

**Framework for implementing STEM learning
technologies to alleviate students' challenges of the
21st-century skills at a Zimbabwean university**

by

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TITLE OF DISSERTATION

Framework for implementing STEM learning technologies to alleviate students' challenges of the 21st-century skills at a Zimbabwean university

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DECLARATION

I Doris Chasokela declare that the project hereby submitted is my work, and that all of the work of other researchers has been duly acknowledged and has not been published by any institution.

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ABSTRACT

The implementation of teaching and learning technologies at universities does not meet the requirements. Universities are currently faced with the dilemma of using technology for teaching and learning. Course/module software and learning management systems are underutilized by universities. This study provides a framework for the introduction of STEM learning skills at Zimbabwean universities to mitigate the skills challenges of 21st-century students. This study adopts a qualitative research methodology and uses a case-study design as the operational basis for data collection. Data were therefore collected from a university of technology in Zimbabwe. The sample consisted of 32 students from STEM departments in the university, 9 STEM lecturers, and 3 STEM laboratory technicians. A series of interviews were conducted with lecturers and technicians to obtain an in-depth analysis of the study. Additionally, to learn more about implementation levels and course/module software and learning management systems, the researchers observed first- and final-year undergraduates and postgraduate students in their learning environments. This study found that course/module software and learning management systems were not properly implemented for teaching and learning, and required transformation. The study found that both lecturers and students faced skills shortages in the 21st-century, resulting in minimal implementation of course/module software and learning management systems. The technical support provided by the technicians to lecturers and students was disappointing as the technicians were helpful, but had little or no knowledge and skills in using the software. The technicians were overwhelmed by the number of students as it was difficult to reach them one by one. Another finding was that student motivation and academic performance improved when teaching and learning implemented course/module software and learning management systems. The problems were insufficient course/module software, poor internet connection, power outages, lack of knowledge and skills in using the software, lack of computer/laptop because it is not compatible or unusable with the computer/laptop. They also found less implementation of course/module software and learning management systems due to classroom time. In most cases, lecturers turned to learning management systems for learning materials, homework and additional discussions, which were difficult to use. Inadequate implementation of the course/module software and learning management system for the 21st-century skills

has its effects in that technology is evolving rapidly and lecturers and students need to be abreast of it so that they do not face challenges in the workforce. This study suggests that the budgets of the technical universities interviewed should be allocated to the acquisition of STEM educational technologies and all related technologies. It promotes robust teaching and learning for STEM students preparing for the 21st-century workplace. In addition, staff development of refresher courses, seminars, or workshops for technicians and lecturers on various courseware/modules and LMS implementations facilitates effective demonstration of students in the classroom. Lecturers and students must recognize the importance of 21st-century technology, and students must remove technology from students. The university also encourages lecturers to effectively integrate STEM learning technologies into everyday teaching and learning. Recommendations for further research are to conduct a comparative and contrast study with other universities of technology in Zimbabwe, as well as regionally and globally. There is a need to learn more about the implementation of courses/modules and learning management systems in teaching and learning.

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DEDICATION

This dissertation is dedicated to my children Lyril, Lesley and Nicole, not forgetting my late father Mr T. Ndlovu who was my role model and a source of inspiration.

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LIST OF ACRONYMS

ICT - Information, Communication and Technology

LMS - Learning Management System

MKO - More Knowledgeable Other

STEM - Science, Technology, Engineering, and Mathematics

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CHAPTER 1: INTRODUCTION

This chapter includes an overview of the study and the background to the study, as well as the motivation for conducting this research. The justification for doing the study is discussed with the problem statement. The study's objectives and detailed research questions are presented. The significance of this study is examined, as well as the study's setting. Finally, definitions of keywords utilized in the study and chapter summaries are supplied.

1.0 Background to the research study

The study proposes a framework for implementing STEM learning technologies to alleviate students' challenges of 21st-century skills at a Zimbabwean university. Konca (2022:1) claims that studies in the United Kingdom and the United States of America indicate that the implementation of technology is often limited to communication and games. Markgraf and Pollitz (2022:71) and Erdogan and Yazici (2022:62) agree that universities are struggling to implement technology in teaching and learning. Academics in American universities were found to be fairly proficient users of old technology in their teaching and learning (Arslantas & Gul, 2022:1; Githinji, Ongeti & Wanyonyi, 2022:15-18; Oyelami, Sofoluwe & Ajeigbe, 2022:2; Maphosa & Maphosa, 2022:151). Muwani et al. (2022:185) state that technologies are underutilized in education in Uganda, Malawi, Kenya, Tanzania, Zimbabwe and Zambia. Semlambo, Sengati and Angalia (2022:115) and Nyathi (2022:2) also state that implementation of technology at Tanzanian and Zimbabwean universities is still very low. Finally, according to Mhlanga, Denhere and Moloji (2022:3) and Shava (2022:79), there are barriers preventing the implementation of technologies in teaching and learning in South African and Zimbabwean universities. Research at Zimbabwean universities indicates technology implementation as still lagging behind (Nyathi 2022:2; Zhou et al., 2022:17).

This study aims to uncover the implementation of science, technology, engineering and mathematics learning technologies and their impact on 21st-century skills at a Zimbabwean university. Technology implementation challenges are therefore determined by a number of factors, which include adequacy of knowledge, skills and resources (Vermesan & Friess 2022:55). Technologies is an umbrella term for the

Internet of Things and includes communication devices or applications (radio, television, mobile phones, computer hardware or software, networks (WhatsApp, Blog, YouTube, Twitter, Wiki, Quiz) and systems satellites) and the services connected to them. There are various technologies that this research focused on and specialized software packages such as AUTOCAD, MATLAB, CORELDRAW; Online environments such as virtual hands-on, online laboratories, simulations; Modelling and learning management systems (Sakai, Moodle, Angel) among the most important. Parreira do Amaral and Tikkanen (2022:2) and Kinchin (2022:2) argue that universities and globalization have converged for centuries to affect the lives of individuals and societies. Universities are under pressure to respond to global integration and implementation and STEM is education for global leadership. However, Zimbabwe, like other third-world countries, faces challenges in terms of teaching and learning skills. Technology can be found everywhere in the classroom, at home, and among students. Researchers have watched with interest how lecturers and students react to the rapidly evolving technologies. The growth of social media and conversational technologies has helped shape new ways for people to communicate, collaborate, do business, interact and learn. These technologies fundamentally define the way we think, work and live. So any type of education or approach that does not take into account that digital wave will undoubtedly face serious problems (Dominici 2022:2). Tzifopoulos (2020:1) and Okoye et al. (2022:2) cite that digital technology have entirely normalized these young folks. "Digital technology is a fully integrated aspect of their lives." Therefore, it is essential that educational technology is part of the learning process. The issue is pervasive, because it involves faculty knowledge and experience in using educational technology, the willingness of university administrations to use technology, and the university culture around educational technology in general. Because people live in a technological society and universities are part of that society, modern progressive universities actively introduce educational technology (Matthews 2022:2). However, it is normal for people to often resist change and try to stick to traditional ways of doing things. They see this as a challenge that makes their job more difficult and this is observed on both lecturers and administrators in universities. The researchers intend to gather lecturers' opinions and thoughts about the effects of educational technologies in the classroom because there have been numerous concerns raised about these technologies' efficacy (Yukselturk & Altiok 2017:791).

Researchers have made interesting observations about the impact of technology in the classroom. It is a wavelength that cannot be ignored. Economic growth in the 21st -century comes from a country's ability to generate ideas and transform them into innovative products and services (Gadzirayi et al. 2016:1). According to Gadzirayi et al. (2016:4), there is a new understanding among political, scientific, business, and educational leaders that a nation's ability to innovate and compete in the global marketplace is closely tied to innovation. However, staff development, which includes two important components, is not progressing as expected or at the expected rate because qualified and untrained lecturers reject training and further training for professional or teaching qualifications (Chitamba 2015:21). Due to the financial restraints of high university fees in the current economic climate, secondary, certificated, and semi-qualified educators struggle to develop and upgrade their qualifications.

Using technology for efficient teaching and learning presents a challenge for lecturers. According to Hungwe (2002:133), the use of textbooks in Zimbabwe due to a lack of technology threatens the quality of the country's education system. Therefore, university officials frequently direct their limited financial resources to worthwhile endeavours. The interaction between students and lecturers is greatly aided by technology. According to Gorder (2008:64), "educators need to know how" and "why" to use technology meaningfully during the learning process. A sound grasp of why educational technology should be employed serves as the beginning point. This aids lecturers in comprehending how educational technology might support the completion of course objectives. Researchers are now looking into how lecturers might employ digital technology to aid students in the classroom as a result of the unexpected influx of it. Students in the city rely heavily on tablets, cell phones, and other contemporary communication tools. While lecturers cannot ignore this tendency, they can use it to their advantage and aid students in their learning. While technical topics include wood technology, metalworking, technical drawing, architecture, and others, STEM encompasses disciplines like biology, chemistry, computer science, food science, mathematics, physics, and others. The *Sunday Mail* reported on 7 February 2016 that stakeholders have divergent opinions on STEM activities in the educational field. Fewer schools provide STEM programs, which disadvantages students living in rural areas.

The advantage is that university administrators can educate prospective STEM students, and the government now can pay tuition fees for the enrolled students through the Ministry of Higher Education, Science and Technology Development (*Sunday Mail* 2016:1). STEM jobs will soon have the strongest employment growth and wages (*Sunday Mail* 2016:1). Shizha and Kariwo (2011:4) claim that Zimbabwe's educational advancements in the early 21st-century has been affected by the political and economic crisis, leading to low academic achievement and a serious brain drain. There is a shortfall of 1 521 science and mathematics lecturers in the nation due to the brain drain (Chitate 2016:28; Ncube 2016:5).

1.1 Statement of the research problem

Implementation of technologies has become a central issue for STEM education. Various literature recognises the importance of technology implementation in the universities. There is insufficient implementation of STEM learning technologies and their perceived impact on teaching and learning in the 21st-century at Zimbabwean universities of science and technology. According to Chitanana, Makaza and Madzima (2008:10), Mahlangu and Makwasha (2023:3), and Muchabaiwa and Gondo (2022:121), lecturers at Zimbabwean universities are facing problems such as lack of computers, insufficient technology training, poor internet connectivity, lack of technical/administrative support and a lack of awareness on ways to integrate and implement the software into the courses/modules and lack of access to the computer room with the courses. Musarurwa (2011:5) cites a number of challenges in mainstreaming technologies, such as the fact that the technology budget is not prioritized for ICT infrastructure and resources. Sife, Lwoga and Sanga (2007:63-64) and Ndibalema (2021:444) indicate that many Tanzanian universities face challenges such as lack of ownership, systematic approach to technology implementation, awareness and attitude towards technology integration, administrative/technical support, transformation of higher education and insufficient resources. Another argument for the challenges facing South African universities is that higher education is under pressure to deal with social change, skills and diversity in the academic preparation of students (Jaffer et al. 2007:1; Mhlanga et al. 2022:466). According to Ndou (2004:12) and Zarei and Mohammadi (2022:85564), in developing countries in general, e-government is a powerful engine for wealth creation and growth, but various

challenges remain that hinder the exploration and exploitation of its opportunities, such as insufficient infrastructure, policy issues and change management, technology implementation strategy, leadership and lack of skills in the use of technologies. Hay and Fourie (2002:2) describe perceptions of staff at Zimbabwean and South African higher education institutions and find that the main challenge is financial constraints, which contribute to insufficient resources and an unequal distribution of resources. Materu (2007:49-54) presents the challenges of technology implementation in South Africa, higher institutions such as cost and funding constraints of technologies and effective communication, lack of national policies, lack of incentives and standards.

1.2 Main research question of the study

What framework can be developed to enhance the implementation of STEM technologies to alleviate students' challenges at a university of technology?

1.2.1 Secondary research questions

The study was guided by the following questions:

- i. What are the STEM learning technologies that are used in the 21st-century at the Universities of Technology in Zimbabwe?
- ii. What are the skill challenges faced by students in the 21st-century?
- iii. What are the students' perceptions regarding the use of STEM learning technologies?
- iv. To what extent are STEM learning technologies implemented at a Zimbabwean university of technology by lecturers?
- v. How are STEM learning technologies implemented for the 21st-century skills and their effects in Zimbabwe?

1.3 Main objective of the study

To develop a framework to enhance the implementation of STEM technologies to alleviate students' challenges at a university of technology

1.3.1 Further objectives of the study

The study seeks to:

- ✓ Explore STEM learning technologies used for 21st-century at the University of Technology in Zimbabwe.
- ✓ Examine the skill challenges faced by students in the 21st-century.
- ✓ Establish the students' perceptions regarding the use of STEM learning technologies.
- ✓ Investigate the extent to which STEM learning technologies are implemented at Zimbabwean universities of technology by lecturers.
- ✓ Evaluate how STEM learning technologies are implemented for the 21st-century skills and their effects in Zimbabwe.

1.4 The purpose of the study

The purpose of this study was to review recent research and to establish how learning technologies are implemented in STEM disciplines in the 21st-century and their effects at the Zimbabwean universities. This study also suggests and develops a framework for the implementation in STEM disciplines in the 21st-century for the universities.

1.5 The significance of the study

The findings should make an important contribution to the field of STEM to lecturers, students, technicians, education administrators, parents, the Ministry of Higher and Tertiary Education and other interested parties. The study hopes to drive technological advances in the appropriate use of technologies by lecturers and students to achieve a knowledge-based economy. The budgets allocated for technology would be another factor that would be used to evaluate whether universities that commit a lot of technological resources benefit from it or not. This would go a long way in informing education administrators, parents, the ministry of education and all stakeholders as a whole whether or not it is wise to invest in education technology. Students have a good chance to benefit from this research, as the research would reveal the need to use technology in the classroom and determine whether or not educational technology motivates students. The study would try to determine whether the use of educational technology helps in teaching, studying, researching, and communicating with peers.

On the other hand, lecturers would find the right technology to blend with the teaching and learning of STEM courses. Additionally, lecturers will determine whether educational technology helps teach lessons and to what extent it can help explain concepts verbally and to what extent it can enhance the learning and teaching process.

1.6 Definition of key terms

STEM: is an acronym that stands for Science, Technology, Engineering and Mathematics. These are disciplines that enable students to be creative, promotes critical thinking, improves communication and enhances the ability in problem-solving (Chu et al. 2023:42).

Learning environment: This term suggests a place or space which could be a classroom, laboratory or a library. It is also believed that it is not just a physical structure but an emotional and intellectual entity (Osborne 2016:2). Keller (2016:1) adds to say that it encompasses the learning resources and technology, means of teaching, models of learning where a lot of teaching takes place.

21st-century: According to Deng et al. (2023:143), this is seen as the start of the Digital Age, a period of extraordinary technological growth and accompanying information explosion. New technologies and tools are being developed on a daily basis throughout this era.

21st-century skills: These are the abilities required for success in the 21st-century. Life, career, and learning skills are identified as 21st-century skills (Karaca-AtikMeeuwisse et al. 2023:2).

21st-century challenges: These are outcomes of use of technologies that cause cyber warfare, unemployment, health, overpopulation amongst others.

Learning technology: According to Januszewski and Molenda (2013:1) and Dron (2022:6), learning technology is also known as instructional technology or educational technology that deals with science of applying scientific knowledge to practical problems used to support teaching and learning.

Information Communication Technologies (ICTs): ICTs are simply technologies arising from scientific and technological progress in computers sciences, electronics and telecommunications and are used to store, manage information, create,

disseminate and communicate, e.g. computers, projectors, software, internet (Biggs 2012:396).

Course/module software: Also known as training or learning software in a computer that assists to execute programs and output information.

