdullahi (2007) states that science is an activity culminating into a testable, verifiable body of knowledge through the systematic and rational organization of facts about a particular phenomenon of interest. The focus of students in sciences is largely concerned with the comprehension of the natural phenomenon and creating a model for better functionality.

Our world is made up of matter and by the study of matter; teachers and learners get to know more about it. Thus, the teacher and learner experiment and acquire skills to make the observation, record, and make good and concrete conclusions (Chukwuedozie, B.C, 2016). Studying science gives both the teacher and learner training in scientific methods, for example, carrying out an experiment, observing recording, and making inferences. Technology-enhanced learning using objects close to the student does a great task in the execution of instructional objectives efficiently and effectively.

Jesse, Twoli, Maundu & Twoli, (2014) conclude that the use of computer-assisted instruction (use of technology) improves secondary school learners' performance in science. The use of technology enables learner-centered teaching and learning approaches that actively involve the learners in the learning process for effective mastery of the subject content matter. Jesse (2011) argued that many topics in science may need very innovative methods of instruction like the use of technology to enhance understanding and enable good coverage of mathematics and science concepts. Rusanganwa (2013, p.1) in a study of multimedia as a means to enhance the teaching of technical vocabulary in physics, says that "The effect of multimedia on the recall of concepts taught is large." Therefore, if there are qualified teachers, recommended textbooks, but no adequate technology-enhanced activities and facilities, this may affect the learning and teaching of science (Chukwuedozie, B.C, 2016). It is on this note that this study is considered necessary.

The following are the questions guided the research study:

How does technology promote teaching presence towards the mastery of mathematics and science concepts?

How are technology-enhanced mathematics and science concepts accessible by the learners using physical proximity strategies?

Which technology is used by learners to grasp mathematics and science concepts?

Materials and Methods

Research design

This research study used a mixed-method research design which did not involve random assigning of subjects to a sample group but assigned an intact class to the sample groups. This design permitted the researcher to reach reasonable conclusions. Technology-enhanced mathematics and science education draws on constructivism in order to examine how teachers and students co-construct meaning in technology-enhanced science education through physical proximity of learning and a community of inquiry. The research methodology was grounded in qualitative case studies but also some quantitative data was collected and analysed to understand relations between key variables like accessibility of technology-enhanced mathematics and science concepts and grasping of the concepts.

3.3 Location of the study

The study was conducted in two districts, Kayonza (Eastern province) and Gasabo (Kigali), Rwanda. The participants were University of Rwanda postgraduate students studying at the College of Education, Rukara, and Remera Campus. The research area offered the ideal environment that is both technologically empowered with the appropriate participants who took part in the study.

3.4 Target population

The respondents for this research were masters' students in the college of education (ACEITLMS) and Remera campus. Both females and males had equal chances of participation. The master students undertaking a master degree in chemistry, mathematics, physics, and biology education were the participants in this study because of their exposure in interacting with chemistry, mathematics, physics, and biology and various forms of technology-enhanced learning. Moreover, they seemed more objective and less biased in their opinions and suggestions therefore provided concrete and rich data. The language barrier was also limited while using the university students.

3.5 Sampling procedure and sample size

Sampling is a process of choosing a part of a whole on the basis of which a judgment about the aggregate is made (Kothari, 2004). The choice of the study area at the college of education was done purposively due to the availability of technology resources and participants. The participants were as well chosen by purposive sampling since the study involved a whole class of science students (Kothari, 2004).

A sample size of 88 students (master students) from both Remera and Rukara campus was purposively selected. Participants have an age range of 21-40. These students have mixed ability levels. The students have different cultural backgrounds, different economic and social statuses. The sample for the study was arrived at by using non-probability convenience sampling.

Convenience sampling is the sampling technique in which the sample is chosen based on availability, time, location, or ease of access with the participants (Razaveih et al., 2015).

