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Research Article

Role of Technology Integration in the Development of 21st-Century Skills STEM University in Zimbabwe

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Abstract
Technology use is crucial and fundamentally alters how universities teach and learn in the twenty-first century. The influx of various technologies supports the development of three key 21st-century skills: life and career skills, learning and innovation skills, and information, media, and technology skills. Social constructivism theory serves as the study's theoretical foundation, emphasizing the importance of collaborative learning environments where students construct knowledge through social interaction. A case study design and a qualitative methodology were employed in the investigation to gain deep insights into the experiences of participants. Those involved in the study included STEM lecturers, faculty technicians, and both first- and final-year undergraduate students; they were chosen using a purposeful sampling procedure to ensure a rich variety of perspectives. Data were collected through in-depth interviews, which provided valuable qualitative insights. The paper explores the 21st-century skills essential for STEM learning, focusing on the implications, competencies, and perceptions of various stakeholders. The study established a pressing need for training in technology integration among faculty. Additionally, there was minimal support from administration and technicians, as well as a lack of adequate resources. Participants expressed the need for ample time to prepare for lessons, highlighting the challenges educators face. Consequently, it is recommended that the implementation of technologies should begin with strong support from administrators and technicians in sourcing necessary resources. Lecturers play a crucial role in preparing students for the modern workplace, and they require continuous training and support from technicians. Furthermore, administrators should foster collaboration with other STEM-offering universities to stay current with rapidly evolving technologies, ensuring a comprehensive approach to education in the digital age. This collaboration can significantly enhance the educational quality and effectiveness of STEM programs.

Keywords: Learning and Innovation Skills and Information (4Cs), Life and Career Skills, Media and Technology Skills, Technology Integration, Twenty-First-Century Skills

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1. INTRODUCTION

In Education 5.0, lecturers and students incorporate technology into their teaching and learning processes. Technology is developing quickly, therefore it's important to stay up to date. Education 5.0 is essential for a university's teaching and learning to remain relevant in the age of rapidly changing technology and gain external recognition (Yaras & Ozturk, 2022:459). Since there are many types of technology, the researcher in this article focuses on the course/module software and learning management systems (LMSs) used in STEM teaching and learning. There are several different learning management systems (LMSs) that are used in teaching and learning, and a few examples are Moodle, Blackboard, Sakai, Google Classroom, Canvas, Edmodo, Angel, and Attutor (Paguirigan, 2023; Fibriasari et al. 2023). According to Asparukhova et al. (2019); Gonzales (2022), the course/module software that can be used in STEM amongst most are proteus software, ChemDraw, GAZEBO robot simulation software, Robologix logical design, Webbot 7, Robotics Developer Studio, MATLAB.

Technology integration in the classroom is extremely important for giving students the skills they need for the twenty-first century and boosting their academic performance (Birisci & Kul, 2019). The 21st-century skills that lecturers and students must acquire to integrate LMSs and course/module software are collaboration, communication, critical thinking, creativity, and digital literacy (Chun & Abdullah, 2022). Technology support, implementation, and integration differ per university in Zimbabwe, and this has hampered the acquisition of 21st-century skills (Kennedy & Sundberg, 2020; Shadiev & Wang, 2022; Amadi, 2023; Ayanwale, 2023).

1.1. Theoretical Framework

Social constructivism analyses existing theories and may be used to guide STEM teaching and learning. According to Amineh & Asl (2015), philosophers and educators like Vygotsky, Piaget, and Perkins believe social constructivism offers solutions to the problems with traditional teaching and learning. Social constructivism, by Maryati, Permanasari, and Ardianto (2022), assesses the knowledge and understanding that students have jointly constructed based on reality. According to Tubman, Oztok, and Benachour (2016), the social constructivist learning strategy requires excellent student participation as they learn by doing to develop knowledge, skills, and positive attitudes. Vygotsky based social constructivism on social and cultural context, artifacts, tools for peer engagement, and most knowledgeable others (MKO) (Schrader, 2015). The social constructivism theory was built on Vygotsky's contribution to education at the beginning of the twenty-first century (Daniels, 2016). The social constructivism approach includes social interaction, zone of proximal development (ZPD), more knowledgeable others (MKO), and scaffolding.