LMS: This stands for learning management system. It is software that assists in the seamless operation of an e-learning platform (Chatterjee et al. 2022:1475). According to Badaru and Adu (2022:68), the LMS is a set of software solutions that serve as a virtual classroom for online teaching and learning activities involving both the lecturers and students.

1.7 Assumptions of the study

The researcher also assumes that the university under study have sound STEM education and that they have an understanding of technology (sound knowledge and background of STEM education), as well as that there are records to indicate the technologies and usage in the institutions.

1.8 Delimitations of the study

The study focused on one Zimbabwean university of technology. The geographical location of university under study is 1 642,1 kilometres from Bloemfontein. The study mainly focused on specialised software and learning management systems in the teaching of STEM. The research focused on STEM learning tools and learning settings that contribute to prepare students for 21st-century issues at Science and Technology University in Zimbabwe. This study had nothing to do with e-learning, projectors, and other technologies. The main focus was on specialised course/module software packages like AUTOCAD, MATLAB, CorelDRAW and learning management systems like MOODLE, Sakai, Canvas, amongst most.

1.9 Limitations of the study

The study was limited to one institution, which is one of the limitations. Another potential problem is that the scope of the thesis might be too broad as technology is broad. With the advancement of mechanization, some lecturers and technicians are not equally trained with proper implementation of technology, so it may be difficult to

collect authentic data in such cases. Findings could not be generalized as the researcher dealt with a single institution in the country. During focus groups some students might take a back seat and allow the vocal ones to participate in the discussion, maybe because of shyness and other reasons known to themselves. During lesson observations the researcher might affect the situation by being present; therefore getting invalid findings.

1.10 Chapter organisation

The dissertation thesis is composed of seven themed chapters. The overall structure of the study takes the form of seven chapters, including:

Chapter One – Introduction: gives a brief overview of the recent background on the implementation of STEM technologies, the statement of the research problem, main research question of the study, main objective of the study, the purpose of the study, the significance of the study, definition of key terms, assumptions of the study, delimitation of the study, limitations of the study and chapter summary.

Chapter Two – Theoretical framework: begins by outlining the theoretical dimensions of the research and examines introduction, theoretical framework of socio-constructivism, social interaction, More Knowledgeable other, Zone of Proximal Development scaffolding, synthesizing the phenomenon and identifying gap which the study has fulfilled, relevance of socio-constructivist framework to the study problem, model to map factors involved in the implementation of technologies, aspects involved in technology adoption, roles within and beyond the institution, learning organization, organizational climate, staff training and development, infrastructure and resources, ICT/Technology policy significance of the highest influential factors, the configuration of learning, student role, lecturer role, content of the curriculum, relevancy of the socio-constructivist theory as a framework for the study and chapter summary.

Chapter Three – Review of related literature: is concerned with the review of literature from other authors and includes introduction, benefits of STEM education, nature and scope of STEM education, type of connection/linkage among the STEM disciplines, duration, size and complexity, dominant discipline, STEM learning technologies used in the 21st-century, Learning management systems, classification of Learning management systems, course/module software package implementation

in STEM 21st-century skill challenges faced by students, challenges in the use of the LMS and course/module software, life and career skills, Information media and technology skills, learning and Innovation skills, critical thinking higher-order skills, communication higher-order skills, collaboration higher-order skills, creativity higher-order skills, students' perceptions, attitudes and barriers on the use of STEM learning technologies, extent of STEM learning technology implementation, STEM learning technology implementation for the 21st-century skills and their effects and chapter summary.

Chapter Four – Methodology: deals with methodology used for this study and includes: introduction, research paradigm, epistemology of a paradigm, ontology of a paradigm, methodology of a paradigm, axiology of a paradigm, research approach, qualitative approach, research design, the population and sample sampling procedures, the data collection research instruments, semi-structured interview guides, focus group interview guides, observation schedules, data collection procedures, data analysis and presentation techniques, validity and reliability, ethical issues and chapter summary.

Chapter Five – Data presentation and analysis: This chapter presents and analyses data and includes an introduction, distribution of participants and their biographical data, teaching and laboratory experience for the lecturers and technicians, STEM technology implementation in universities of technology, STEM learning technologies (course/module software and LMS) used in the 21st-century at the university, understanding what 21st-century skills are, frameworks useful in determining skills and competences for excelling in teaching STEM programmes, challenges faced by the lecturers, technicians and students in the implementation of course/module software and LMSs, Students' perceptions regarding the use of course/module software and LMSs, beliefs, knowledge and attitudes in the implementation of course/module software and LMSs in the teaching and learning of STEM, perceived usefulness of technologies to improve students' 21st-century skills, perceptions, practices and comfort with teaching and learning STEM programmes, gadgets/software availability and extent of use in teaching and learning of STEM programmes, extent of STEM learning technology implementation, implementation of STEM learning technologies for the 21st-century skills and their effects in the teaching and learning, Technical and financial support, promotion of STEM to students, possible solutions to the challenges

faced in teaching STEM programmes, and any other information shared in regard to the implementation of technologies in STEM learning.

Chapter 6 – Summary, conclusions and recommendations: presents the introduction, summary, conclusions, recommendations and suggestions for further study.

Chapter 7 – Proposed Framework: This is the final chapter that has a proposed framework created by the research to alleviate students' challenges of the 21st-century skills at a Zimbabwean university. It includes an introduction, technology implementation framework, key elements of technology implementation framework, ICT/technology policy, administration and technical support, awareness of technologies, staff development, internet broadband connectivity, availability of infrastructure and technology resources, student development in basic computer literacy and chapter summary.

1.11 Chapter summary

The paper outlined the rationale for the study to identify challenges and factors affecting students and lecturers in the use of technology in STEM in higher education institutions in Zimbabwe. Technologies in higher education offer a myriad of benefits to enrich the quality of learning. Despite the ubiquitous nature of technologies, they have never been fully integrated into the teaching and learning process. Technologies at these institutions will revolutionize teaching and encourage the development of students' innate scientific inquiry and critical thinking skills. Therefore, it is safe to conclude that the role and functions of lecturers have changed tremendously with the advent of modern technologies. Lecturers today are therefore forced to adapt to new technologies. As such, modern technologies present a range of challenges for lecturers, and the challenges extend to administrators and everyone else involved. However, there is no doubt that modern educational benefit students as well as lecturers and a modern university cannot ignore them in any way.

The next chapter discusses the theoretical framework of the study.

CHAPTER 2: THEORETICAL FRAMEWORK

2.0 Introduction

The researcher elaborated on the study's background, goals, importance, assumptions, and delimitations in the previous chapter. These topics were also covered. As a result, the study's importance, assumptions, constraints, and delimitations were all analysed, and research questions and objectives were developed. The theoretical framework that can be used to develop stem learning technologies to address learner issues is the main topic of this chapter. According to Guseva and Solomonovich (2017:776), the educational component should unquestionably be about skills opportunities that have helped the student if the goal of education is to support student growth. Gilmore and Anderson (2016:687) assert that the exchange of knowledge among university students serves as a venue for personal development. The spread of knowledge also acknowledges the emotional and interpersonal effects required to foster learning and support the scientific imagination. The constructivist theory is one that complements other ideas in corresponding areas.

A socio-constructivist theory of education was employed in this study, Vygotsky's constructivist theories can take many forms. Constructivism is not something that should be taught to students by lecturers, as stated by Grier-Reed and Williams-Wengerd (2018:2), Suhendi, Purwarno and Chairani (2021:76), and Reid-Martinez and Grooms (2018:2587). Instead, students build knowledge by implementing it with the objects in their surroundings. One of the most crucial learning activities for students is social participation (Ahn & Davis 2023:2; Salta et al. 2022:94).

The integration of technology as an enabler in the educational system is acknowledged to be exceedingly complicated (Rose & Kadvekar 2015:559). Technology implementation has been a research issue for many, "from adoption of technology to its advanced use and across the globe" (Rose & Kadvekar 2015:559). Several institutions have provided ICT frameworks with requirements that lecturers must meet (Tondeur et al. 2017:462). In many countries, digital competence frameworks were initially created for students and have only lately begun to focus on lecturers (Tondeur et al. 2017:462). A framework for lecturers has recently been developed in the Netherlands (Tondeur et al. 2017:462), to specify "what competences lecturers need

to integrate technologies in such a way as to improve their teaching more attractive, more efficient and/or more effective".

By distinguishing knowledge, skills and attitudes in the learning process, the socio-constructivist theory/framework offers institutions an organized approach to the use of technologies in curriculum and evaluations. It also offers lecturers a manual for implementing technology into teaching and learning and for evaluating such technologies across all courses and modules (Voogt & Roblinj 2012:303). The framework is founded on the idea that, when used strategically and with the right resources, technologies may enhance teaching and learning. Utilization of the technologies framework differs from university to university, depending on a number of academic aspects, including access to technology resources and equipment, lecturer proficiency and confidence with technologies, and the level and stage of development of the school planning for technologies in the curriculum and assessment. Technology frameworks enable lecturers to help students be creative, communicate, collaborate, think critically and creatively, understand the social and personal impact of technologies, and develop knowledge, skills and concepts. The socio-constructivist theory has been used in the study for effective implementation of STEM learning technologies and its proponent is Vygotsky (Vygotsky 1978:19).

2.1 Theoretical framework of socio-constructivism

The best theory to direct STEM teaching and learning is socio-constructivism, because it examines existing theories. Philosophers and educators, including Vygotsky, Piaget, and Perkins, contend that socio-constructivism offers solutions to the challenges associated with conventional teaching and learning , as stated by Amineh and Asl (2015:11). According to Maryati, Permanasari and Ardianto (2022:155), socio-constructivism evaluates the knowledge and understanding that students have collectively built based on reality (Amineh & Asl 2015:12). Students' invention-related activities help to form reality, while activities involving interactions with surrounding objects help to construct knowledge. The socio-constructivist learning approach necessitates high-quality student participation, as they learn by doing to acquire information, skills, and positive attitudes (Tubman, Oztok & Benachour 2016:2). According to Schrader (2015:14), Vygotsky based socio-constructivism on a number of elements, including the social and cultural context, artifacts, instruments for peer

participation and Most Knowledgeable Other (MKO). Vygotsky's contribution to teaching and learning in the early 21st-century served as the foundation for the socio-constructivism theory (Daniels 2016:173). Social interaction, zone of proximal development (ZPD), More Knowledgeable Other (MKO), and scaffolding are strategies included in socio-constructivism that enhance teaching and learning.

2.1.1 Social interactions

Students learn through peer cooperation, reciprocal teaching, cognitive learning, problem-based education, web-based quests, computers, and many other approaches (Amineh & Asl 2015:14; Chiang & Lee 2016:709; Afandi et al. 2019:90). According to Amineh and Asl (2015:14), students engage with and learn from their faculty lecturers, laboratory technicians, peers, informed members of society, and the physical environment in general. In order to promote their collaboration properly, students can gain advantages from connecting with online resources and social media (Hsieh 2017:118).

2.1.2 More knowledgeable other (MKO)

These are better-informed people in society who possess the knowledge that students require. They could be professionals from business, government, or other educational institutions, lecturers who are knowledgeable about how things ought to be done and how to address specific issues (Smith 2017:260 & Drew 2022:1). Lecturers are the nearest More Knowledgeable Others (MKOs), according to Amineh and Asl (2015:14), since they aid students in understanding the subject matter. There, the professor gives the students the information during their initial interaction before the students approach additional stakeholders. By providing course/module introductions, the lecturers serve as the students' basis. Smith (2017:259) acknowledges that MKOs are crucial, because they improve students' ability to think critically, and that one of their capabilities is to mentor. MKOs are crucial for improving students' thinking skills, and one of their capabilities is to mentor others in their zone of proximal development (Smith 2017:260). Smith (2017:260) claims that peer and MKO collaboration is ultimately what makes the teaching and learning process successful.

2.1.3 Zone of Proximal Development (ZPD)

Amineh and Asl (2015:15) and Vygotsky (1978:86) state that learning begins at a much higher level than the current level of what the student initially knows, and this usually occurs in the area of proximal development (ZPD). Several researchers (Guseva & Solomonicivh 2017:776; Hsieh 2017:116; Hu & Yu 2017:179; Shrestha 2017:3-4; Abeysiriwardhane et al. 2016:51; Gao & Li 2016:888; Gros & Lopez 2016:2; Abeysiriwardhane, Lutzhoft, Petersen & Enshaei 2016:51; Stott 2016:26; Haider & Yasmin 2015:170; Fernandez et al. 2015:54; Kurucay & Inan 2017:3; Amineh & Asl 2015:14; Channa & Nordin 2015:581; Schrader 2015:14; Vygotsky 1978:86) who defined ZPD use the known definition as the difference between the actual degree of development as determined by independent issue solving and the potential level of growth as determined by problem solving under adult supervision or in partnership with more knowledgeable individuals.

Vygotsky's ZPD approach, according to Mattar (2018:201), is a more adaptable framework that can even incorporate social networks, course/module software, and learning management systems into teaching and learning. ZPD is described in Vygotsky's work as a subject that psychologically assesses students' capacities as individuals (Fernandez et al. 2015:55). Vygotsky suggested evaluating students' abilities on an individual basis, with or without assistance. The distinction between what a student can learn on their own and what they can acquire with the supervision of a professor is described by Clapper (2015:4) and Vygotsky (1978:86). The execution of design projects, according to Abeysiriwardhane et al. (2016:50), is student centred and hence connected to Vygotsky's ZPD and socio-constructivist theory. As cooperation is promoted in ZPD and collaborative problem solving, students can tackle all assigned issues working in teams while interacting with lecturer support rather than working alone (Abeysiriwardhane et al. 2016:53). Students' interactions with other stakeholders' aid in ZPD, since they gain information and skills, claim Kurucay and Inan (2017:3). Initially, the lecturer designs the learning activities, and the students practise being helped at first before starting on their own to see if they have understood the duties or steps of a procedure. The four-stage ZPD model is described in the following manner by Channa and Nordin (2015:582): Stage 1 is where students are first helped to learn through interaction by the lecture, peers, specialists,

technicians, and the MKO. The second stage is where students work on their own with little supervision to build the information and abilities necessary to confirm that they comprehend the instructions. In this instance, Stage 3 gives students the chance to work independently and without assistance from the lecturer. Stage 4 is the final level, where students fully develop their independence and can work independently both inside and outside of the classroom, building on what they have learned thus far.

2.1.4 Scaffolding

The same ideas about scaffolding are held by Hsieh (2017:115-116), Smith (2016:133), Abeywardhane et al. (2016:53), Haider and Yasmin (2015:170), and Fernandez et al. (2015:54). Scaffolding refers to the process by which underachieving students are assisted by the lecturer and peers in order to fully comprehend a concept. It is possible to test students, offer advice, demonstrate models, and review lessons they have already learned. Students can also engage in peer interaction to develop new forms of communication and critical thinking. Online resources, including blogs, tutorials, Google Scholar, and electronic reading material, constitute a source of scaffolding (Hsieh 2017:116). The lecturer directs the students' attention to the prescribed task, simplifies the task, supports it by gratifying the student, and provides idealized models of how to complete the assignment (Fernandez et al. 2015:56).