3.6 Data collection Tools

These are devices that are used to gather data from test subjects (Salmons, 2011). A multiple case research methodology was used since it provides more extensive descriptions and explanations of the subject under study. This was ideal to investigate a small number of cases but giving out a voluminous amount of information. Interviews were used to collect data on the student personal reports. 6 In-depth semi-structured interviews were extended to students in the university in addition to classroom observation which was used. The research also used questionnaires. The respondents were assessed before, during and after a set period of time in order to see the difference that comes along the way.

The questionnaire

According to Creswell (2014), a questionnaire is an instrument in which respondents write answers to questions asked or mark items that indicate their answers. In this study, close-ended questionnaire was issued to collect data from the students since all the respondents were able to read and write(Creswell, 2014). The questionnaire was administered to eighty-eight (88) respondents. This was done towards the end of semester for postgraduate students in cohort 2 and 3 of Rukara campus and cohort 3 of Remera campus. The design of the questionnaire items follows Garrison's (2017) and Gunawardena and Zittle's (1997) tools for assessing online collaborative learning in the CoI. These authors had used the tool in their research projects where they proved to working very well. For example, Gunawardena and Zittle (1997) used a similar instrument in their research entitled, *"Social presence as a predictor of satisfaction within a computer-mediated conferencing environment"* online learning.

The questionnaire had three sections with all questions that were closed-ended. Section A of the questionnaire had respondent's bio-data questions items which were seven in total. Section B had 12 items for the social cognitive presence while section C had 14 items for the cognitive presence. A total of 33 questionnaire items were used. Section B and C had 26 Five-point Likert scale items to measure the relationship between social and cognitive presence in online collaborative learning. The questionnaire assessed participants' online collaborative learning, psychological proximities (social presence and cognitive presence) as identified from the literature to be significant factors that influence online learning. The questionnaire items were validated by piloting the study to a similar population who were not involved in the study.

The pilot study is conducted to achieve the validity in any research (Gani,Rathakrishnan & Krishnasamy, 2020). It is a pre-test version of a research instrument before carrying out the actual study (Gani et al., 2020). Its reliability was checked by computing the Cronbach alpha reliability coefficient using SPSS, version 25.0. A reliability test was done to check if all the questionnaire items measured the same latent variables. The recommended values of Cronbach alpha range between 0 and 1, where the value of 1 is excellent, > 0.5 is poor, and < 0.5 is unacceptable. For the pilot study, a Cronbach alpha value of 0.8 was obtained which showed that the questionnaire tool was working very well. Furthermore, the validity of the questionnaire items was vet by a team of experts that included university of Rwanda professor in digital education and other masters' students where the questions were modified before using the tool to collect data in the research study.

Interviews

In this study, the respondents answered semi-structured questions about why, how, and what they experienced while doing their studies online. The interview guide had two sections A and B. Section A had seven questions on respondent bio-data while section B had 14 questions about students' experiences of online learning and how the online small group discussions assisted them during their studies. These questions were free response and other follow up questions were asked in order collect in depth and detailed information about online collaborative learning and how social and cognitive presence supports it. Just a glimpse of the questions, respondents replied on themes like language, on small group discussions, ICT skills, opportunities, strengths, and challenges that they faced during their online collaborative studies. This approach allowed the collection of first-hand (primary data) and in-depth information from the participants (Gani et al., 2020). The data collected was used to supplement the one obtained using the social and cognitive presence questionnaire.

Most of the interview sessions were conducted in face-to-face approach while other sessions were conducted via phone call for students that were not in reachable areas (international students) as most of the data was collected while we were still in the lock down due to Covid-19 pandemic. The data was recorded in order to gather accurate information for transcription using otter software and analysis. Additional notes were written for each session in order to supplement the recordings. The written notes saved to add more information on the recordings so that after transcription, the patterns in the data are clearly seen.