Students interact with and learn from their faculty lectures, laboratory technicians, classmates, informed members of society, and the physical world in general (Amineh and Asl, 2015; Afandi, et al. 2019). Students can benefit from establishing connections with online resources and social media to effectively promote their collaboration (Hsieh, 2017). More knowledgeable others could be lecturers who are educated about what should be done and how to address particular challenges from the company, government, or other educational institutions (Smith and Shen, 2017:86). According to Amineh and Asl (2015), lecturers are the closest more knowledgeable others (MKOs) since they help students learn the subject. Before the students approach further stakeholders, the lecturers provide the information to them during their initial interaction. Smith and Shen (2017:86-87) acknowledge that MKOs are important for developing students' capacity for critical thought and that one of their skills is mentoring.

Learning starts at a far higher level than what the student originally knows, the zone of proximal development (ZPD) (Amineh and Asl, 2015). Several researchers defined ZPD as the difference between a student's actual level of development as measured by their ability to solve problems on their own and their potential level of development as measured by their ability to solve problems with the supervision of lecturers or in cooperation with more experienced people (Guseva et al., 2017; Hsieh, 2017; Hu and Yu, 2017; Shrestha, 2017; Abeysiriwardhane et al. 2016; Haider and Yasmin, 2015; Kurucay and Inan, 2017; Amineh and Asl, 2015; Channa and Nordin, 2015; Schrader, 2015). According to Mattar (2018), the ZPD approach developed by Vygotsky is a more flexible framework that may be used to integrate social media, course/module software, and learning management systems into teaching and learning. According to Clapper (2015) discusses the difference between what a student can learn on their own and what they can learn under the guidance of a lecture.

According to Abeysiriwardhane et al. (2016), the execution of design projects is student-centered and hence tied to Vygotsky's ZPD and social constructivist theory. Students can successfully complete all assignments by working in teams and interacting with lecturers, as cooperation is encouraged in ZPD and collaborative problem-solving (Abeysiriwardhane et al. 2016). According to Kurucay and Inan (2017), students who connect with other stakeholders benefit from ZPD because they learn new information and abilities. The lecturer initially creates the learning exercises, and the students' experience being assisted at first before moving forward on their own to determine whether they have understood the responsibilities or steps of an approach.

Channa and Nordin (2015) give the following explanation of the four-stage ZPD model: Students are first assisted in learning during stage one by contact with the lecturers, peers, experts, technicians, and the MKO. In the second phase, students work independently with limited guidance to develop the knowledge and skills required to ensure that they have understood the instructions. In this case, stage 3 allows students to work freely and without the lecturer's help. The fourth level is the one where students fully acquire their independence and can expand on what they have learned so far by working independently both inside and outside of the classroom.

Hsieh (2017), Smith and Shen (2017), Abeysiriwardhane et al. (2016), Haider and Yasmin (2015), and Fernandez et al. (2015) all share the same perspectives that scaffolding is the technique by which the professor and peers help underachieving students to completely understand an idea. Students can be quizzed, given guidance, show models, and go over topics they've already learned. Peer engagement is another way that students might learn new ways to communicate and think critically. According to Hsieh (2017), online resources such as blogs, tutorials, Google Scholar, and electronic reading material serve as a source of scaffolding. The lecturer draws the students' attention to the assigned work, clarifies it, and encourages them to complete it by rewarding them (Fernandez et al. 2015).