According to Haas, Lavicza and Kreis (2023:4), Zhang et al. (2021:2), and Owen and Stupans (2009:274), universities are essential in providing students with the learning scaffolding they need to succeed. Therefore, during the apprenticeship and following the industrial incorporation, students adhere to a protocol and counselling practice. Industrial businesses continue to support students, which fosters a learning environment or develops into a community of practice. According to Owen and Stupans (2009:273) and Alhalafawy et al. (2021:109), the creation of scaffolds is facilitated by social interaction (with peers, speakers, and MKO) as well as by environmental, physical, and symbolic tools (books, laboratories, assessments). Scaffolding, in the opinions of Hu and Yu (2017:179), Bannert et al. (2015:293), Guo (2022:811) and Zheng (2016:189), is the best method for assisting teaching and learning. Last, but not the least, Reda (2023:145), Sundari and Febriyanti (2023:17), and Owen and Stupans (2009:274) characterize scaffolding in ZPD as knowledge building through critical thinking, cooperation, and students directed by the MKO.

2.2 Synthesize the phenomenon and identifying the gap that the study fulfilled

The study closes the technology implementation gap by developing a framework for social networks, technological course/module software, and learning management systems that may be successfully integrated into the teaching and learning of STEM programs. Without any difficulties, the framework changes how we interact locally, regionally, and worldwide in our daily lives. The framework for implementing technologies combines well with the elements that affect this process.

2.3 Relevance of socio-constructivist framework to study problem

The proposed framework is pertinent to the issue being investigated in terms of how well technology is being integrated into STEM learning disciplines. Technology implementation will be fully accomplished if the framework is used appropriately in teaching and learning. The students plan ahead for real-world problems and collaborate more effectively with peers, lecturers, and other subject-matter experts to find better solutions. Universities and its stakeholders are able to put technology into practice and produce students with 21st-century skills who can function in a complicated and unreliable computerized world. The application of course/module software and LMSs in the learning activities is relevant to the learning by doing element.

2.4 Model to map factors involved in the implementation of technologies

Socio-constructivist theory is supported by a model of the aspects involved in implementing technologies in teaching and learning. Nachimias et al. (2004:294) suggest a model to map the components involved in implementing innovations utilizing his, as shown in Figure 1. In order to provide students with knowledge, skills, and positive attitudes, it is then employed in all social networks and technological tools that are integrated into teaching and learning.

2.4.1 Factors involved in implementation of technologies

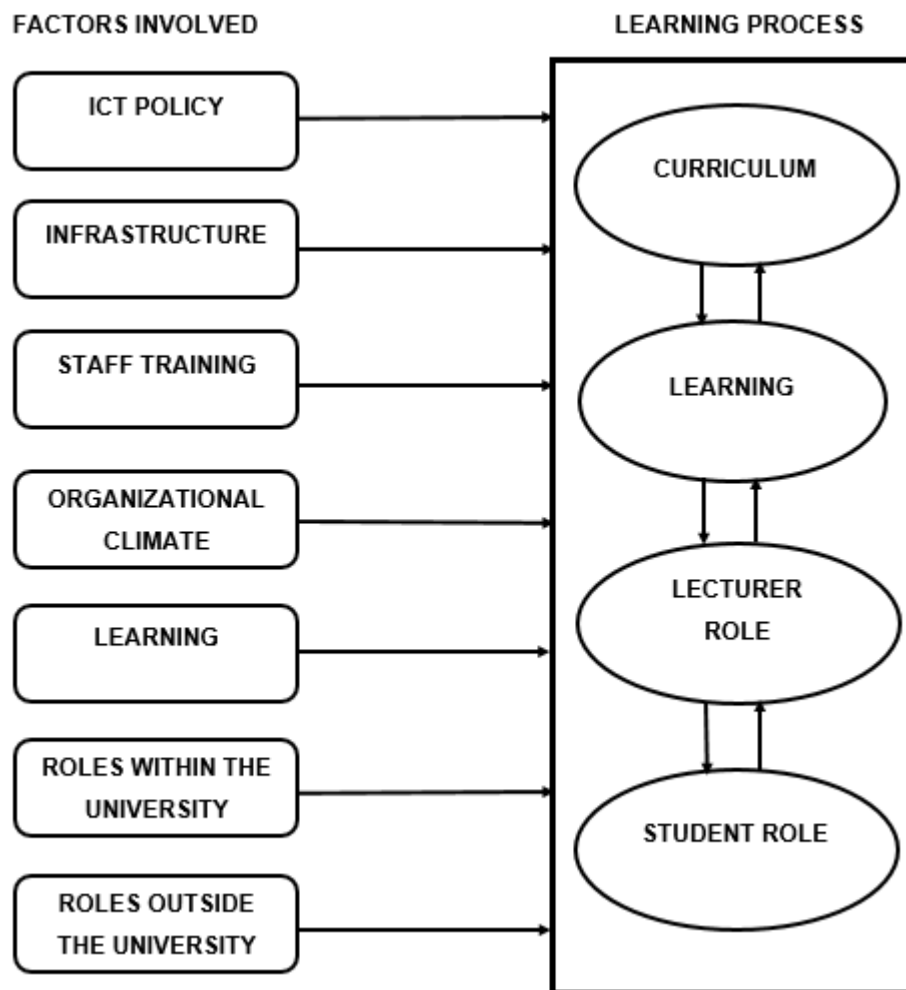


Figure 1: Model for factors involved in innovations implementing ICT
(Nachmias et al. 2004:294)

According to Njui (2018:106-107), stakeholders, such as students, parents, lecturers, administrators and the government, are involved in the implementation of technologies and are expected to perform their roles well in order to accomplish quality education. Roles inside the school, roles outside the school, the organization of learning, organizational environment, staff training and development, infrastructure – resources, and technology policy are factors with the greatest influence on the application of technologies.

2.4.1.1 Roles within the university

The Vice-Chancellor, Pro-Vice-Chancellor, Deans, Departmental Chairpersons, Technology Coordinators, technicians, and leading lecturers are some of the

management roles at the university. Other responsibilities include selected staff members with additional functions in the operation of the invention who have made remarkable contributions to the technological implementation (Gichoya, 2005:175-176; Nachimias et al. 2004:294; Zhang et al. 2023:2). Albugami and Ahmed (2015:38), Ghamrawi (2013:13-14), and Pozzi, Rossi and Secchi (2023:141) all agree that management of the institutions plays a crucial role in the implementation of technologies because they must create a learning-friendly infrastructure, organize training, offer consultation and promotion, and monitor and evaluate learning. Therefore, managers should be seen as the ones who facilitate the use of technology at the collegiate level. This implies that a good working environment cannot be created to encourage lecturers to integrate and utilize technologies in the teaching and learning if management does not offer them enough support and encouragement. According to Albugami and Ahmed (2015:39), management's attitudes and views must be positive in order for technologies to be adopted by the institutions and put into use. Razzak (2015:3) also agrees to management representation as that "technology is about change and change requires strong leadership".

This thus helps in overcoming a number of difficulties that frequently accompany the institutional technology installation. Both Kennah (2016:12) and Razzak (2015:4) concur that management plays a key role in education and that educational authorities in every nation must prioritize improving institution principals' leadership abilities in light of the current educational climate. Uluyol and Sahin (2016:67) assert that when lecturers incorporate technologies into their teaching and learning, they need organizational support in addition to technical and pedagogical support. Uluyol and Sahin (2016:3) concur that peers, management/administrators, technology coordinators, or other stakeholders may offer such help. Uluyol and Sahin (2016:72) contend that institutional administrators must be wholly committed to implement technology before they can ever hope to persuade and inspire professors to make such a change for themselves and to believe in the importance of doing so. Uluyol and Sahin (2016:72) note that a higher percentage of skilled and tech-savvy management leads to quicker pedagogical reform and more effective adoption of technology. According to Uluyol and Sahin (2016:72), leadership openness to change is important for institutional development and improvement. Technology coordinators do not appear to be experts in implementing technology into teaching and learning, or to have

much prior experience doing so (Uluyol & Sahin 2016:73). Therefore, it is crucial to draw a distinction between lecturers, whose knowledge and skills are in facilitating and pedagogically supporting technology integration in the curriculum, and laboratory technicians, who support technology and infrastructure.

University leadership is a crucial element to support the implementation of 21st-century competency (Voogt and Roblinj 2012:311). Njui (2018:112) asserts that management's job during technology implementation is to convey established educational policies to administrators, lecturers, technicians, and students in order to raise awareness and secure support. According to Kennah (2016:26), universities must collaborate with other (network) universities, coworkers, the industry, and the community in order to establish new approaches for teaching and learning. As technology leaders, university administrators across the globe now have a new duty to fulfil, according to Kennah (2016:38). Since technology is growing quickly, they must acquire new skills to play this new role successfully and allow beneficial technology deployment.

According to Kennah (2015:39), the Vice-Chancellor (VC), as a leader of learning and the president of a university, must demonstrate a deep awareness of the technological programs through communication, inquiry, decision-making, and problem-solving. The VC is also a student entitlement leader, addressing major concerns of fairness in access to technology for all students and lecturers. VCs play an important role in introducing and implementing technology at a university for teaching, learning, and management purposes (Laouni 2023:49). A capacity-building leader is a leader who acts as an active change agent by collaborating with lecturers, monitoring the development of a vision for the pedagogical use of technologies at the institution, and serving as a mentor or coach to lecturers. He or she is a community leader, involving industry, community, including parents, other non-governmental organizations, and corporate partners in accomplishing the goal of effective pedagogical use of technology at a university. The VC also shares triumphs and problems with the community and builds networks that expand students' learning beyond the university's doors. The Vice-Chancellor is in charge of managing the university's resources for effective pedagogical use of technology. Last but not the least, the VC makes critical judgements on wiring and computer placement (Flanagan & Jacobsen 2003:132-140; Yee 2000:292).

In order to integrate technologies effectively into teaching and learning, leadership should promote effective internet connectivity and make time for lecturers to plan, cooperate, and network internationally (Task Team outcome paper 2013:23; Wastiau et al. 2013:13). Technologies embrace and support learning management systems, helping lecturers with their administrative responsibilities and establishing policies, practices, and expertise in the technology implementation. This improves the efficiency of teaching and learning in the 21st-century. According to Unwin (2005:122-123), the Ministry of Higher Education should be in charge of strategic leadership at the national level, which should be owned by the government as a whole. Unwin (2005:122-123) continues by stating that Ministry projects have the potential to fully overlap with ongoing work. As such, they must be strong in this area and provide universities with hardware and software from the private sector, donors, or civil society organizations. According to Wastiau et al. (2013:12), it is crucial for universities to have a plan and leadership in place when implementing new technologies to ensure that they are effectively embraced and utilized in the teaching and learning process.

The ability and willingness to apply innovation, assist, and engage lecturers and students through innovative 21st-century teaching and learning are characteristics of meaningful leadership/administrator (Kent & Giles 2017:10). According to a number of researchers, administrators' self-efficacy significantly affects lecturers' self-efficacy views (Kent & Giles 2017:11; Thompson et al. 2021:276; Namaziandost et al. 2023:2279). Without leadership and self-efficacy, it is hard for universities to move closer to their main objective (Kuvaas & Buch 2019:119; Sifelani 2022:20; Scott et al. 2023:2). In other words, one can say that improving student accomplishments, raising academic performance, and dealing more effectively with the turmoil and uncertainty that characterize universities are associated with good leadership.

2.4.1.2 Roles outside the university

Outside of the university, there are parents, external institutions (such as academic, industrial, business, and pedagogical institutes), subject matter experts (virtual lecturers, curriculum writers, and researchers), position holders in the Ministry of Higher Education (such as supervisors and technology advisors), and municipal position holders (such as the director of the education department and the regional coordinator). The involvement of many stakeholders from the public and commercial

sectors is important for the deployment of technologies (Voogt & Roblinj 2012:310). According to Voogt and Roblinj (2012:311), lecturers must learn how to employ a variety of technological tools to create learning environments that support 21st-century learning. There is a need for lecturers to comprehend the significance of these competences and the methods in which they could be included into the curriculum given the complexity and cross-disciplinary character of 21st-century competences. The possibility for lecturers to participate in ongoing, work-related professional development activities and/or to witness real cases while participating in professional learning communities could then be made available. Parents have a significant impact on how technology are used in universities around the world, but especially in Africa (Kennah, 2016:12). According to Unwin (2005:123), it is crucial that the process of implementing technology involves the relevant stakeholders and potential partners at an early stage. These stakeholders and partners should at the very least include representatives like lecturers' unions, involved lecturers, curriculum developers, and hardware and software providers. He continues by saying that these stakeholders must comprehend the significance of introducing innovations gradually over several years. One can then say that MKOs fall under this category as they can assist the students, lecturers and the university at large with knowledge and skills on technology implementation.

2.4.1.3 Organization of learning

The two primary components of the organizational structure of the university are the organization of learning and organizational of teaching. It lists the lessons, set time blocks, activity hours, and student distribution into learning groups thus single-aged, multi-aged, based on interests, content, etc. (Nachimias et al. 2004:295; Gichoya 2005:175). According to Tearle (2004:9), Janssen et al. (2023:4), Ma, Shi and Hou (2023:2), and Tran et al. (2023:3), management and coordination are crucial for the key individuals, hence the senior management must be identified. Creating a course/module outline that flows naturally for all courses/modules at all educational levels is the focus of this sort of educational planning. The goals and requirements of the individual as well as the demands of the greater society are taken into consideration while planning education. Examples of how to set educational objectives include forming a curriculum committee to develop the curriculum and choose effective teaching methods, planning content units, evaluating the curriculum, reviewing the

curriculum, utilizing the library, developing remedial instruction for slow students, and creating special accommodations for gifted students (Ogunode, Eyiolorunse-Aiyedun & Olatunde-Aiyedun 2021:140). Social interaction is involved as peers interact, MKOs are also consulted by the students and the lecturers for knowledge and skills where necessary. In the teaching and learning the lecturers find out what the students know about the studied topics and they take it from there. This allows the lecturers to structure the lectures so that they incorporate all the students' needs. The lecturers have a duty to scaffold students who lag behind imparting them with relevant knowledge and skills so that they are at the same level of learning.

2.4.1.4 Organisational climate

The vision and aspirations for technology at the institution are included in this category of organizational climate. The stage of vision consolidation and clarity is used to gauge involvement. The university's history of innovation, as determined by past involvement in innovations, openness to innovations, and readiness to experience innovations is another important consideration (Gichoya 2005:176-179; Nachimias et al. 2004:295). This type of educational planning is macro-level by nature, since it comprises organizing lessons in a classroom setting around a specific course/module subject. The organizational climate and emotional climate of the classroom are both covered in this lesson plan. The vision and aspirations for technology at the institution are included in this category of organizational climate.

2.4.1.5 Staff training and development

All educational ministries and agencies should train educational planners on how to use technology for planning (Ogunode et al. 2021:145). In the category of staff training and development, there are two aspects: the source, which is determined by the resources that are accessible to innovation operators, and the content, which is determined by the applicability of the training activities (i.e. how well they meet the needs of lecturers). The range includes continuing internal training that is simple to access and less convenient external training (Nachimias et al. 2004:295; Gichoya 2005:176-180). Tearle (2004:9) asserts that different lecturing techniques and lecturers' role models are necessary. He continues by noting that academics need help in a number of different areas to use technology more frequently in their instruction and learning. According to Ghavifekr and Rosdy (2015:177), lecturers

should receive training in order to gain the technical proficiency needed to deploy technology and the high level of confidence needed to apply it in teaching and learning. They go on to state that universities should use a range of tactics to provide professors with additional professional development outside of the teaching of essential skills. Universities must support short courses on appropriate pedagogy and technologies for relevant curriculum, improving technology skills, broadening knowledge, and shifting to a positive attitude in the implementation of technologies, according to the Task Team output document (2013:23). According to Unwin (2005:124), workshops will be held to give lecturers hands-on experience with social networks, technological tools, and other new technologies. Unwin argues that developing techniques for lecturers to use technology at an early stage is crucial. This is crucial so that administrators, government representatives, and lecturers' leaders may understand and recognize the significance of the changes and contribute effectively to the creation of such initiatives. Collaboration is achieved by consulting the MKOs during and after staff development.