Probing questions were asked to get more information from the participants. Like the questionnaire items, the online interview guide items were piloted to examine if the tool had any flaws that need to be adjusted at an early stage (Gani et al., 2020). During piloting it was noted that the interview guide questions had minor problems that includes complex sentences but also use of difficult vocabularies. The questions were revisited and edited after which they were tested again. The flaws were addressed by a team of experts from the University of Rwanda, college of education, and other masters' students studying at University of Rwanda, College of Education before implementing the tool for data collection program.

Social Demographic Description of respondents

Age	**Female**	Male	**Total**
	N (%)	N (%)	**N (%)**
21-30	14(15.9)	21(23.9)	35(39.8)
31-40	10(11.4)	40(45.5)	50(56.9)
41-50	0(0.00)	3(3.3)	3(3.3)
Total	**24(27.3)**	64(72.7)	**88 (100)**
Cohort			
2	19(21.6)	48(54.5)	67(76.1)
3	5(5.7)	16(18.2)	21(23.9)
Total	**24(27.3)**	64(72.7)	**88(100)**
Major subject			
Biology	9(10.2)	12(13.6)	21(23.8)
Chemistry	10(11.4)	15(17.0)	25(28.4)
Mathematics	4(4.5)	20(22.7)	24(27.2)

Physics	1(1.1)	17(19.3)	18(20.4)
Total	**24(27.3)**	64(72.7)	**88(100)**
Campus			
Remera-ACEITLMS	5(5.7)	23(26.1)	28(31.8)
Rukara-ACEITLMS	19(21.6)	41(46.6)	60(69.2)
Total	**24(27.3)**	64(72.7)	**88(100)**

There were 88 students who took part in the study and 24 were females representing 27.3% while 64 were males with a percentage of 72.7%. In this study, 69.2% of the respondents were studying in Rukara campus while 31.8% were studying in Remera campus. There were 5 female respondents from Remera campus representing 5.7% with 23 males representing 26.1%. Rukara campus also had 19 females representing 21.6% with 41 males with a percentage of 46.6. Remera had a representation of 31.8% while Rukara had a representation of 69.2%. From the summary, 67 respondents were from cohort 2 while 21 were from cohort 3. From the data, it was realized that 76.1 % of the respondents were in cohort 2 and 23.9 % were in cohort 3 totaling to 88 students. The study involved a total of 88 postgraduate students out of which 60 were doing their studies at University of Rwanda, College of Education, Rukara campus, and 28 were studying at Remera campus, weekend program.

The respondents from both cohorts had students pursuing chemistry, biology, physics and mathematics. Chemistry had 25 respondents representing 28.4%, biology had 21 participants representing 23.8% and physics had 18 students representing 20.4% with mathematics having 24 a representation of 27.2% totaling to 88 students representing 100%.

In this study, the respondents had ages that ranged from 21 to 50. The age bracket of 21-30 were 35 representing 39.8% while the age 31 to 40 were 50 having 56.9% and this is the bracket that comprised more than half of the respondents. The age bracket from 41 to 50 were only 3 with a percentage of 3.3%.The average age of the respondents was noted to be within the range of 31 to 40. This shows that the respondents were satisfactorily mature to provide relevant information regarding the questions asked.

3.7 Data analysis methods

Data analysis was principally inspired by discourse and content analysis and grounded theory. The qualitative data from semi-structured interviews and observations, the researcher used the thematic analysis method since the research evaluated main ideas from interviewer and observations scripts grouped in themes; for the quantitative data from the document content analysis and Questionnaire, different techniques were applied such as editing, interpreting, relating, coding and tabulation and were analysed descriptively.The researcher then coded salient issues from the transcripts and field notes.

Quantitative data collected was coded and analyzed using R software version 3.5.3

3.8 Validity and reliability of the study

Validity means the degree to which a test can be able to measure what it's supposed to measure. To ensure validity the researcher worked closely with the Science lecturers in the college more so those experienced in the use of ICT in teaching. The researcher also incorporated other advisors from the field of mathematics and science education.