Universities are crucial in giving students the learning scaffolding they need to succeed (Haas, Lavicza, and Kreis, 2023; Zhang et al. 2021). Therefore, students follow a protocol and counseling practice during the apprenticeship as well as before, during, and after industrial incorporation. Social interaction (with peers, speakers, and MKO) as well as access to instruments that are tangible, environmental, and symbolic (books, labs, assessments) all support the construction of scaffolds (Alhalafawy et al. 2021). Scaffolding is an ideal strategy for facilitating teaching and learning (Hu and Yu, 2017, Guo, 2022; Zheng, 2016). Finally, Reda (2023), Sundari & Febriyanti (2023) define scaffolding in ZPD as knowledge development through critical thinking, teamwork, and students under the direction of the MKO.

1.2. Literature Review

1.2.1. 21st-Century Skills in STEM Teaching and Learning

21st-century technology is not as new a concept as it once was, but now it depends on technology and how it transfers, and advanced information evolves rapidly (Urbani et al. 2017; Affuneh et al. 2020). As 21st-century skills are developed in STEM by students, lecturers, and the outside world, STEM lecturers therefore play an important role as facilitators (Anagun, 2018; McGunagle & Zizka, 2020 and Affouneh et al. 2020). Shum and Crick (2016) complain that employers in the world of work pass exams with flags and pennants because graduates of the university system still fail to address the specific challenges of 21st-century skills. World Economic Forum (2016); Shum and Crick (2016) contend that the emphasis on knowledge and skill acquisition in education systems from primary, high school to university has to change. Griffin and Care (2015) argue that technology will always evolve in the future because inventions are endless. The modern workforce in all countries is interested in hiring STEM graduates with 21st-century skills (Borgogni et al. 2017; Cihat, 2015:41; Guilbault, 2016). According to ManpowerGroup (2015), 38% of graduating students have 21st-century skills. Furthermore, the Manpower Group (2015) indicates that there is a 21st-century workforce shortage for graduate students (83% in Japan and 11% in Ireland). Yadav, Hong and Stephenson (2016:566) Declare that students can build answers and model challenges using 21st-century skills. With their peers, lecturers, and other people around the world, students can cooperate and exchange knowledge. Farisi (2016) and the Center for Curriculum Redesign (2015:4) agree that the educational system should incorporate 21st-century technologies. This is significant because performing allows pupils to learn and show comprehension. According to some lecturers, 21st-century skills are divided into life and professional skills; information and technology skills; and learning and innovation skills collaboration (Chu et al. 2016; Farisi, 2016; Parde, 2020; Talib and Aliyu, 2019; World Economic Forum, 2016; Applied Education Systems, 2020; Bai and Song, 2018; Fitzgerald et al. 2016). These 21st-century skills therefore accommodate critical thinking and problem-solving; creativity and innovation; and communication. Some of the issues facing developing nations like Zimbabwe include access to technology and technological literacy. The digital divide indicates the difference between individuals in accessing technology and being able to use it now and again (Cloete 2015 and Cloete 2017). Several researchers add that adequate integration of 21st-century skills is facilitated by utilising different teaching approaches by lecturers (Ayanwale, 2023; Alenezi et al. 2023; Ma'rifah & Sinaga, 2023).

1.2.2. The Role of Technology Integration in the Development of 21st-Century Skills

Technology is now a crucial part of how we educate and learn daily due to the rapid advancement of technology. Technology planning, which includes infrastructure, tools (computers, software), support, and strong internet access, can be used to achieve this effectively. The importance of lecturers in the incorporation of technology into teaching and learning cannot be disputed. According to Harrell & Bynum (2023), there are various technologies used in teaching and learning that have many internal and external factors. These factors tend to negatively influence the integration of technologies in teaching and learning. Internal factors include lecturers and student perceptions (Pearson, 2015), low lecturer self-efficacy (Li et al. 2015; Hsu et al. 2020; Hur, et al. 2016), student lacking digital skills (Delcker & Ifenthaler, 2021; Gomez-Trigueros, 2020). External factors include poor infrastructure (Build the 21st Century Classroom, 2018; Pooja, 2021), inadequate technologies (Pearson, 2015), lack of sufficient computers/software, poor internet connectivity (Pearson, 2015) rapid power outages, professional development, administrators' support, and appropriate budgets (Hur, Shannon and Wolf 2016; Pooja, 2021). Integration of technology enhances digital skills in course delivery, course resource sharing, student happiness and anytime and anywhere engagement (Alenezi et al. 2023; Ma'rifah & Sinaga, 2023); motivation (Raja et al. 2020); and student academic performance (Alenezi, 2018; Ayanwale, 2023). According to Brown-Martin (2017) twenty-first-century skills are significant for students so as to be easily fit in the outside world with evolving technologies.