2.4.1.6 Infrastructure and resources

In order for educational planners employed by various ministries and agencies to fulfil their planning duties online in the event of a pandemic in the future, the government ought to equip them with modern technology infrastructure (Ogunode et al. 2021:145). This area includes the amount of peripherals, accessibility, and usage of infrastructure as well as the ratio of student-to-lecturer computers, availability, and infrastructure utilization. Additionally, the institution measures technical support based on the sort of support provided both internally and externally. Technologies and their satisfaction were also looked at in the innovation budget (Gichoya 2005:180-181; Nachimias et al., 2004:295). According to Tearle (2004:8), the accessibility of technology continues to get the greatest attention paying close attention to the computer location, dependability, type, quantity and access. At universities, funding is the key feature of government intervention in the use of technologies. According to Nachimias et al. (2004:295) and Albugami and Ahmed (2015:39), institutions need to have a robust infrastructure and more opportunities to facilitate and access technologies. Infrastructure and technological facilities are required to supply universities around the country (Ghavifekr & Rosdy 2015:176). Ghavifekr and Rosdy continue by saying that using technology, having enough computer labs, having access to the internet, and

having technology equipment available are all important factors. According to Ghavifekr and Rosdy (2015:176), the accessibility of resources guarantees that lecturers have quick access to technological resources whenever necessary. Each and every lecturer has to have a computer in their office, and the student-to-computer ratio should be low to allow for simple access (Ghavifekr & Rosdy 2015:176). To reduce hurdles, technical support is essential as well, and that includes low connectivity, virus attacks and printer not functioning, amongst the most. Technical support reduces frustration for students and lecturers as it reduces interruptions in teaching and learning process. Mereku and Mereku (2015:9) mention the number of internet-connected computers and the computer-to-students' ratio, both of which should be reasonable. The students need to have a lot of access to the technology and show off how capable they are. According to Kennah (2016:12), there have been numerous initiatives to persuade lecturers to integrate technology into the teaching and learning process ever since computers, learning software, and the internet were introduced at universities. Thus, it is necessary to push certain lecturers from being non-users to infrequent users and from light users to serious users through ongoing scaffolding encouragement.

Kennah (2016:25) further states that sharing resources through cooperative action is a key component of an effective technology adoption. This therefore enhances a sound teaching and learning process by improving the lecturers' knowledge and skills. According to the Task Team's output document (2013:23), infrastructure geared toward teaching and learning has to have access to hardware, software, enough internet connectivity, laboratories, and ongoing technical assistance in order to facilitate the application of technology. Unwin (2005:23) asserts that in order to form the implementation strategies, infrastructure, computers, internet connectivity, resources, and other technology must be made available. According to Wastiau et al. (2013:11), university technology infrastructure includes desktop computers, mobile devices like laptops, tablets, and smartphones, broadband connectivity, the school website, e-mail addresses, virtual learning environments, the deployment of equipment in classrooms, computer laboratories and libraries, as well as maintenance being part of the job. These factors have a significant impact on how technology is employed in the teaching and learning process. For implementation of technologies to

be a success, infrastructure and resources are key and MKOs are involved so that they assist on views about the right technologies and any other relevant information.

2.4.1.7 ICT/Technology policy

National and municipal technology policies are included in the category of technology policy. The principles of the university's pedagogical policy are taken into account, as shown by the staff development programs, adequate technology, and internet access. According to Nachmias et al. (2004), technology policy is evaluated based on the kind of assistance provided in relation to the budget, training, and impact. Government technology policy is examined as an external input that affects how technology is implemented at universities (Wong & Li 2008:7). Through curriculum, technological access and assistance, and internet connectivity, government technology policies have a direct impact on teaching and learning. Olugubenga (2017:16) criticizes the goals and objectives of Africa's technology policy and those who were involved in its creation. He continues by saying that creating technological policy drafting and adoption in Africa should not be the exclusive preserve of government, the middle-class capitalist entrepreneurs, and representatives of foreign capital alone. Therefore, drafting and adoption should adopt a bottom-up procedure incorporating cooperative governance that is similar to the new network society that we currently inhabit. According to Ghavifekr and Rosdy (2015:176), national technology policy can fulfil a number of essential roles in the adoption of technologies. Because they offer a justification, a set of objectives, and a vision of how educational institutions would function if technology is implemented into teaching and learning, the policies are important to students, professors, parents, and the general populace of a specific country.

Koh et al. (2015:536) contend that macro-level elements that lecturers should actually take into account include national and international educational trends in technology policies. They go on to say that frameworks for 21st-century skills commonly advise colleges to educate administrators with abilities including critical thinking, productive work organization, social cultural awareness, and technical proficiency. Technology policies have an impact on universities' commitment to and support for investing in technology (Koh et al. 2015:536). The need of effective policy execution for the attainment of high-quality teaching and learning is acknowledged by Njui (2018:112).

Albugami and Ahmed (2015:39) contend that the administration of universities must be committed to offering enough technological resources, suitable facilities, and staff development programs for academics and technicians. The technology policy needs to be effectively communicated, put into practice, and reinforced in the university vision.

Koh et al.'s (2015:379) research shows that lecturers can be encouraged to experiment with different educational strategies and technological resources. The types of software and technology that are available to lecturers and students are governed by university policy. Technology policy, in the opinion of Mahama-Ewurah (2018:119), must take into account not only the administration and control of technology but also its broader effects on the economy, society, and governance. According to Olugbenga (2017:1), the importance of technology policy enables it to satisfy academic needs for social and economic recovery as well as the advancement of the many national and continental goals. As a result, Olugbenga (2017:1) applauds a multi-stakeholder approach to technology policy formulation that is followed not only by African governments, but also by other participants in Africa's technological revolution. In order to advance Africa to its next stage of development, this argument supports universities by showing how technological policies will change, adapt and be advantageous for sustaining positive development. Olugbenga (2017:13) adds that the historical, political, economic and cultural contexts should be used to determine the objective of the nation's technology policy. In this digital age, Unwin (2005:123) emphasizes the importance of giving technology implementation top priority in teaching and learning. According to Wastiau et al. (2013:2), leadership must consider seriously the importance of university technology policy in the teaching and learning process. Social interaction within and outside university is key so as to share the knowledge on the ICT policy.

2.5 Significance of the highest-influenced factors

The most important variables that have an impact on how learning is configured, what students and lecturers do, and that the curriculum is for the successful integration of technologies in teaching and learning. To apply STEM learning technology effectively, the socio-constructivist theory is heavily emphasized within these variables.

2.5.1 The configuration of learning

Learning is accomplished through configuration, which is the way learning is done. This comprises the amount of time spent learning and the environment where software and other technologies can be used successfully. According to Kennah (2016:28), the flexible use of space and technology enables a more engaging learning experience than the traditional standard method in which lecturers are limited to a certain place. Social interaction of students with their peers, lecturers and MKOs is also important in learning. The students and lecturers benefits more knowledge and skills through this interaction and it can be global, regional and local.

2.5.2 Student role

The students must be capable of easily comprehending and utilizing the offered technology. Research is one way to do this, and working with professors, technicians, and students locally and from other universities is also vital. In addition to learning skills, it has been proposed (Wrong & Li 2008:7) that a student's attitude toward learning is crucial, since it affects their competency in generic skills and active learning. According to Wong and Li (2008:7), learning attitudes are focused with showing drive and zeal during the learning process. The domains covered by the perceived changes in students' learning are learning aptitudes and attitudes (Razzak 2015:3). Students should be engaged, self-reliant, responsible, and interested in using technology (Task Team outcome paper 2013:22). They should also feel at ease and passionate about it. The Task Team's output document (2013:22) also emphasizes the need for students to acquire fundamental technological literacy and proficiency in order to attain objectives. Students have a responsibility to proclaim confidence in their digital competencies, including skills, internet usage, and technological training (Wastiau et al. 2013:12). Students are involved in social interactions with their peers, lecturers and MKOs to gain more knowledge and skills.

2.5.3 Lecturer role

To make technology easier to use in teaching and learning, lecturers should improve their abilities and knowledge of technology (Akinoso 2023:81). Effective technology use requires collaboration between the lecturers and the students. When implementing technologies, lecturers must balance competing expectations such as

passive versus interactive learning, as well as breadth versus depth of information (Koh et al. 2015:536). According to Koh et al. (2015:536) and Angeli and Valanides (2009:159), lecturers' use of technologies in the classroom cannot be separated from the environment of the classroom and the characteristics of the students. Albugami and Ahmed (2015:41) examined the role of the lecturer in the success of technology implementation and argue that it is up to them to adapt to new approaches and contribute to the teaching and learning process as the ones who supply information and knowledge. The importance of lecturers as the major participants in the implementation of technologies in their everyday dynamic and proactive teaching and learning is supported by Ghavifekr and Rosdy (2015:175).

Albugami and Ahmed (2015:39) continue by stating that a lecturer's views and ideas about technology can have a significant impact on how well they perform in terms of teaching and learning. The Task Team's final report (2013:22) states that lecturers' roles as technology implementers include being passionate, interested, and comfortable with utilizing technology tools. They also need to have the relevant knowledge and abilities and, most importantly, they should take technology short courses as needed. Lessons are the first to use digital tools in teaching and learning in the beginning stage, thus lecturers should be interested in the use of computers, thus have ample time prepare technology materials for the lessons. Uluyol and Sahin (2016:72) assert that lecturers must be capable of supporting themselves and using the available technology. According to Voogt and Roblinj (2012:310), the role of lecturers and their professional growth are crucial to the implementation of technology. Wastiau et al. (2013:12) note that lecturers must also affirm their trust in their technological training, internet connectivity, and digital competences (skills). This helps the institution to assess the lecturers' skills and provides support as needed for efficient teaching and learning. The competency of lecturers has been identified as a significant component in the successful adoption of technologies at universities (Englund, Olofsson and Price 2016:73). Lecturers have a duty to facilitate social interactions of students with their peers and MKOs from other universities or industry. ZPD takes place as the lecturers assess what the students know as they introduce topics in the teaching and learning. The lecturers also have a duty to scaffold students who lag behind by assisting them so that they are at the same level with the rest of the students.

2.5.4 Content of the curriculum

The use of technology in teaching and learning must be integrated into both instructional practices and assessments. A technology curriculum, according to Mereku and Mereku (2015:8), refers to the resources available for teaching and learning as well as the educational procedures taking place at the institution. According to Ghavifekr and Rosdy (2015:176), a review of the curriculum is essential before implementing technology to ensure that only relevant applications and resources are used. To incorporate technology into their teaching and learning processes effectively, lecturers need understanding of the pedagogical role of technologies (Ghavifekr & Rosdy 2015:177). According to Kennah (2016:28), implementing technology into the formal curriculum and assessment procedures are the only way to use it in the teaching and learning process. Therefore, it is imperative that the use of technologies in teaching and learning be explicitly stated in the curriculum and communicated to lecturers and students. Njui (2018:105-106) underlines the importance of providing a comprehensive education through the curriculum that promotes knowledge, skills, moral character, and metacognition. In order to cultivate students with 21st-century skills, it is further maintained that the curriculum should be interdisciplinary. Technologies also aid in gaining a comprehensive perspective of knowledge and enlarging minds to prepare users for the many difficulties of a dynamic environment. Due to the fast-paced evolution of technology, this type of curriculum places expectations on different universities to adapt their curricula to teach students 21st-century abilities. This will guarantee that colleges produce qualified graduates who can live and work anywhere in the world.

2.6 Relevancy of the socio-constructivist theory as a framework for the study

Socio-constructivism is pertinent to the study, since it addresses issues with traditional teaching and learning and works well with the model of factors influencing technology adoption. Students can create their own concepts, theories, and formulas and independently evaluate them for viability, because knowledge is produced through interaction. If implemented properly, the framework lowers obstacles that currently

prevent the integration of technologies into STEM learning, improving lecturer and student preparation, technology infrastructure, reusable learning objects, and design.

2.7 Chapter summary

In conclusion, socio-constructivism stresses a learning process in which every student has his/her own ZPD, engages in group projects, communicates, and receives feedback. Social connection, MKO helping students, scaffolding, moving through ZPD, constructive and timely feedback, and finally student collaboration are practices that facilitate learning that are founded on constructivist theory. The socio-constructivist approach, which involves all parties involved in teaching and learning, is supported by a model that includes elements for an easy and successful deployment of STEM learning technologies. The review of the study's related literature is covered in the following chapter.

CHAPTER 3: REVIEW OF RELATED LITERATURE

3.0 Introduction

The previous chapter focused on the theoretical framework that can be used to create STEM learning tools to meet students' challenges. The socio-constructivist framework guides students' use of technology in teaching and learning. This idea is based on the belief that technology adds value to teaching and learning when used appropriately and with sufficient resources. This chapter aims to review the literature related to this study as well as the data provided by other researchers/scientists or authorities that reflect the broader debate about implementing STEM learning technologies to alleviate student challenges. The ideology motivating this study is constructivist theory based on the philosophy of constructivism.

Therefore, the literature is evaluated based on the following topics:

- Benefits of STEM education,
- Nature and scope of STEM education,
- STEM learning technologies used in the 21st-century,
- Course/module software package implementation in STEM 21st-century skills challenges faced by students,
- Students' perceptions, attitudes and barriers on the use of STEM learning technologies,
- Extent of STEM learning technology implementation and STEM learning technology implementation for 21st-century skill and their effect.

STEM education has been the subject of much discussion in educational circles in recent decades (Kelley & Knowles 2016:2; Al Quraan & Forawi 2019:82; Sergis et al. 2019:724). STEM education encompasses all subjects, disciplines and programs related to science, technology, engineering and mathematics. The National Science Foundation (NSF 2003:1) coined the acronym STEM to refer to educational programs related to science, technology, engineering, and mathematics. Jang (2016:7-8) defines a STEM career as one that requires education in science, technology, engineering and mathematics. Biology, Chemistry, Computer Science, Engineering,

Environmental Science, Earth Science, Life Science and Physics are part of STEM. STEM is a blended learning method that promotes student-centred learning by encouraging students to learn and think about solutions to real-world problems (Florida Department of Education 2020:2; Nguyen 2020:2). STEM meets the social, emotional, physical and academic needs of students with the help of universities, families and community partners. STEM is becoming increasingly important as lecturers and students engage with the issue (Wu et al. 2019:475; Liston, Barry & O'Sullivan 2023:297). STEM education has become a national focus for innovation and entrepreneurial investment, as evidenced by industry projects such as 21st-Century Ghosts. STEM programs aim to equip students with 21st-century skills such as creativity, problem solving, effective collaboration and strong digital skills to enable them to compete globally (Talib & Aliyu 2019:774; Selman & Jaedun 2020:244; Mukaromah & Nurlenasari 2020:2; Lidinillah, Mulyana, Karlimah & Hamdu 2019:2; Ministry of Higher Education and Science and Technology Development 2016:5). According to the NSTC of the National Science and Technology Council (2018:4) and the United States Department of State (2022:1), STEM has helped stabilize the United States economy while increasing global competitiveness.