The reliability of the instruments was determined to ensure that results obtained are the same even if it is repeated many times(Otieno, 2017).The researcher found that the reliability index was greater than 0.7 since any reliability index of 0.70 and above is assumed to be a good level that one can rely on this instrument for good results by the end of the study, thus ensuring good analysis and better conclusions will be made (Kothari, 2004).

3.9 Ethical considerations

To ensure confidentiality, the participants were given fictional names, and their participation including technology-enhanced mathematics and science education audio and video recordings, were fully voluntary and based on informed consent with an option to withdraw at any time of the research process. Personal data was anonymized and stored securely. Before data collection, the researcher sought for ethics clearances from relevant ethics committees in Rwanda.

The researcher first considered and adopted into the study the guidelines and regulations for academic research from the University of Rwanda (UR). This study was conducted after getting a written consent approval from UR through ACEITLMS and authorization from the high authority of the Study areas. Also, the roles, responsibilities and rights of each participant including denying to participate or withdrawing at any stage of the study were communicated to them before conducting the study.

Results

A questionnaire was administered to examine how technology promotes teaching presence towards the mastery of mathematics and science concepts from the respondents. The focus was on the thematic areas that comprise teaching presence including the design, facilitation and direction of cognitive and social processes for worthwhile learning outcomes. The respondents were asked 12 questions which were mainly aimed at collecting the information about their experiences and opinions about how technology has been helpful to them in their studies. Teaching presence comprises of various aspects which include: Instructional design and organization, facilitation of discourse, direct instruction.

The process of designing and organizing an online course is extensive and time consuming than the normal process in classroom-based teaching. To design the course for online teaching, teachers are forced to ponder over the process, structure, evaluation and interaction components of the course (Anderson et al., 2001). To find out how instructional design and organization was helpful to learners, the respondents were asked how the teacher uses ICT to clearly communicate topics, course goals, time frames of learning activities. Most respondents agreed that the teacher used ICT to communicate clearly course topics and this included 43 respondents while 33 respondents strongly agreed out the 88 that took part. Moreover, the respondents agreed by 49 respondents that ICT was used to communicate important course goals while 23 strongly agreed too. 44 respondents agreed that the teacher uses online platform to clearly communicate important due dates/time frames for learning activities while 29 strongly agreed over the same. The courses evaluated were based on findings and researches prepared as notes by the teachers and how they were delivered to the respondents. This was the guide for moderating discussions and facilitating assignments. This was integrated with PowerPoint presentations for students to view during the learning session. These presentations could also be shared to the learners through their emails with more details on the course content and structure. It is therefore significant that more than three quarters of the respondents acknowledge that there was effective instructional design and organization majorly because it enhanced clarity of communication to learners. The top three expectations of students according to Mupinga et al., (2006), include communication with the instructor, instructor feedback and challenging online courses. Moreover, they noted that one of the reasons that made students leave online learning or lose concentration was the instructor teaching style. Based on this study, there was no indication that any student left the course, instead the respondents indicated a lot of satisfaction with how the teacher used ICT to achieve instructional design and organization.

Facilitation of discourse is also a very crucial segment of the teaching presence and it involves use of ICT in identifying areas of agreement and disagreement on course topics used to learn during online classes. 42 respondents agreed that ICT was critical in the process while 22 strongly agreeing. More than half of the respondents amounting to 52 agreed that the teacher was helpful in guiding the online class towards understanding course topics in a way that helped to clarify thinking with 21 strongly agreeing on the same. 50 respondents acknowledged that the teacher helped keep the course participants in online learning task, in a way that helped learners to learn while 22 strongly agreed. Through ICT also, the teacher encouraged course respondents to explore new concepts in this course and 38 respondents agreed so while 35 respondents strongly agreed to that. It is therefore evident that students will have an encounter of teaching presence through the facilitation of online discourse just as Palloff and Prat (2011) noted, "Skillful facilitation allows students to interact with one another and the instructor at a high level". Discourse is facilitated when through the instructor, students are able to introduce themselves and create a rapport with other students, participating in ice-breaking and establishing a netiquette policy which will foster teaching presence. Anderson et al. (2010) notes that, "facilitating discourse during the course is critical to maintain interest, motivation and engagement of students in active learning." In a learning environment, various issues spring up which can facilitate discourse that include the building of consensus for a common understanding after giving divergent views or opinions, noting areas of agreement and disagreement, cementing a learner's contributions, climate setting for learning and capturing the attention of learners in order to prompt a discussion. When a teacher finally summarizes a heated online discussion, it shows the effectiveness of teaching presence putting the teacher in control. The teacher is at the Centre of it all in the facilitation of course which will contribute to an effective teaching presence and from the respondents, it can be concluded that the online learning environment, offered an ideal platform to facilitate discourse and the teacher enhanced a successful discourse amongst learners. Most learners had a feel of teacher presence through the facilitation of an effective and robust discourse guided by the teacher.