1.2.3. Lecturers and Students' Perceptions of the 21st Century Skills Benefitted Through Technology Integration

Lecturers and students have their perceptions of the 21st-century skills they benefit from through technology integration (Alenezi et al. 2023). Perceptions can therefore be categorised negatively or positively depending on the feelings of individuals. LMSs and course/module software increase accessibility for lecturers and students. They engage, enable immediate feedback, and foster digital citizenship; provide students with the opportunity to work with technology and connect anytime and anywhere; they are user-friendly, and accessible (Martin, 2021; Alenezi et al. 2023).

1.2.3.1. Lecturers' perceptions of the 21st century skills

Lecturers benefit from professional development in technology-enhanced teaching and learning (Alenezi et al. 2023; Martin, 2021). The straining effort required to learn the new technology was perceived by the lecturers (Harrell & Bynum 2023:15). This matches previous research on lecturers' readiness or lack of skill which had the greatest overall impact on whether or not to use the technology (Ghavifekr & Rosdy. 2015). Additional preparation time and training to integrate technology into teaching is required and lecturers also have a negative perception (Johnson, et al. 2019). Technology integration calls for planning, best practices in classroom management, and attention that is not typically given to those areas.

1.2.3.2. Students' perceptions on the 21st century skills

Students' perceptions of LMS use include poor internet connectivity, a dearth of learning resources and assimilation, and negative social media impacts were negative (Ndzinisa & Dlamini, 2022; Mulyani et al. 2021). The survey additionally revealed that 59.6% of the conclusions regarding pupils' motivation to include technology were favorable. This is due to the potential for new learning opportunities and exploration, which presents a sense of excitement and possibility, sufficient success and fulfillment, the flexibility of time and place, and the growth of digital technology usage and adaptability. Alenezi et al. (2023); Ghavifekr & Rosdy (2015) indicate that students enjoy and their academic engagement is improved when they gain 21st-century skills.

1.2.4. Challenges/Barriers of 21st-Century Skills to Technology Integration

Challenges /barriers of 21st-century skills technology integration include lack of external resources, lecturers' perceptions and confidence, insufficient lecturer preparation and competence, too much time needed for lesson preparation, lack of training, class size and inadequate technical and administrative support (Alenezi, 2018; Francom, 2020). First-order barriers are related to a lack of external resources (technology, software, training) while second-order hurdles revolve around lecturers' views and confidence in integrating technology (Aziaka & Nwogu, 2023; Harrell & Bynum 2023; Francom, 2020, Martin, 2021). According to Alenezi (2018) and Abid Azhar and Iqbal (2018) insufficient lecturer preparation and technological competence are further issues that prevent lecturers from using instructional technology like learning management systems and course/module software. According to Manhibi (2019); (Mulyani 2021); (Gomez et al. (2022), one obstacle to technology integration in the classroom is a lack of lecturer confidence in its use. There was also lack of technology preparedness and trust among lecturers (Abid et al. 2018). Students have access to technology at home despite a lack of infrastructure and networking (Martin, 2021). Lack of equipment and network requirements; lack of lecturer trust in using new technology; burnout in lecturers who adopt new technologies; insufficient time to learn learning management systems and course/module software; lack of professional development opportunities (Chun & Abdullah, 2022; Martin, 2021).