3.1 Benefits of STEM education

The need for STEM education is highlighted by the need for those developing STEM careers (Oner & Capraro 2016:2). STEM also helps to create positive attitudes towards the subject and the economic development of the country. Technical skills are developed, resulting in ongoing knowledge and academic achievement. Previous research has shown that STEM education has the potential to develop a future competitive workforce equipped with 21st-century skills (Mustafa et al. 2016:4225; Alade et al. 2016:433). Graduates in today's industry need to connect with technology in real-time to solve problems. Analysing, critical thinking, decision-making and problem-solving are skills needed to prepare students for the workforce (Bagarukayo et al. 2016:130; Akbaba 2017:4; Chitate 2016:31; Erdogan & Ciftci 2017:1056; Gulhan & Sahin 2016:603). As the number of STEM professions increases, so does the need for STEM education (Oner & Capraro 2016:2). STEM also contributes to positive attitudes towards the disciplines and to the economic development of the country. It provides continuing education and develops the skills necessary for academic

achievement. Previous research has shown that hands-on and educational learning can increase student interest, motivation and performance and develop 21st-century skills (McDonald 2016:531, Jindanurak 2016:162; Oonsim & Chanprasert 2017:55). According to Harman (2023:1), students can enjoy good career opportunities and attractive career opportunities in globally recognized fields. Ultimately, STEM promotes the development of innovative, creative, confident, imaginative and technology-savvy individuals.

According to Sadler et al. (2018:586), recent years have shown that the goal of "university education for all" is not being met. STEM is considered important in all countries, as it drives economic growth, and students need a solid foundation in this subject to function successfully in the 21st-century (Umoh 2016:1). STEM education encourages students to integrate critical thinking, analysis, and engagement with the real world (Burrows & Slater 2015:322; Shernoff et al. 2017:1; Cinar et al. 2016:120; Onanuga & Saka 2018:110, Ndinechi & Okafor 2016:1). Through STEM teaching and learning, students gain more experience and develop their passions for positive outcomes (Triana, Anggraito & Ridlo 2020:182; Suwarma, Astuti, & Endah 2015:373). According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) (2016:1), Delaware STEM Advocate (2018:1), Tulivuori and Ramanathan (2022:3), and Trouillet (2023:1), STEM fields are important. to solve global problems. This means that a successful STEM education can provide students with the skills they need to function effectively in today's knowledge-based society, which Nigeria and many other countries describe. College graduates with a STEM degree are expected to be innovative, project-oriented, and develop and solve problems with new technologies. According to McCabe, Lubinski and Benbow (2019:1), STEM employment is a driving force in the modern economy. According to Baran et al. (2016:9), STEM has become public policy in countries such as the United States. A 2015 report on STEM education in Turkey highlights the critical need for Turkish students to acquire STEM skills (Baran et al. 2016:9; Akgunduz et al. 2015:1367). Differences in student motivation today encourage change in STEM education (Chittum et al. 2017:2). According to the United States (US) Department of Commerce, there were 9 million STEM workers in the United States in 2015, representing approximately 6,1% of the total workforce (US Department of Commerce 2017:1).

STEM policies are an important part of the education systems of many countries today. (Al Quraan & Forawi 2019:84). Recent efforts to implement STEM require reforms at university level. This change requires change at three levels: students, faculty, and the university as a whole. The Florida Department of Education (FDE) (2017:1) notes that STEM education benefits all aspects of our lives, because science is ubiquitous and ever evolving. Shameema and Christian (2017:1) also note that as new technologies emerge, skills become obsolete, so teaching students STEM skills is essential to help them adapt to new technologies. According to Portz (2015:2), the purpose of STEM education is to embed essential skills from STEM courses/modules in real-world applications that simulate how they are used in industry. Similarly, Shameema and Christian (2017:1) emphasize the need to integrate technology into STEM education. According to Igboanugo and Egolum (2017:8), STEM education provides students with creativity, analytical skills, judgment and skill expansion. Experience shows that some universities, especially in Nigeria, teach STEM courses/modules independently rather than in the recommended multidisciplinary approach. STEM education at many universities has focused on science and mathematics to enable students to engage in an increasingly digital environment (English 2015:7). Positive experiences in upper primary education can help students to engage in STEM subjects in the future. Unfortunately, many students who become interested in STEM subjects in high school do so to improve their chances of going to college (McDonald 2016:530). These students take STEM subjects to acquire the skills needed for college entrance exams, and then drop out of those courses. However, the job market needs STEM individuals who can solve problems, generate ideas, and have technical thinking skills in creativity. Similarly, Matazu and Julius (2017:47) note that the main purpose of STEM implementation is the transfer of knowledge and skills. According to the National Research Council (NRC), introducing a STEM course or module increases student motivation and academic achievement (2014:1). According to McDonald (2016:531), STEM education aims to increase students' conceptual knowledge of the relationship between science and mathematics and develop their understanding of engineering and technology. Sakiyo and Badau (2015:33) and Ugo and Akpoghol (2016:7) identified different student outcomes in STEM subjects. Aderemi et al. (2013:120), Umoh (2016:269), and Sakiyo and Badau (2015:36) found that more students enrolled in STEM subjects. Ugo and Akpoghol (2016:7) found discrepancies in STEM

involvement. Consequently, there are conflicting results regarding student enrolment and performance in STEM-related subjects and various government initiatives to produce STEM. This is because our focus is on developing STEM skills that prepare students for a complex and ever-changing society. For eligible students, this study went beyond examining trends in student performance in STEM-related subjects. According to Erdogan and Ciftci (2017:1056), STEM education plays an important role in developing 21st-century opportunities. According to Asri (2018:74) and Yulianti and Anjani (2019:28), STEM teaching and learning improve students' ability to think critically, solve complex problems, be creative, collaborate and communicate effectively over time who works on tasks. STEM education is a way to integrate disciplines and lead to success (Yildirim & Altun 2015:29). According to Masunda et al. (2018:69-70), the demand for entrepreneurial learning is increasing in Zimbabwe, especially with the introduction of STEM programs at universities. But while Zimbabwean universities need to develop an entrepreneurial mindset in all STEM students, the question is what and how to teach STEM students. According to Yang et al. (2015:55), there is a growing concern that most American high school students are failing in maths and science because of a lack of lecturers in these subjects. Ingersoll and Perda (2009:1) state that concerns about the shortage of mathematics and science lecturers have reached a new level. According to the Australian Curriculum, there is a move towards an integrated STEM curriculum for STEM education to address these issues (Chalmers et al. 2017:27; Education Council 2019:4). The issue of low graduation rates in STEM fields has been obscured by the field's relative failure to attract and retain diverse students (Aderemi et al. 2013:119; Lancaster & Xu 2017:176). In both STEM education and other positive types of work, lecturers act as organizers, examiners and guides. Students actively acquire knowledge and apply it to real-world problem solving. STEM-focused education has been led by the Ministry of Education and Training for many years through "integrated, interdisciplinary" education, which plans lessons with practical content on STEM-focused topics. According to Chien (2019:89) and Zhang and Tang (2017:1382), a recent study reported STEM-related extracurricular activities.

3.2 The nature and scope of STEM education

The nature and scope of STEM education are characterized by three elements that link STEM fields: duration, size and complexity, and dominant order (Shernoff et al. 2017:3). The Table below shows the courses/subjects/modules belonging to the mentioned disciplines.

Table 1: Zimbabwean University STEM programmes

SCHOOL	PROGRAMME	ENTRY REGULATIONS	DURATION	DURATION	UNDERGRADUATE				POSTGRADUATE				TOTAL		
					UNDER GRADUATE	POST GRADUATE	FIRST YEAR		FINAL YEAR		FIRST YEAR			FINAL YEAR	
							MALE	FEMALE	MALE	FEMALE	MALE	FEMALE		MALE	FEMALE
NATURAL SCIENCES AND MATHEMATICS	BIOLOGY	*All UNDERGRADUATE:	4 years	All post graduates	21	5	15	2	10	6	23	10	92		
	CHEMISTRY	5 'O' Levels including	4 years		18	10	10	4	14	4	17	6	83		
	MATHEMATICS	Maths, English, Science	4 years	1 and half years	26	8	30	10	17	11	15	4	121		
	PHYSICS		4 years		35	3	25	9	19	6	20	3	120		
ENGINEERING SCIENCE AND TECHNOLOGY	MECHATRONICS ENGINEERING	*All POSTGRADUATE: A' Level 12 points	5 years		15	1	23	5	13	8	16	3	84		
	PRODUCTION ENGINEERING		5 years		25	6	10	6	23	17	19	11	117		
	ICT & ELECTRONICS		4 years		17	15	23	19	20	12	23	14	143		
	ENVIRONMENTAL ENGINEERING		4 years		23	7	17	12	16	7	22	9	113		
	FUELS AND ENERGY		5 years		30	6	21	11	19	11	19	7	124		
	FUELS AND ENERGY ENGINEERING		5 years		35	2	17	6	11	4	25	5	105		
INSTITUTE OF MATERIAL SCIENCE PROCESSING & ENGINEERING TECHNOLOGY	MATERIAL SCIENCE AND ENGINEERING TECHNOLOGY		5 years		27	5	11	4	14	7	16	7	91		
AGRICULTURAL SCIENCES & TECHNOLOGY	AGRICULTURAL ENGINEERING		5 years		21	7	16	13	21	14	15	8	115		
	FOOD SCIENCE & TECHNOLOGY		4 years		29	26	21	14	16	4	20	15	145		
	ENVIRONMENTAL SCIENCE AND TECHNOLOGY		4 years		30	12	31	3	14	5	14	4	113		
HEALTH SCIENCES AND TECHNOLOGY	BIOTECHNOLOGY		4 years		30	8	16	3	17	5	22	13	114		

3.2.1 Link between master courses/type of connection

Programs include general courses/modules such as Introduction to Computing, Heritage and Research. The general courses/modules cut across the stream, meaning all part ones, regardless of discipline, has the same general course/modules which they do.

3.2.2 Duration, size and complexity

The undergraduate programmes for Biology, Chemistry, Mathematics, Physics, Environmental Science and Technology and ICT are built over a period of four years. The rest of engineering undergraduate programmes have an additional year, which makes them run for five years. Postgraduate programmes run for one and a half year, as the curriculum was revised.

3.2.3 Dominant discipline

One subject that many students focus on is agricultural engineering. In all cases, male students predominate over female students.

3.3 STEM learning technologies used in the 21st-century

A variety of STEM learning technologies are used in teaching and learning. STEM learning technologies offer several advantages to students in university teaching and learning. Thus, technology improves students' experiences from a pedagogical perspective, and increased use of appropriate learning technologies, increases student motivation and promotes the development of positive attitudes (Markova, Glazkova & Zaborova 2017:686; Loughlin 2017:336; Akcayir & Akcayir 2018:334; Awidi & Paynter 2018:269; Al Yakin et al. 2022:1054; Setyani & Susilowati 2022:504; Akinoso 2023:80). More concrete learning occurs when real-world problems affecting the world align with the real world. Well-structured teaching and learning using STEM learning technologies improve students' motivation, knowledge and skills, as well as academic performance (Hew et al. 2020:2012; Hu & Xie, 2019:29). STEM learning technologies include educational games, special software packages, learning management systems, simulations and simulations, global learning, probes and sensors, technological advances Instagram, Facebook, LinkedIn, Twitter, projectors and more (Huda et al. 2017:694; Oladele, Ayanwale & Ndlovu 2023:240-241; Sabharwal et al. 2018:387; Kessler 2018:2).

Today's classrooms must go beyond physical walls and reach out into the world so that classrooms are multicultural and multi-ethnic, transcend racial, religious, and tribal issues, and have a positive impact on the employability of college graduates today. Several studies at some universities have shown a lack of technology integration in students' self-regulated learning (Yot-Domínguez & Marcelo 2017:14-15; Egielewa et al. 2021:20; Valverde-Berrocoso et al. 2020:1; Chumbley et al. 2018:154). Furthermore, Henderson, Selwyn and Aston (2017:1568) suggest that how technology is integrated does not change university curricula. African academic institutions face obstacles in providing the effective teaching, research and service environment necessary for the development of the continent (Teferra & Altbachl 2004:21). According to Tarus, Gichoya and Muumbo (2015:121), new technologies, including

information and communication technology (ICT) and e-learning, are driving many institutions today, including universities. According to Griffin and Care (2015:7), technologies that have not yet been invented will appear in the near future, and students will need to acquire good attitudes and values and learn new skills. The adoption of learning technologies by universities is essential in all countries (Van de Heyde & Siebrits 2019:1). Van de Heyde and Siebritz (2019:2) state that emerging learning technologies are generally underutilized in South African physics teaching and learning environments. A study by Dube & Scott (2018:305) of the University of Zimbabwe found that universities have failed to create environments where students can use digital technologies for learning. However, long gone are the days of a lecturer standing at the front of the classroom teaching very bored and very uninterested students (Strati, Schmidt & Maier 2017:5; Strydom 2017:50; Trivedi & Patel 2020:2). As the term 'technology' is broad, this study is based on the implementation of a learning management system (LMS) and software package for courses/modules in the STEM education and learning programs under study.

The theoretical framework comes in and the ICT policy indicate implementation of technologies in the teaching and learning. There is social interaction between students and their peers, students with their lecturers and students with technicians. ZPD is involved as the lecturers find out what the students know about the technologies at the initial stages of learning. Students and lecturers also consult MKOs where they feel they lack knowledge and skills in the STEM technologies used in the 21st – century. There is also room of student scaffolding by lecturers especially for those who lag behind in knowledge and skills so that they are at the same level with other students. The Nachmias model in Figure 1 is also involved in this case as technology use is spelt out in the ICT policy of the university. On technology use the administration and technology supported is needed for a sound implementation. Lecturers are staff developed so that they keep abreast with the evolving technology. Lecturers play a vital role by interacting with students for effective teaching and learning by using several teaching strategies on the technology use. Students also have a role to use the technologies offered by learning how to use them by interacting with peers, lecturers, technicians and MKOs.

3.3.1 Learning Management System (LMS)

According to Hasan (2019:110), Aldiab et al. (2019:732), Lopes (14:5361), Darko-Adjei (2018:3) and Chaubey and Bhattacharya (2015:159), an LMS is a course management system (CMS) or virtual learning environment (VLE), a personal environment for learning (PLE), a course management name. Learning Management Systems are used by students and lecturers to facilitate online learning (CMS), e-learning courses and teaching management systems (TMS). Van de Heyde and Siebritz (2019:2) and Aldiab et al. (2019:732) define LMS as web-based application software that organizes online learning for students, lecturers, administrators, etc. According to Akpomi and Bupo (2018:48), LMS software coordinates learning activities such as training, assessment, tracking results and receiving and reporting feedback throughout the process. The advantages of LMSs include low costs, little infrastructure, software maintenance and updates, a secure platform, the creation of a two-way communication environment between lecturer and student, assessment capabilities, data storage support, and on-demand and anytime access (Siddiqui et al. 2019:340).

Several universities in the UK, Canada, USA, Saudi Arabia and Australia are implementing LMS into teaching and learning (Swart 2016:41; Zanjani et al. 2017:19; Aldiab et al. 2019:731). According to Mtebe (2015:1), most higher education institutions in the Western continent and Sub-Saharan Africa now have Learning Management Systems (LMS) installed and one of the most widely used learning management systems is Sakai. LMS integration is important, because it can improve student performance in the courses offered (Mtebe 2015:51; Blau & Shamir-Inbal 2016:83; Ali, Khan & Alouraini 2023:1). LMS can be used for student assessment, storage of learning resources and collaboration (Little-Wiles & Naimi 2018:2; Wikipedia 2019:1; Powell et al. 2019:1; Spangler 2019:29; Ulanday et al. 2021:39). University of Georgia (USG) students can access course/module learning materials and collaborate with peers and professors (Spangler 2019:29; USG 2019:1). LMS integration for physical education supports higher levels of learning, including creativity, collaboration, critical thinking and digital competence (Van de Heyde & Siebrits 2019:5; Blau & Shamir-Inbal 2016:78).