Direct instruction involves teachers using explicit teaching techniques to teach a specific skill to their students. "Indicators of direct instruction include presenting content and questions, focusing the discussion on specific issues, summarizing discussion, confirming understanding, disposing misperceptions, injecting knowledge from diverse sources and responding to technical concerns" (Shea et al., 2006). Direct instruction will also take the form of statements that can be used to ascertain understanding through assessment and explanatory feedback from the students. Based on the various factors used to gauge the degree of direct instruction, and according to the respondents, 41 respondents agreed that teacher's actions reinforced the development of a sense of community among course respondents by use of ICT while 30 strongly agreed. 47 respondents agreed that the teacher helped to focus discussion on relevant issues in a way that helped students to learn by use of ICT with 23 respondents strongly agreeing. Through direct instruction students are offered a choice and opportunity to take responsibility for their learning where the teacher is more than a guide but less than the sage who takes over the entire learning experience. Learning here is socially shared. By use of ICT, it is therefore evident that teaching presence was promoted by the effective direct instruction from the teachers.

Based on the assessment of the respondents on how technology promoted teaching presence towards the mastery of mathematics and science concepts it can be concluded based on the findings from the respondents that employing technology is the ideal tool to foster teaching presence in its three forms. This shows further that ICT is a formidable tool and an appropriate medium to replace or supplement the face-to-face model of learning but still ensure there is effective instructional design and organization, facilitation of discourse, direct instruction. A healthy teaching presence yields to a strong learning experience and sense of community for the students.

SN	STATEMENT	SA	A	N	D	SD
1.	The teacher uses ICT to clearly communicate course topics	33	43	9	1	2
2.	The teacher uses ICT to clearly communicate important course goals	23	49	12	2	2
3.	The teacher uses online platform to clearly communicate important due dates/time frames for learning activities	29	44	11	4	0
4.	The teacher through the use of ICT was helpful in identifying areas of agreement and disagreement on course topics that helped me to learn during online classes	22	42	19	4	1
5.	The teacher was helpful in guiding the online class towards understanding course topics in a way that helped me clarify my thinking	21	50	13	4	0
6.	The teacher helped course participants engaged and participating in productive dialogue by use of ICT	23	44	18	3	0
7.	The teacher helped keep the course participants in online learning task, in a way that helped me to learn	22	50	13	3	0
8.	The teacher encouraged course participants through ICT to explore new concepts in this course	35	38	13	1	1

9.	The teacher's actions reinforced the development of a sense of community among course participants by use of ICT	30	41	11	6	0
10.	The teacher helped to focus discussion on relevant issues in a way that helped me to learn by use of ICT	23	47	15	3	0
11.	The teacher provided feedback that helped me understand my strengths and weaknesses on various concepts	30	36	18	2	2
12.	The teacher provided feedback in a timely version	14	40	26	6	2
	Total responses= summation of all response	305	524	178	39	10
	Mean = $\frac{\text{Total responses}}{\text{Number of responses}}$	25.41	43.66	14.83	3.25	0.83

How are technology-enhanced mathematics and science concepts accessible by the learners using physical proximity strategies?