2. METHODS

A case study qualitative (QUAL) approach design was used for the study. A qualitative method often seeks information on opinions, attitudes, perspectives, beliefs, or preferences (Hammarberget al. 2016). The participants are aware that once the researcher has finished working with them, their relationship with the researcher is over. The case study design is the most effective choice for this study's analysis of the University of Technology. It involved gathering qualitative data, analysing it, and then interpreting it. A case study technique was employed to assess management practices and capture any subtitles of the phenomenon in the usage of STEM technology. The researcher employed practical sampling to select department heads, professors, and technicians because they are sparsely populated relative to students. Data was then collected using interviews through interviews and was thematically analysed in themes. Participants were composed of heads of departments (chairpersons), STEM teaching lecturers; faculty technicians, and first-year and final-year students.

2.1. Research Design

The study employed a case study to understand the institution understudy. The case study therefore assists in understating the complex interactions and it is flexible. It also helps to generate rich data through interviews and offers actionable insights to the stakeholders involved.

2.2. Participants

The population for the study was a Higher Institution of Technology involved in STEM disciplines. Those involved in the study included 3 STEM lecturers, 3 faculty technicians, and 3 first- and 3 final-year STEM undergraduate students; they were chosen using a purposeful sampling procedure to ensure a rich variety of perspectives.

2.3. Research Instruments

The data were collected through in-depth interviews, which provided valuable qualitative insights. The study therefore explored the 21st-century skills essential for STEM learning, focusing on the implications, competencies, and perceptions of the lecturers, technicians, and students at large. The data was transcribed by jotting down participants' main points. The participants were also assigned codes and lecturers were coded as L1, L2, and L3. The technicians were coded as T1, T2, and T3. The first-year students were coded as FirstYStud1, FirstYStud2, and FirstYStud 3. The final-year students were coded as FinalYStud1, FinalYStud2 and FinalYStud3. The data was grouped in themes which emerged from the research questions.

2.4. Procedures

The research sought consent from the university under study and the participants. The researchers assured the participants that they will be deemed anonymous and they were free to decline being interviewed at any given time.

2.5. Data Analysis

A thematic analysis was used to facilitate data analysis and identify patterns and themes of the study.

3. RESULTS

The analysis of the data revealed four major themes related to the integration of technology in STEM teaching and learning, particularly regarding the development of 21st-century skills: (1) the significance of 21st-century skills in STEM education, (2) the impact of technology integration on these skills, (3) perceptions of lecturers and students about the benefits of technological tools, and (4) the barriers to effective technology integration. These findings connect directly to the study's objectives, which sought to explore the efficacy of technological tools in enhancing essential skills for the modern workforce and address the challenges faced in this integration.

3.1. 21st-Century Skills in STEM Teaching and Learning

All the students claimed that utilizing technology to its fullest aids in the development of the four 21st-century skills (creativity, critical thinking, effective communication, and collaboration with peers and lecturers).

L2: "*I know the 4Cs that is communication, critical thinking, problem-solving, collaboration, and creativity*"

L1 and L3 were not familiar with the 21st-century skills. Technicians mentioned creativity and digital skills as 21st-century skills.

3.2. The Role of Technology Integration in the Development Of 21st-Century Skills

The use of technology in teaching and learning, in lecturers' opinion, has a good effect on students' active engagement in class activities. This is explained by the interactive features of the used technical tools.

L1: "*When using programs like WhatsApp, Zoom, and Moodle, the students are very thrilled and motivated. These software programs offer chances for interactive and group learning*".

L2: "*Technology integration promoted learner autonomy by giving students more chances to review the material covered to strengthen their conceptual grasp*".

L3: "*By taking quizzes, students can learn independently with the help of Moodle. The ability to receive quick feedback, which is crucial for their learning, thrills students*".

T1, T2 & T3: "*Technology facilitates collaboration among students and lectures and personalised learning is achieved*".

FirstYStud1, FirstYStud3, FinalYStud1, and FinalYStud2 shared the same sentiments that technology plays a major role in developing 21st-century skills and technology enhances their digital skills.