Aldiab et al. (2019:733) state that the relevance of implemented LMS functions is determined by the university administration and that the integration of LMS in teaching and learning leads to efficient, flexible and powerful instruction. In contrast, as noted by Mtebe (2015:51) and Abdel-Jaber (2017:2), LMSs at universities in developed countries are integrated more successfully than at universities in developing countries. According to university technology integration, Africa is lagging behind globally and something needs to be done (Lashayo & Johar 2018:76).

However, LMSs have unique challenges that affect their acceptance and use by students, lecturers, and administrators (Alkhaldi & Abualkishik 2019:6; Ahmad et al. 2023:2). University students have their own feelings about LMS integration in STEM courses/modules (Chugh, Ledger & Shields 2017:8; Altunoglu 2017:96-97; Baleghi et al. 2017:50-57). According to Mtebe and Kissaka (2015:1), the integration of LMS in universities by students and lecturers is minimal. Contrado (2016:5) states that the challenges of implementing LMS in universities are lack of student preparation and awareness, infrastructural stability, and lack of easy access and support for technology. Furthermore, several studies have shown that most LMS tools are not used by students (Zanjani et al. 2017:19; Back et al. 2016:267). Students use the LMS to download and store materials. Another study on LMS integration at Jeddah Community College in Saudi Arabia found that 56% of students occasionally or rarely use an LMS (Binyamin, Rutter & Smith 2016:8). A study from the University of Tanzania identified intermittent electricity, resistance to change, binding policies, addressing changing technologies, insufficient internet bandwidth and insufficient funding as challenges to implement LMS into teaching and learning (Mtebe & Raphael 2017:109-110). Dube & Scott (2016:307) states that, on LMS integration at the University of Zimbabwe, students expressed concerns about information technology infrastructure, lack of computers, bandwidth and Wi-Fi connectivity. Students also noted that lecturers rarely implemented an LMS. However, despite financial support, most LMS implementations in sub-Saharan countries have failed (Wright, Cilliers, Van Niekerk & Seekoe 2017:35). More importantly, universities in different countries present different challenges (Mtebe 2015:1).

LMS use can be connected to the theoretical framework and model in chapter two. LMS use is spelt out in the university ICT policy where use of e learning indicated. The website of the university also have the e learning portal that can be used by the

students, lecturers and the rest of the staff. Administration and technology support is needed for the implementation of the LMS. The support is basically have a proper infrastructure like laboratories with adequate computers, good internet connectivity, relevant course/module software. Technicians and lecturers should undergo staff development for effective LMS implementation. Thereafter the lecturers together with the technicians collaborate and develop the students so that they can use the LMS with minor challenges. The students and lecturers have a role to play in the LMS use for it to be a success. Social interactions take place in LMS use as students-students, student-lecturer, student-technician, lecturer-technician, student/lecturer/technician-MKOs. Social interactions is important as knowledge and skills are shared from all walks of life. Lecturers also involve the ZPD as they find out what the students know and skills they possess about the LMS. This assist to know where to really give a thrust on the teaching and learning of the LMS. Students who need help on LMS use are scaffolded by the lectures so that they reach the same level with the rest of the students for effective implementation.

Several studies have suggested strategies that can be used to increase the use of LMS (Mtebe 2015; Huang, Lu & Yang 2023:3). Strategies include improving usability, uploading quality learning materials, improving support services, revising relevant policies, raising awareness, enhancing LMS with social media, using mobile apps, reducing bandwidth costs, providing support services of trust and use of open educational resources (OER).

LMS is divided into three types: Proprietary LMS (or Commercial LMS); Open-source LMS; Cloud-based LMS and Hybrid LMS (usually self-developed) (Dobre 2015:316; Shdaifat & Obeidallah 2019:32).

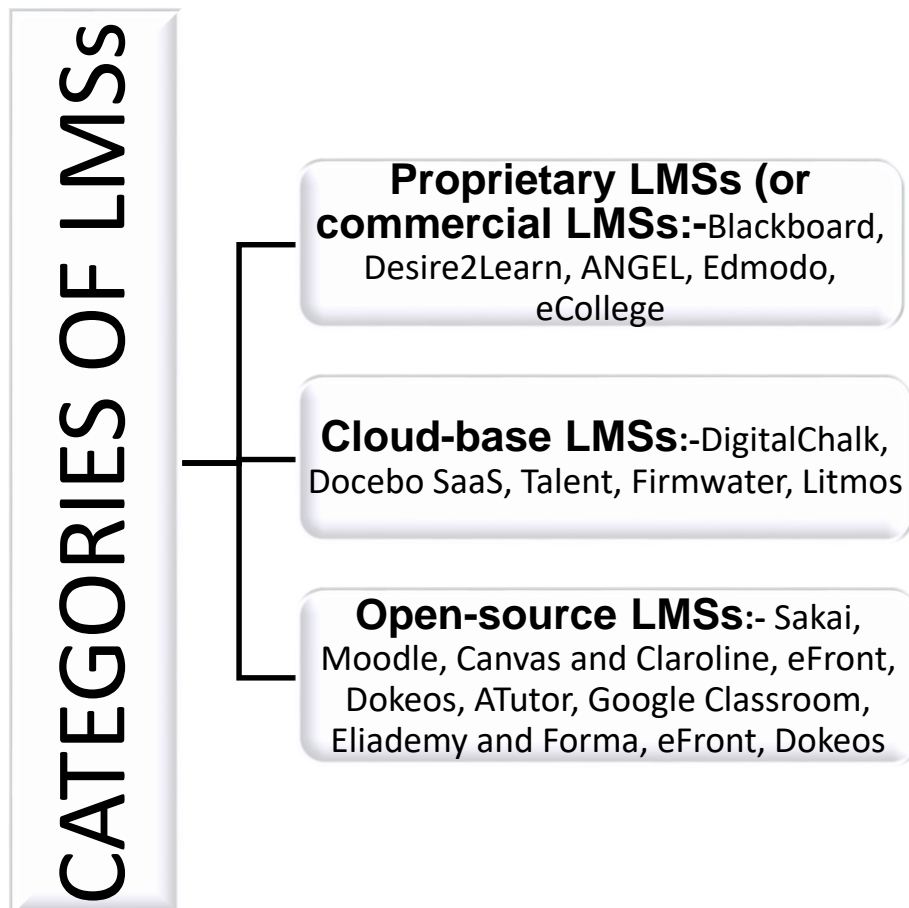


Figure 2: Categories of Learning Management Systems (Designed by Doris Chasokela 2022)

3.3.1.1 Proprietary LMSs

Proprietary/commercial LMS software is said to be proprietary, because it is licensed and owned by the developer (Dobre 2015:318; Van de Heyde, Siebrits 2019:2; Chaubey & Bhattacharya 2015:160). Universities wishing to implement an LMS must have computer labs, internet and electricity. Most importantly, the platform must be installed on the university's servers and computers. If the university infrastructure is not in place, students will not be able to access the system from outside. The most popular and widely used proprietary LMS currently is Blackboard Learn, and other major proprietary LMSs include Design2Leran, Edmodo, ANGEL (owned by Blackboard), Blackboard, and eCollege being the most popular in this category (Dobre 2015:318; Chaubey & Bhattacharya 2015:160).

3.3.1.2 Open-source LMS

An open-source LMS is publicly available with a free licence that allows users to modify, explore, create and distribute results to anyone for free (Dobre 2015:318; Van de Heyde, Siebrits 2019:2; Chaubey & Bhattacharya 2015:160). University users receive a code to access the LMS. According to Dobre (2015:314), universities do not require advanced infrastructure and software licences, and maintenance and upgrades are relatively cost effective. Universities are free to choose what software they can control (Badaru & Adu 2022:66; Megalou et al. 2022:6619). Moodle is the leading open-source LMS (Pertiwi et al. 2021:373; Gamage, Ayres & Behrend 2022:2; Huerta, Caballero-Hernández & Fernandez-Ruiz 2022:2; Sevnarayan, 2023:14; Garcia-Murillo, Novoa-Hernández & Serrano Rodríguez 2023:2; Lavidas et al. 2023:2; Oussous et al. 2023:8). There are also several open-source LMSs, namely Sakai, eFront, Dokeos, ATutor, Google Classroom, Eliademy, Canvas, Claroline and Forma LMS (Dobre 2015:318). The most preferred open-source LMS are Moodle and Sakai due to their flexibility and ease of use (Van de Heyde & Siebrits 2019:2; Paguirigan 2023:304-305; Fibriasari et al. 2023:165; Megalou et al. 2022:6619). According to Van de Heyde and Siebrits (2019:2), Sakai is considered the best tool, as it relies on a large user base that is easy to install and deploy including high ratings in both evaluations.

3.3.1.3 Cloud-based LMS (CB)

According to Dobre (2015:318) and Chaubey and Bhattacharya (2015:160), cloud-based (CB) LMS packages contain cloud computing capabilities and require an internet connection and a computer to access them. Thus, students can access the LMS anytime, anywhere. Cloud-based LMS is a user-friendly and dedicated service provider, compared to open source (Chatterjee et al. 2022:1477). A CB LMS is a low-cost LMS that “can take advantage of the convenience and flexibility aspects of the technology” (Chatterjee et al. 2022:1474). Chatterjee et al. (2022:1474) continue the advantages of cloud-based LMS in that it requires no installation, requires only internet access, uses an internet browser for access, is cost-effective and suitable for medium-sized groups. Cloud-based LMSs include DigitalChalk, Docebo SaaS, Talent, Firmwater, and Litmos.

At the four universities in Zimbabwe where the CB LMS was studied, students were frustrated by problems with internet connectivity, computer access and data access outside the university campus (Mlitwa & Simbarashe 2019:7829). At four universities, students struggled with uploading audio/video and images (Mlitwa & Simbarashe 2019:7829). Students were also concerned about accessing resources at all times outside the university campus. Another study from the University of Zimbabwe found that less than 50% of lecturers needed in-service training in cloud computing implementation (Musunwini et al. 2016:58-60).

Table 2: Summarised differences between Proprietary LMSs, Open-source LMSs and Cloud-based LMSs

	Proprietary LMS	Open-source LMS	Cloud-based LMS
Cost	<ul style="list-style-type: none"> • Vendors charge a licence fee. • Licence fee and support is expensive. 	<ul style="list-style-type: none"> • If not free, Operating System LMSs are cheaper than proprietary LMSs. • No need to pay for maintenance and support. 	<ul style="list-style-type: none"> • Very cost-effective. • Cost is based on usage. • No need to pay for maintenance and support.
Support and service	<ul style="list-style-type: none"> • Vendors provide customer service support for each licence. 	<ul style="list-style-type: none"> • Lack of support and service. • Heavy dependency on the online community. 	<ul style="list-style-type: none"> • Depends on tools you choose.
Authentication	<ul style="list-style-type: none"> • Authentication to software is usually by a username and password. 	<ul style="list-style-type: none"> • Authentication to software is usually by a username and password. 	<ul style="list-style-type: none"> • Authentication might be an issue: depends on tools you choose but mainly use username/password.
Code and Innovation	<ul style="list-style-type: none"> • Vendors hold possession of the code. • Vendors do not allow users to view or alter the source code. 	<ul style="list-style-type: none"> • Vendors share the code with their users. • Users have the freedom to share and update the software without restriction. 	<ul style="list-style-type: none"> • Vendors hold possession of the code. • Vendors do not allow users to view or alter the source code.

Availability	<ul style="list-style-type: none"> Available through companies that own the rights to the packages. Free trial is available to try before buying. 	<ul style="list-style-type: none"> These are freely available to download directly over the net. 	<ul style="list-style-type: none"> Free social applications are available online. Free trial is available to try certain tools before buying.
Installation	<ul style="list-style-type: none"> Certain LMS tools require special hardware/software installation to access and use it. 	<ul style="list-style-type: none"> Certain LMS tools require special hardware/Software installation to access and use i.t 	<ul style="list-style-type: none"> No need to install additional hardware/software to access and use it.

Adapted from Dobre (2015:316) and Shdiafat and Obeidallah (2019:32).

3.3.1.4 Classification of LMS

Moodle and Blackboard are software that support e-learning in designing/managing learning environments, tracking student progress, and providing learning materials (Yalchin & Kutlu 2019:2415). During the Covid-19 pandemic, several universities around the world implemented LMS to create safer teaching and learning environments (Setiawan & Wicaksono 2020:71; Racca & Aaron 2020:11). Integrated LMSs for teaching and learning include Google Classroom, Modular Object-Oriented Dynamic Learning Environment (Moodle), Blackboard, Sakai, Google Classroom, Canvas and Learn to Desire (D2L), WebCT, Talent, Bridge, Open edX, Drupal, Claroline KEWL, Instructure, DigitalChalk, Docebo SaaS, Talent, Firmwater, Litmos (Ni 2020:221; Sibaya 2018:10; Aldiab et al. 2019:734; Mtebe 2015:51; Darko-Adjei 2018:2; Garone et al. 2019:2468). Popular LMSs implemented by many universities are Moodle, Blackboard and Sakai (Mtebe & Kondoro 2016:1; Lopes 2014:5362; Darko-Adjei 2018:28).

3.3.1.4.1 Moodle LMS

Globally, Moodle has gained popularity in 2018 and is easy to use and implement in teaching and learning at universities (Salekhova, Grigorieva & Zinnurov 2019:393; Damjanovic, Jednak & Mijatovic 2015:497; Islam & Azad 2015:109; Ifinedo, Pike & Anwar 2018:94). Currently, Moodle implementations at universities around the world have grown rapidly (Moodle 2018:1; Perez-Perez, Serrano-Bedia & García-Piqueres 2019:2). According to Salekhova et al. (2019:395), Kazan Federal University implements Moodle as the main e-learning platform for all courses.

Several web servers support Moodle tags to support online learning. A university Moodle can be implemented according to the institution's curriculum and policies (Miller 2015:3; Khlaisang & Likhitdamrongkiat 2015:760; Khlaisang & Koraneekij 2018:3852; Guo et al. (2015:60). According to Hasan (2019:111), universities are not yet using all Moodle features. Despite the positive implementation of Moodle at universities, there is a lack of research on students' perceptions of opportunities and challenges not being used or communicated (Hasan 2019:111).

3.3.1.4.2 Blackboard LMS

Blackboard is a commercial LMS that requires a registration fee, an annual renewal fee, and some features require an activation fee. Blackboard is formed and managed by the parent company. Blackboard is used by universities around the world and can be integrated with blended learning (Dobre 2015:317; Arason 2019:104; Cele & Cilliers 2015; Alokuk 2018:143). According to Binyamin et al. (2017:1), who studied factors influencing the use of Blackboard by students at King Abdulaziz University in Saudi Arabia, they found that Blackboard integration was low. So, as universities place great importance on LMSs, students need help to use them in their learning environment. In Saudi Arabia, about 90% of universities use Blackboard LMS for teaching and learning course/module at the University of Zimbabwe improved critical thinking skills, effective communication, and student engagement and interest (Sanganyado & Nkomo 2018:3-4).

3.3.1.4.3 Sakai LMS

Sakai is an open-source LMS that integrates teaching and learning by students and lecturers (Darko-Adjei 2018:7). Currently, Sakai is recognized as one of the most common LMS (Darko-Adjei 2018:28). Sakai-based LMSs are also known as eFunds (Jako 2016:2). A study by Nuta and Puska (2017:1) on the implementation of the Sakai LMS system by Danube University students indicates flexibility and time saving. Another study from the University of Legon Ghana found that the Sakai platform makes teaching and learning highly effective and interactive (Oheneba-Sakyi & Amponsah 2018:33). Students were more than happy to be given a softcopy rather than a hardcopy, which was great for students who did not prefer in-person contributions. Furthermore, a study of students at the University of Ghana revealed problems with LMS integration and a lack of computers (Biney 2019:4). University of Ghana students

have suggested improving internet connectivity and ongoing focus on LMS integration (Biney 2019:9-10).