There was an overwhelming acceptance that the use of technological resources (simulations, games and animations enhances mastery of science and mathematics concepts. 45 respondents strongly agreed with 33 respondents agreeing to that. This demonstrates that technological resources are an important tool in fostering mastery. 52 respondents agreed that they have access to ICT sources for exploration of mathematics and science concepts. Moreover, concentration on key concepts was greatly improved when using technology which 40 respondents strongly agreed and 33 agreed to that. The level of understanding of science and mathematics was also enhanced when technology was employed with 41 students agreeing and 26 students strongly agreeing.

Through the aid of ICT both the teacher and the learner were able to carry out experiments in science which was agreed by 39 respondents whereas 17 strongly agreed. ICT resources which involved games and simulations helped students to see how different concepts can be manipulated with 37 respondents strongly agreeing and 35 agreeing to that. Many agreed that it they were able to see and touch diagrams better through the use of ICT with 70 respondents agreeing to that.

Technology provides an ideal avenue and opportunity in mathematics and science instruction. This promotes further the learning process and makes concepts more understandable through engaging and interactive media. Multimedia was found to bring learning to the student's level through the videos, animations and other media to help students develop skills and understanding. The technology also provided opportunities for learners to see and interact with mathematical concepts as students can explore and make discoveries with games, simulations and other digital tools.

Integrating technology in the mathematics and science classroom allowed students to have an interaction with people outside the classroom to widen and deepen their understanding regarding what they are studying. Teachers can put up live interactive video calls with experts on a wide variety of concepts in mathematics and science curriculum. This bridges the gap of physical proximity among learners through the various virtual technology instruments. Through the concepts learnt in the mathematics and science classroom, they can be applied to everyday life.

SN	STATEMENT	SA	A	N	D	SD
1.	The use of technological resources (simulations, games, animations etc.) enhances mastery of mathematics and science concepts	45	33	7	3	0
2.	I can easily access the ICT resources to explore mathematics and science concepts	19	52	11	4	2
3.	My concentration on key concepts in your major subject (e.g., mathematics, physics, biology, chemistry) is greatly influenced when using technology	40	33	11	3	1
4.	The level of understanding of mathematics and science concepts with the teacher during learning using technology is better.	26	41	16	4	1
5.	Through the use of ICT, it helped both the teacher and the learner to carry out experiments in science.	17	39	20	5	7
6.	The use of ICT resources (animations, games, simulation etc.) in learning helped me to see how different concepts can be manipulated.	37	35	11	4	1
7.	I was able to touch and see diagrams much better through the use of ICT.	34	36	15	1	2
	Total responses= Summation of all responses	218	269	91	24	14
	Mean= Total responses / Number of responses	31.14	38.43	13	3.43	2

Which technology is used by learners to grasp mathematics and science concepts?
Technology is the platform in which delivery of mathematics and science concepts is embedded in. Integration of technology in learning was found to be effective in promoting mastery through various ways. An interview was administered across the 88 participants from the various cohorts and subjects in order to affirm how technology was instrumental in fostering mastery of concepts and ultimately teaching presence. Majority of the participants that took part in the study were from cohort 2 who undertook their studies during the peak of the covid-19 pandemic that necessitated that they conduct their lectures online to ensure continuity of their academic calendar.

The interview was aimed at identifying various forms of technology or tools used by instructors to assist in the grasping of mathematics, chemistry, biology and physics concepts, how the concepts were learnt using technology, impact of technology in visualization of concepts, role of the teacher in teaching new concepts with technology, student role while learning using technology and the challenges in technological learning. From the findings, all participants had interacted with technology and based on an interview on the students with 100% having had the experience of using technology, most of the tools used included computers and laptops, embedded projector which was used for presentations during face-to-face class sessions.