FirstYStud2 and FinalYStud3 also shared that technology allows them to learn at their own pace as they explore topics of interest.

3.3. Lecturers and Students' Perceptions of the 21st Century Skills Benefitted Through Technology Integration

All the students claimed four 21st-century skills which are creativity, critical thinking, effective communication, and collaboration with peers, lecturers, and the outside world to be enhanced by integrating most technology. The lecturers also claimed that through technology integration, student engagement is improved. They also went on to say that technology integration allows students to retrieve the resources for a good understanding anytime when the need arises. Students claimed that their academic performance improved due to technology integration. The lecturers and students share the same sentiment that students gain skills, knowledge, and good attitudes.

3.4. Skill Challenges/Barriers 21st Century Skill Technology Integration

All the lecturers, students, and technicians mentioned scarce resources like computers, course/module software, unstable internet connectivity, and power outages. Technicians also mentioned minimal support by the administration. L1 and L2 claimed no support from the administrators and technicians. All the students cited that they had minimal technical support from the lecturers and technicians. Lecturers said that they need ample time to prepare for the lessons. L2 and L3 went on to say that they need training on technology integration as staff development. L1 also said that during their learning technology has changed rapidly and they were not engaged to the current technologies. All the technicians and lecturers said that they are not technology savvy with this new technology thus explaining their minimal support to students. Lecturers indicated that they have no experience with this technology which is evolving rapidly thus hindering technology integration.

4. DISCUSSION

Education 5.0 offers excellent opportunities for technology integration in STEM teaching and learning to support the development of 21st-century skills and competencies. The study's key findings demonstrated that incorporating technology promotes student engagement in class activities. The use of technology was also believed to encourage learner autonomy by offering students additional opportunities to review the subject matter and strengthen their conceptual understanding. These findings are consistent with a study by Alenezi et al. (2023); Ghavifekr & Rosdy (2015); Farisi (2016) and the Center for Curriculum Redesign (2015:4) that showed how technology integration and digital classrooms promote teaching and learning while raising overall student achievement. Technology can transform education and prepare students for the global market thus giving students access to the right apps and tools, which will allow them to engage in the global community (Borgogni et al. 2017; Cihat, 2015; Guilbault, 2016). The lecturers contend that incorporating technology into instruction and learning is essential for the advancement of 21st-century competencies and skills in the life sciences. According to Alenezi et al. (2023); Ma'rifah & Sinaga (2023) by employing integrated digital technologies, students can advance their skills and knowledge. Improved technological pedagogical subject understanding is necessary for the effective use of technological resources in STEM teaching and learning. Different educational approaches were used by the lecturers to incorporate technology into teaching and learning. The lecturers used a variety of technological instruments, including desktop PCs, laptops, and smartphones, when integrating technology into teaching and learning.

5. CONCLUSION

In conclusion, this study showed how essential technology integration is to the growth of 21st-century competencies in both teaching and learning. There are a lot of pedagogical innovation prospects with the introduction of Education 5.0. Such changes should be taken advantage of to promote meaningful teaching and learning that will instill the necessary skills in students and lead to a transformative shift in society. The development of 21st-century skills in an appropriate educational environment reflects greater use among all members of society because these skills are life skills. Recommendations arising from the study indicate utilising the pedagogical benefits of technology integration is crucial for incorporating 21st-century skills and abilities into STEM teaching and learning. Lecturers must be trained on how to integrate the technologies and supported by technicians. To achieve the predetermined educational goals, lecturers who are essential change agents in education should be urged to fully embrace the digital revolution. Students should also receive proper training and technical assistance so they may receive instruction on how to use the system to retrieve information and post their assignments. The implementation of technologies should start with the administrators' and technicians' support in sourcing the resources. Twenty-first-century skills are key to keeping abreast with the outside world. Administrators are also urged to collaborate with other STEM-offering universities to keep abreast with the rapidly evolving technologies.

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