3.3.1.4.4 Google Classroom LMS

Google Classroom is an LMS widely integrated at universities to improve communication between students and lecturers (Al-Marroof & Al-Emran 2018:112; Setiawan & Wicaksono 2020:71). Students can access and share resources, submit assignments, and track progress through Google Classroom. According to Shampa (2016:12) and Ni (2020:223), Google Classroom is flexible, free, saves time, and improves student collaboration with peers. Lecturers use Google Classroom to assess performance and provide feedback to students (Iftahar 2016:12).

A study of three students in Ghana reports that Google Classroom improved learning and encourages its use in all classes (Ansong-Gyimah 2020:239-240; Jovic, Stankovic & Neskovic 2017:73; Kisanga 2016:110). According to Ni (2020:221), Google Classroom is excellent for teaching and learning, and softcopies of resources are environmentally friendly. According to Pappas (2015a:2-3), the benefits of Google Classroom include encouraging creativity, collaboration skills, media literacy, and information literacy.

3.3.1.4.5 WebCT LMS

Stellenbosch University in South Africa, has adopted WebCT technology as a complementary technology for teaching and learning (Bagarukayo & Kalema 2015:172).

3.3.1.4.6 Edmodo LMS

Edmodo is a free and secure LMS integrated by lecturers and students who can connect online anytime, anywhere (Charoenwet & Christensen 2016:298; Siahaan 2020:13; Afifa & Prastiwi 2023:485). Edmodo LMS brings students together for presentations and builds collaboration, digital skills, and self-esteem (Tahang & Sunubi 2020:90; Hasan 2023:41). Lecturers can assign assignments to students, upload videos, manage events, and convert traditional learning to online learning. Lecturers and students have limited opportunities to share resources, but can easily navigate the system (Adesope & Ezeoguine 2018:34-35). A study by Adesope and Ezeoguine (2018:34-37) found that students had no barriers to communicating with

Edmodo because it was fun and they did not show social isolation. Another study by Al-Said (2015:173) found that Edmodo has an impact when it comes to improving interaction and communication between students and lecturers.

3.3.1.1.7 Canvas LMS

Canvas is considered an open-source LMS software (Aldiab et al. 2019:735; Oussous et al. 2023:12). A current study from the Flemish University of Belgium found that Canvas LMS replaced previous systems (Garone et al. 2019:2468).

In conclusion, most of the students who were new to WebCT, Sakai and Moodle were satisfied with WebCT (Hasan 2019:112). Blackboard and WebCT are very powerful LMSs, but they are expensive to license. Dube (2017:2153-2154), in a study of public universities in Zimbabwe, found that students preferred MOODLE over Sakai and said that the former LMS was easy to use and efficient. Students criticized Sakai LMS for its broken and buggy user interface and lack of audio and video streaming. Another concern was the lack of guidance and technical support for both lecturers and students. LMS integration at South African universities is approximately 55% (Wright et al. 2017:35). Universities in Nigeria, Zimbabwe, and Ghana report low rates of LMS usage among faculties (Kotoua et al. 2015:2404). According to Alkhaldi, Pranata and Athauda (2016:332), implementing virtual labs into any LMS is difficult because it requires different resources. LMSs need virtual lab capabilities because there are many experiments with STEM subjects (Aldiab et al. 2019:736). Dobre (2015:320) states that although target size does not limit LMS integration, universities should invest their resources wisely in determining which LMS to use. LMS has the same communication and management features, but currently lacks laboratory experimentation capabilities.

3.3.2 Course/module software package implementation in STEM

Several course/module software can be integrated into different courses/modules.

Table 3: Course/module software used in programmes/disciplines

PROGRAMME	POSSIBLE COURSE/MODULE SOFTWARE
AGRICULTURAL ENGINEERING	Simulink, Storm Water Management Model (SWMM), Hydraulic Engineering Centre' s River Analysis System (HEC-RAS), Geographic Information System (GIS(ArcGIS)).
BIOLOGY	Geneious Prime, Blast, Cytoscape
BIOTECHNOLOGY	Geneious Prime, Blast, Cytoscape, Clustal Omega, GenoCAD, Python, R, Matlab
CHEMISTRY	Chem draw for drawing chemical structures, Graph pad prism for graphs, Master nova for interpretation of organic structures. Gaussian, Avogadro, Spartan
ENVIRONMENTAL ENGINEERING	Epanet, WaterCAD, SWMM, Water Evaluation and Simulation Tool (WEST), Finite Element Flow and Contaminant Transport (FEFLOW), ArcGIS
ENVIRONMENTAL SCIENCE AND TECHNOLOGY	R. Matlab, Python, ArcGIS
FUELS AND ENERGY	Matlab, Aspen, Auto CAD, Ansys, Solidworks, AutoCAD, Fortran, LABVIEW
FUELS AND ENERGY ENGINEERING	Matlab, Aspen, Auto CAD, Ansys, Solidworks, AutoCAD, Fortran, LABVIEW
IT	Rstudio, Anaconda, Visual Studio
MATERIAL SCIENCE AND ENGINEERING TECHNOLOGY	Matlab, Aspen, Ansys, Solidworks, AutoCAD, Fortran, LABVIEW
MATHEMATICS	Maple, R, Python, SPSS. Mathematica, Matlab, Geogebra. Mendezabal and Tindowen (2018:385) confirms integration of the applets created with the assistance of GeoGebra and used in differential calculus teaching as positively effecting on the understanding and knowledge of the student.
MECHATRONICS ENGINEERING	Circuit maker for simulations, MS Visio, Proteus to simulate circuits, MATLAB, Java C++, Muga, mikro-C-Embedded computers, Arduino IDE-designs based on Arduino microcontroller, visual studio for software development, RS Login for PLC programming, RS Logix;

	CADKey, Simulink, pspice, Ansys, Solidworks, AutoCAD, Fortran, LABVIEW
PHYSICS	Matlab, Comsol, Proteus, Mathematica, Maple, Python,
PRODUCTION ENGINEERING	Siemens for PLC, CAD CAM, Arena, Matlab, Logic ladders, Auto cad, Solidworks, VB, Java, C++, Python, Cisco packet tracer, Retscreen, Polysun, 3D printing, Menderley. Ansys, Solidworks, AutoCAD, Fortran, LABVIEW

(Source: Compiled by Doris Chasokela 2022 by collaborating with lecturers from the named programmes)

3.4 Twenty-first (21st) century skill and resource challenges faced by students

In all walks of life students face several skill and resource challenges in the 21st-century. In STEM several skills are needed so that the students can be accepted in the global world with no problems. 21st-century skills are crucial in the context of STEM subjects because they help students develop the abilities needed to succeed in today's rapidly changing world. In the context of STEM subjects, 21st-century skills are essential for preparing students for the future. The skills are important because they help students to think critically about the world around them, solve complex problems, generate new ideas, and work effectively with others. The skills are especially important in STEM subjects because they help students to make connections between different concepts, apply their knowledge to real-world problems, and solve problems creatively. Additionally, 21st-century skills help students to become lifelong learners who are able to adapt to new technologies and changing circumstances. The 21st-century skills include communication, critical thinking, creativity and problem-solving, collaboration, adaptability and information literacy skills. Communication involves being able to express ideas clearly, both verbally and in writing, which is essential in STEM fields. Critical thinking is being able to analyze information, solve problems, and make informed decisions is essential in STEM fields. Creativity is thinking outside the box and coming up with innovative solutions is key in STEM subjects. Collaboration involves working effectively with others, sharing ideas, and communicating clearly are important skills in STEM projects. Adaptability is the ability to adapt to new technologies and changing circumstances is crucial in STEM subjects. Information literacy involves knowing how to find, evaluate, and use information effectively is important in STEM fields. Therefore by developing these 21st-century skills, students

can become more successful in STEM subjects and better prepared for the challenges of the future.

Resource challenges include inadequate infrastructure like laboratories with few computers, poor Internet connectivity, and inadequate course/module software. One of the major challenges facing students when it comes to implementing technology is the lack of adequate resources. In order to effectively use technology in teaching and learning, students need access to devices such as laptops or tablets, as well as reliable internet connectivity. However, many students do not have access to these resources, either due to financial constraints or because their university do not have the adequate infrastructure. This can make it difficult for students to participate in online learning, complete assignments, or research topics. Without the necessary resources, students may feel left behind and unable to keep up with their peers.

3.4.1 Skill Challenges Faced by Students

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 (Abdullah 2016:7; O'neal, Gibson & Cotton 2017:193; Kaufman 2013:78, Urbani et al. 2017:28; Sahin, Affuneh et al. 2020:858). As 21st-century skills are developed in STEM by students, lecturers and the outside world, STEM lecturers play an important role as facilitators (Anagun 2018:827; McGunagle & Zizka 2020:7; Affouneh et al. 2020:859). Shum and Crick (2016:6) complain that employers in the world of work pass exams with flags because graduates of the university system still fail to address the specific challenges of 21st-century skills. The World Economic Forum (2016b:1), and Shum and Crick (2016:7) argue that education systems from primary to high school need to evolve beyond a focus on the acquisition of knowledge and skills. It must be assessed within a predetermined curriculum and usually in a supervised testing environment. This perspective assumes that the world remains relatively stable during learning and that the necessary skills can be tested in practice. The 21st-century skills that students, future citizens and leaders need to address a range of societal challenges are essential in the 21st-century workplace (Egan et al. 2017:21; DiBenedetto & Myers 2016:33-28; Geisinger 2016:247-248; Germaine et al. 2016:19; Onanuga & Saka 2018:110; Rateau, Kaufan & Cletzer 2015:52); Khlaisang & Koraneeky 2018:3852). Today's world seems to be advancing rapidly in terms of technology, so students need to acquire the skills to be effective in any country's workforce. Griffin and Care (2015:7)

argue that technology will always evolve in the future because inventions are endless. This means that students will be exposed to both critical thinking and learning and will leave college with the knowledge, skills, good attitudes and values appropriate for the digital age. According to Anderson (2018:2), implementing science and mathematics curricula with technology and engineering enable students to develop 21st-century skills. The modern workforce in all countries is interested in hiring STEM graduates with 21st-century skills (Abas & Imam 2016: 119; Borgogni, Kathan & Gary 2017:208; Cihat 2015:41; Guilbault 2016:132; Chikazhe, Makanourye & Itani 2016:102). The challenge of technology in the 21st-century is one of the challenges of teaching and learning (Tindowen, Bassig & Cagurangan 2017:1). According to ManpowerGroup (2015:3), 38% of graduating students have 21st-century skills. Furthermore, the Manpower Group (2015:3) 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) state that students with 21st-century skills can model and simulate, create solutions and solve problems. Students can share their knowledge and collaborate with peers, lecturers and the world. Several researchers are working on a variety of 21st-century skills, showing that education prepares students for new ways of thinking and working in the digital age (future workforce) (Ahonen & Kinnunen 2015:395; Andrade 2016:143; O'Neal et al. 2017:192; Nissim et al. 2016:36; Sias et al. 2017:227). Farisi (2016:19) and Center for Curriculum Redesign (2015:4) share the opinion that 21st-century technology should be introduced into the educational system. This is important because students learn and demonstrate understanding through performance. Several researchers summarize 21st-century skills into three categories: life and professional skills, information and technology skills, and finally learning and innovation skills (Alismail & McGuire 2015:151; Chu et al. 2016:3; Cruz & Orange 2016:1; DiBenedetto & Myers 2016:33; Farisi 2016:21; Geisinger 2016:247; Pardede 2020:71; Talib & Aliyu 2019:775; Hilt, Rize & Soreide 2018:120; Kaufman 2013:79; World Economic Forum 2016a:2; Applied Education Systems 2020:1; Bai & Song 2018:584; Fitzgerald et al. 2016:245; Tekerek & Karakaya 2018:348).

According to Itani and Srour (2016:3-4), STEM graduates with 21st-century skills will advance their peers and move up the ranks. Some of the issues that developing countries like South Africa face include access to technology and technological literacy. These difficulties are frequently referred to as the digital divide, which refers

to the gap between those who have access to technology and those who do not (Cloete 2015:147; Cloete 2017:5). The utilization of technology serves as the foundation for concealing the reality that not everyone benefits from it because they do not have access to it or the ability to use it.

3.4.2 Challenges in the use of LMSs and course/module software

LMS integration is minimal in developing countries as they face various challenges (Sulaiman et al. 2023:1). Integration of LMSs facilitates collaboration, reasoning and critical thinking, improves student academic performance, increases access to education, facilitates personalised/self-directed learning, and access (resources, assignments, and feedback (Alumona & Akinseinde 2023:331; Edelhauser & Lupu Dima 2020:6). The ability to lower the costs associated with traditional classroom-based programs is likely the most important benefit of LMS integration. These costs include maintenance and transportation expenses, among others. Despite the many uses of LMS, there are many issues that cannot be ignored. The challenges include inadequate training, system errors, unstable power supply, and lack of ICT infrastructure, ICT skills, internet access, awareness, weak ICT implementation policy and technical support (Henaku, 2020:55; Tamrat & Teferra, 2020:2; Muchabaiwa & Gondo 2022:115-116; Obidile 2023:8; Svongoro & Mudzi 2023:213).

Some Zimbabwean researchers also share the same challenges as above on LMS use (Mukeredzi, Kokutse & Dell 2020:1; Chinamasa & Ncube 2023:83; Dangaiso et al. 2023:2-3; Muchabaiwa, Gondo 2022:110-111; Zhou et al. 2022:8944; Jegede, Ebio & Iroegbu 2019:34-35; United Nations 2021:8-9; Kuteesa, Namirembe & Ayesigwa 2021:26; Pondiwa, El Nabahany & Phiri 2022:7; Snoussi 2019:666; Koprulu, Tangir & Oznacar 2022:73; Akah et al. 2022:2; Chinamasa & Ncube 2023:90; Bolaji & Jimoh 2023:102-103; Nungu, Mukama & Nsabayezu 2023:17; Mohammad et al. 2023:228). Another study found that when the quality of technology-based teaching and learning is poor, technology use is sub-standard because students lack adequate self-regulation or their home environment is highly distracting and can lead to poor attendance (Wandler & Imbriale 2017:5). The challenges in the use of LMSs and course/module software are linked to the theoretical framework and Nachmias model in chapter two.

3.4.2.1 Inadequate training

In relation to the Nachnias model in Figure 1, it is important to note that staff development is a necessity as it trains and equips lecturers and technicians with knowledge and skills. This assist in social interactions and scaffolding of students on particular tasks to be done in the teaching and learning. Many studies have found that many users of learning management systems do not use the system successfully because of a lack of support services such as orientation to the use of the system and adequate training (Díaz Redondo et al. 2020:3132; Maphalala & Adigun 2021:2). Maphosa, Sibanda and Dhlamini (2020:43) cite lack of training on lecturers in the use of LMSs. Lack of support services such as orientation of the use of the learning management system hinders LMS integration. Many related studies have shown that many users of LMSs do not use the system effectively due to inadequate training (Diaz Redondo et al. 2020:3132; Makumane 2023:211; Ndou et al. 2023:4; Ali et al. 2023:6; Adigun 2021:2; Elmunsyah et al. 2023:4; Ali et al. 2023:11; Ayanwale et al. 2023:596; Daar et al. 2023:404). Maphosa et al. (2020:43) also cite a lack of training on lecturers in the use of LMSs in the Zimbabwean universities

3.4.2.2 Lack of ICT infrastructure

The success of technology implementation requires an infrastructure with adequate resources like computers, good network connectivity, course/module software and an LMS that is easy to navigate. The Nachnias model in figure 1 indicate infrastructure as a factor contributing to an effective implementation of technologies in the teaching and learning. Technical support is important in budgeting for the resources and sharing ideas and skills on how to maneuver in the LMS forums. Muchabaiwa and Gondo (2022:111) mention lack of ICT infrastructures such as computers and network facilities. In addition, Choga (2015:10) Darko-Adjei and Ankrah (2020:17) cite the lack of ICT infrastructure as the reason why students had a negative attitude towards using Sakai LMS. Several researchers mentioned the lack of ICT infrastructures such as computers and network facilities (Muchabaiwa & Gondo 2022:111; Ahmad et al. 2023:8; Ali et al. Zahoor 2023:11; Alzahrani & Alhalafawy 2023:6; Mulla et al. 2023:221; Ndou et al. 2023:4; Ngonda, Nkhoma & Falayi 2023:139; Gyau & Semarco 2023:241; Shumba & Munkuli 2023:2; Shaame et al. Maro 2023:5). In addition, Choga (2015:10) and Darko-Adjei and Ankrah (2020:17) cite the lack of ICT infrastructure as the reason why students had a negative attitude towards using LMSs. A Lesotho university was also observed facing challenges of ICT infrastructure (Ayanwale et al.