Printers were also used to print handouts for learning and scanners were found to be useful in scanning hard copies which could be shared through the email. This is affirmed by Felix who says, “In chemistry, mostly our lecturer or our course instructor used the slide projector and a laptop, printers to print some papers and they could use scanner when they needed to share copies to students.” Communication among learners and the instructor was enhanced using email and WhatsApp especially when reporting when lessons would be undertaken and the required links for the virtual lessons. Emails were also used to share the assignment ad submission of the worked assignments as most of the participants concurred.

E-learning was also facilitated using various virtual tools such as Microsoft teams, Google Meet, Zoom, WebEx among others that were used. Such learning sessions could be accessed by the students using their computer/laptop, phones or tablet whichever that seemed convenient and on a stable internet. Wycliffe gives a deeper insight on how technology tools were employed in the learning process when he says,

> “I remember another important device which is a projector device, which is very important in teaching. So, they use a computer to prepare teaching materials, and also to deliver those material pertaining the course. So, again, they used computers as I said during the preparation for teaching either doing research, getting information in the internet, getting the research writing, if you've got a concept related to the course and also, they can use telephone in delivering the course, then they use a projector to display for easy visualization of what they are teaching. Then they use printer make soft copy hard. Again, hard copies can be made soft through scanning. I think that shows how different devices can be used during teaching and learning process.”

E- learning has been preferred by learners for being adaptable and accommodating to learners since they can learn from the convenience of their rooms.
The technology tools used were instrumental in research purposes, websites and simulation videos that were used. YouTube was highly cited by 84% of the participants that it was the epicenter of most learning activities combined with GeoGebra and Universal Solver that were used for graphics and functions and also solve complex mathematical equations like polynomial of higher degree. Edwin says,

> “What I'll do is that, if the lecturer presents information or presents his response on a particular topic, what I will do is I would go to look for more information on that particular topic or concepts maybe I didn't understand very well. So, what I do I go search for other modalities or other lessons on the similar topic which other people have taught maybe on

> you-tube or maybe I check things like other lessons or PowerPoints that were presented to other universities. But all this was possible, because I have internet and I'm using either my smartphone or my computer to search more details on those particular concepts that we're learning, so that I can have a better understanding by checking a variety of information that is presented on that particular topic."

Learners therefore can easily search/browse information online on the concepts that weren't clear during the lesson presentation. The internet is diversified and as such present complex information in a much simpler way. You can easily download books or publications on various topics of interest.

How technology helped understand the concepts and concepts learnt

Technology can assist students make sense of standard based complex topics and provide a channel to illustrate a given idea or concept to be well understood. This can be through modelling and simulation, visualization. In chemistry, a phone or computer with the internet would come in handy in visualizing concepts from various subjects such as Ellingham diagrams, pyrometallurgy or hydrometallurgy in Chemistry. Also, you can easily access information on the reactivity of various elements. Concepts such as polymers in applied organic chemistry can easily be accessed in such cases as the optimization of equations for industrial products.

Felix supports these findings in his assertion that, "We used PhET simulations that could help us understand to teaching of topic like titration. But we also navigated some websites that have chemistry modalities. when we're studying industrial chemistry, maybe Ellingham diagrams, maybe pyrometallurgy, or hydrometallurgy." Sylivia also concurs with the same, "Like in chemistry I learnt about the mole concept. I learnt much about this concept through PhET simulation, yeah of course that one provided me with ample knowledge because I was able to see: it's like I was in the laboratory but not in the laboratory it was a simulation. So, that one first of all, saved my time but also, I understood the topic very much."

Moreover, PhET simulations were used to help learners understand to how to handle of a topic like titration. Alongside this, the learners have also navigated some websites that have chemistry modalities. Such websites include online laboratories that would make it easy to manipulate the variables but also handle dangerous chemicals that you cannot use in the laboratory. It also saves time and have high accuracy. It provides an avenue to easily repeat the experiment as you do need to use reagents that are expensive in real life situation.

In mathematics and physics, GeoGebra would help in optimizing functions and visualizing them graphically. Additionally, universal solver would help in solving mathematical equations such as polynomial of higher degrees that wouldn't be easy to solve in the traditional teaching set up. YouTube (branded the best teacher) is a fast line of call for concepts that would sound technical and not easy to understand. It presents information in a more relatable manner as opposed to the more abstract ways in the conventional set up.

It is evident from the experiences shared by the participants that various concepts can be well mastered by learners in a technology driven learning environment especially in the field of mathematics and Sciences which involves a lot of practical that need to be visualized for comprehension. 76% of the participants did agree that technology provided the best opportunity to understand a range of concepts.

Challenges of technology

Despite the great benefits that have been accrued in fostering mastery through technology, there however lie various challenges in ensuring the hurdles are overcome. These challenges are hampering the effective use of technology in learning and mastery.

Internet interruptions and instability was noted to be a key challenge among 70% of the participants and since most of them were using internet from their phones sometimes the network was erratic causing a disparity at times.

The use of technology requires high level skill and proper knowhow on the relevant technology. Students don’t have the appropriate skills and knowledge for some technology being used. Added to this is the incessant resistance to change, people are so fond of the traditional methods of teaching and yet the technology space is evolving day and night.

Conclusion

The use of ICT was found that it could effectively foster instructional design and organization from the teachers, facilitate meaningful discourses and interactions between learners themselves and their instructors and also bring about direct instruction where the teacher could offer guidance and direction on various subjects or issues of contention that may need the clarity of the instructor. This result coincides with Zhang et al., (2016) who also assert that teaching presence has a positive impact on learner’s constructive and engagement behaviours therefore highlighting the crucial role facilitators play in design, organization, facilitation and direct instruction. Wang (2022) and Y. Sun et al., 2020 also state that assessment and technological support are effective in promoting teaching presence which will spur learner engagement in discussions and negotiations. They however disagree that direct instruction has a negative effect on learner’s interaction.

This therefore signifies that impactful online engagement can lead to a significant teaching presence and can promote learners to have interactive and enhanced communications and produce a substantial number of outputs that are beyond the learning materials offered by the instructors. It is through an effective employment of technology that learners can participate in learning more intensively by constructing and co-constructing knowledge which demonstrates a deeper understanding of the subject matter. This is how teaching presence is effectively attained by using technological resource

78.5% of the respondents that took part in the study agreed that ICT accessibility positively impacted mastery and concentration on key concepts, deepening the level of understanding and even bringing various diagrams closer to the learner. This study findings concur with Ratamun& Osman (2018) who also note that virtual labs which help in improving the level of mastery of science processing skills has the potential to carry out complex and dangerous experiments. The virtual lab is an ideal tool to help students conduct experiments and even lower the cost of doing the physical experiments. This study reveals that science and mathematics concepts do not only rely on the process of experimenting and problem solving but also depend on the potential content and activities found on e-learning whereby content and activities must aid in promoting mastery of such concepts.

Therefore, it can be concluded that physical proximity has a significant positive effect in enhancing mastery of science and mathematics concepts since learners become actively involved in accessing ICT resources, conducting experiments, simulations. They are motivated to learn concepts that seem hard to understand when they are given opportunities to visualize the phenomenon under study in their physical proximity. With the abundance of teaching aids found in the virtual classroom and available guidance from the instructor, learning becomes centered to the students. Thus, a virtual lab becomes an ideal tool to help mathematics and science instructors to implement experimental sessions with minimal mistakes, costs and problems.

Khouyibaba(2010) agrees with this study that the use of technology is vital in grasping science concepts since it allows for improved visualization, better understanding of difficult concepts and it can be entertaining to the learner when designing various shapes and objects. The National Council of Teachers of Mathematics (2000) note that technology is essential in teaching and learning mathematics since it influences the mathematics that is taught and enhances student learning however technology should not be used as a replacement for basic understandings and intuitions but rather it should be used to foster those understandings and intuitions.

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