2023:596). According to Daar et al. (2023:404), hardware to use to integrate LMSs was not adequate for minimal usage. Gul, Tahir and Ishfaq (2023:4) studied a Pakistani university and discovered that lack of infrastructure has led the universities to be still taking baby steps on LMS use. Van Wart et al. (2019:4) support that universities are not playing a vital role in investing in technologies to be integrated into teaching and learning.

3.4.2.3 Lack of ICT skills

Staff training/development is vital in imparting lecturers and technicians with knowledge and skills and technology is revolving rapidly. Staff training is mentioned as one of the factors in Nachmias model in Figure 1 to facilitate an effective technology implementation. The lack of information and communication technology (ICT) skills is another challenge that can hinder successful technology implementation. ICT skills refer to the ability to use computers, the internet, and other digital tools effectively. Many students and lecturers may not have the necessary skills to effectively use technology, which can limit the benefits of its use. This can be especially problematic in developing countries, where access to training and resources is limited. To address this challenge, schools and communities need to provide ICT training for students and lecturers, and ensure that they have the resources they need to develop their skills. With adequate knowledge and skills on LMS navigation the technicians can train lecturers. The lecturers can then use the knowledge and skills to check what the students know (ZPD) and scaffolding embraced if there are some students who need assistance so that they are on the same level as the rest of the students. Maphosa et al. (2020:43) cite that the lecturers have minimal ICT digital skills. Management, training and ICT support are therefore vital in the implementation of the LMSs. This then confirmed minimal knowledge and experience to use the LMSs and is a clear indication that Sakai LMS is not being used properly. In addition, lack of knowledge was identified as one of the important reasons for the significantly low usage of Sakai LMS.

Shortage or minimal ICT skills can hinder LMS use, as one should be in a position to work on the LMS with minimal assistance. Various researchers cited that the lecturers and students have minimal ICT skills to integrate the LMSs (Maphosa 2020:43; Cao 2023:83; Ahmad et al. 2023:8; Aqdas, Ahmed & Soomro 2023:758; Ali et al. 2023:11;

Alzahrani & Alhalafawy 2023:6; Ayanwale et al. 2023:596; Gyau & Semarco 2023:241; Ndou et al. 2023:4; Shumba & Munkuli 2023:2; Shaame et al. 2023:5). Management, training and ICT support are therefore vital in the implementation of the LMS. This then confirmed minimal knowledge, skills and experience in using the LMSs and is a clear indication that Sakai LMS is not being used properly. In addition, a lack of knowledge was identified as one of the important reasons for the significantly low usage of Sakai LMS. This was confirmed by Dube and Scott (2014:102) and Shao et al. (2023:8), who found that lecturers do not use the LMSs for teaching mainly due to a lack of skills, therefore making it difficult to convince the students to use it. Lecturers in Indonesia were not trained prior to the use of LMSs and therefore lacked the skills (Daar et al. 2023:404). One of the Swedish university studies indicated adequate ICT infrastructure but the lecturers lacked the skills (Hietanen & Svedholm-Häkkinen 2023:43). Obidile (2023:6) also mentions that at Nigerian universities most lecturers have skill challenges in the integration of LMSs.

3.4.2.4 Lack of internet access

Another failure reported in the literature is that lack of internet access is one of the major barriers to using LMS as it affects the implementation (Orijj & Torunarigha 2019:338; Renes 2015:350; Maphosa et al. 2020:44; Muchabaiwa & Gondo 2022:115; Ali 2023:45; Ngeze 2016; Bolaji & Jimoh 2023:101). However, Gautam (2020:3) found that low internet capabilities are the main reason why users do not use the LMS platform. The Nachmias model also indicate internet access under infrastructure as a factor to facilitate an effective technology implementation. In many parts of the world, access to the internet is still limited, either due to cost, infrastructure, or other barriers. This can be a major obstacle for students who need to use the internet for their studies. Without reliable internet access, students may not be able to access online resources or complete tasks that require an internet connection. To address this challenge, schools and communities need to work to improve internet infrastructure and make it more affordable and accessible. The biggest problems faced by users were lack of access to internet tools and low bandwidth, which proved to be a major barrier for users to fully utilize LMS. In addition, the World Bank (2012:1), Barteit et al. (2019:2) and Choga (2015:14) found that the lack of computing infrastructure and the internet is one of the major challenges forcing educational institutions in developing countries, especially in sub-Saharan Africa, to use learning management systems. According to

a survey conducted by Juhari (2014:29), most participants cited Internet problems, including slow and failed connections, as the reason for their reluctance to use learning management systems. The use of an LMS requires a good connectivity of internet and is very important.

3.4.2.5 System error

System error is another complex challenge when accessing LMSs. System error is categorised under the infrastructure factor seen in Figure 1. A sound system must be in place and technical support is vital so the the students and lecturers are able to use the LMS with minimal challenges. System errors are another common challenge that students face when implementing technology. These errors can range from minor technical glitches to major system crashes. While system errors are often unavoidable, they can still cause frustration and make it difficult for students to complete their work. In some cases, system errors can even lead to the loss of important data or work. To address this challenge, it is important to have a robust system in place for reporting and troubleshooting errors. In addition, it is important to have regular backups of data to prevent the loss of information in the event of a system error. Gyau and Semarco (2023:244) report that most students had negative attitudes towards learning management systems. This emanated from system errors as the lecturers and students tried to log onto the LMS and access was not granted. Students and lecturers at a Zimbabwean university faced system errors as they tried to access the LMS (Shaame et al. 2023:2; Estimo & Erll 2023:63).

3.4.2.6 Lack of awareness

Another challenge that can hinder successful technology implementation is a lack of awareness of learning management systems (LMS). An LMS is a software platform that allows for the delivery, tracking, and management of educational content. However, many students and lecturers may not be familiar with how to use an LMS, or they may not be aware of its potential benefits. This can result in students being unable to take full advantage of the system, which can hinder their learning. To overcome this challenge, universities and lecturers need to provide training and resources on how to use an LMS effectively. The students, lecturers and technicians can approach the MKOs and share views, knowledge and skills in LMS use through social interactions. Staff training and student development is also key to LMS use.

Inadequate LMS use also emanates from a lack of awareness. As a result, it is surprising that users and non-users are unaware of some features of the LMS platform (Ahmad et al. 2023:8). Ali et al. (2023:6) indicate lack of awareness of the LMS use in Pakistan universities as Covid-19 struck the nation. Indonesian universities also suffered from a lack of awareness as they needed to be coached in English before using the LMSs (Daar et al. 2023:404). Awareness was never raised to assist the students and lecturers in the use of LMSs (Shaame et al. 2023:4).

3.4.2.7 Unstable power supply

Another challenge that students may face when implementing technology is the issue of unstable power supply. Power supply embraced in infrastructure is key to a successful technology implementation as seen in Figure 1. Many universities in developing countries experience frequent power outages, which can make it difficult to rely on technology for learning. This can be especially problematic for online learning, where a reliable power supply is crucial for accessing materials and completing tasks. In addition, some students may not have access to alternative power sources, such as generators or solar panels, which can further exacerbate the issue. To address this challenge, universities need to find ways to improve the reliability of their power supply. Obidile (2023:7) indicated an unstable power supply as a challenge in Nigerian universities hindering LMS use. Additionally, Dube (2017:2154) and Choga (2015:20) criticized the integration of LMS challenges, as there are frequent electricity blackouts. Similar results are observed in Choiriyah (2023:91) and Chinamasa and Ncube (2023:83), who also mention unstable power supply being a challenge in LMS integration at the universities. South African universities are also facing a dilemma with an unstable power supply forcing lecturers to re-teach some modules (Otu et al.(2023:4).

3.4.2.8 Complex system interface

Another challenge that students face when implementing technology is the complexity of the systems they are using. LMS system functionality is a factor under infrastructure for effective technology implementation. Many of the technologies used in education, such as learning management systems or productivity software, have complex interfaces that can be difficult for students to navigate. This can make it hard for students to find the information they need or complete tasks within the system. In

addition, these systems may not be designed with the needs of students in mind, which can lead to frustration and disengagement. To overcome this challenge, it is important to provide students with training and support on how to use the system and make it more accessible and user-friendly. Technical support is needed so that the LMS can be used with minimal challenges by the students and the lecturers. Ali et al. (2023:11) found that the LMS interface is not as user friendly as expected. The same study reported that the interface deteriorated with updates because it was not designed well to meet user interests. Gerhardsen (2023:12) investigated complex system interfaces due to the challenges of selecting and justifying usability metrics. Another study observed that a lot of students had challenges with the LMS interface (Edelhauser & Lupu Dima, 2020:4; Mukeredzi et al. 2020:1).

3.4.2.9 Lack of technical support

Technical support is an important component of successful technology implementation in education. Technical support refers to the resources and assistance available to students and lecturers when using technology. This can include troubleshooting, software updates, and training on how to use the technology effectively. Technical support is a factor of an effective technology implementation mentioned in the Nachmias model in Figure 1 under infrastructure for an effective technology implementation. Technical support can be provided by a variety of sources, including university administration, technicians, MKOs and online resources. It is important for students and lecturers to have access to technical support when they encounter problems with the technology they are using. Without this support, it can be difficult to overcome technical issues and use the technology effectively. Several studies argue that the role of lecturers and technicians in STEM education is essential when technology is involved to improve technical support for students (Ostreika et al. 2021:74; Ahmad et al. 2023:8; Alzahrani & Alhalafawy 2023:6; Cao 2023:83; Octaviani & Purnamaningsih 2023:12). According to Ali (2023:45), Elmunsyah et al. (2023:4), and Ali et al. (2023:11), one of the barriers that students and lecturers face when using technology is the lack of technical support. Prinsloo (2016:139), Elmunsyah et al. 2023:3, and Chow and Croxton (2017:260) report that despite the use of technologies, there is minimal technical support to the lecturers and students from the universities. Sulaiman et al. (2023:2) share the same sentiments with other researchers, adding that lecturers fail to get technical support and end up not using LMSs in teaching and learning. Ahmad

et al. (2023:12) examine the lack of technical support to lecturers on software installation, operations, maintenance, network administration and security as one of the major challenges of LMS integration.

In conclusion, common problems that prevent good use of learning management systems are lack of internet access, lack of infrastructure, inadequate training and orientation, system abuse, system errors during login, and complex system interfaces, power outages, lack of necessary skills and lack of technical support.

3.4.3 Life and work skills

Life and professional skills are also called personality traits or humanistic knowledge that are mutually valuable and integrate. According to DiBenedetto and Myers (2016:31), Geisinger (2016:247), and Applied Education Systems (2020:1), life skills primarily include flexibility, adaptability, initiative, self-direction, responsibility, goal management, organizational skills, problem solving (creativity) and social skills, personal. Intercultural skills, leadership and time management. According to DiBenedetto and Myers (2016:31) and Geisinger (2016:247), occupational skills primarily refer to intrapersonal skills such as professional decision-making, job search skills, productivity, responsibility, habits/work ethic and leadership and responsibility. Bai and Song (2018:584) identify the Career Skills Partnership for 21st-century skills as a framework for teaching and learning in China, Switzerland and the United States. Social media Wikis have been used to teach students 21st-century skills, and students benefit from information and digital literacy. The exceptional coverage of students' life and work skills creates, among other things, self-management and collaboration (Tunkham, Donpuksa & Dornbundit 2016:219; Anagun 2018:826).

Prajapati, Sharma and Sharma (2017:3) further differentiate life skills such as thinking skills, social skills and emotional skills. Thinking skills include critical thinking and complex problem solving. Social skills include how students communicate, lead, manage and collaborate with peers while solving complex problems. Emotional skills allow you to cope with pressure, stress and emotions. When teaching students, life skills are useful in class discussions, brainstorming, role playing, cognitive games, analysis and situational analysis (Prajapati et al. 2017:3).

3.4.4 Information media and technology skills

Information and technology skills can be seen as literacy or the basic knowledge a student must have to use a computer (Pardede 2020:71). Information and technology competencies include information literacy, media literacy and ICT literacy for 21st-century teaching and learning (Anagun 2018:826; Khlaisang & Koraneekij 2019:117). Information literacy is the level of education that accurately uses available information and meets needs (Khlaisang & Koraneekij 2019:117; Kivunja 2015:168; Higher Education Standards, Information Literacy Performance Indicator and Outcomes 2016:1). Davies, Fidler and Gorbis (2020:10) define media as opportunities to evaluate and develop content using new media formats. Students can access, manage, use and use information ethically (Khlaisang |& Koraneekij 2019:117). Khlaisang and Koraneekij (2019:121) defines media as the ability to integrate digital technologies, communication tools and/or networks to access, manage, integrate, evaluate and create information for a learning society. Students can learn how to communicate, manage, integrate, evaluate and create using ICT technologies (Khlaisang & Koraneekij 2019:121). Students should have basic information or skills to perform arithmetic calculations, scientific literacy, information communication and technology literacy, financial literacy, and cultural and social literacy. According to the researchers, ICT and technological literacy students should be able to use Microsoft packages (Word, Excel, PowerPoint, Publisher and self-manipulation and Internet progress). STEM teaching and learning improve students' information and technology skills (Tunkham et al. 2016:226). Students communicate over the Internet through platforms such as Twitter, WhatsApp, Instagram, Facebook, LinkedIn, and e-mail (Huda et al. 2017:694). Researchers also believe that students share and exchange ideas, notes, software, projects with peers, lecturers, industrialists and other stakeholders. Digital literacy is becoming increasingly important for online teaching and learning in higher education. Universities in India have developed digital teaching and learning to accommodate distance learning students (Khlaisang & Koraneekij 2019:112).

3.4.5 Learning and innovation skills

Project-based learning is an innovative learning model that provides multiple strategies for teaching and student learning success in the 21st-century (Triana, Angraito &

Ridlow 2020:182). Media education is essential to support teaching and learning in the 21st-century (Meilinda et al. 2017:293; Cahyana et al. 2020:170). Media education in STEM is still limited, but there is room for media design (Cahyana et al. 2020:172).

The key skills of the 21st-century identified by various researchers fall under four advanced skills, the "4Cs": critical thinking, communication, collaboration and creativity (Anagun 2018:826; Alismail & McGuire 2015:151; Shum & Crick 2016:7, Geisinger 2016:245, Germaine et al. 2016:19, Zivkovi 2016:102-103, Farisi 2016:19, Skorton 2019:1866, Alismail & McGuire 2015:151, Trust & Maloy 2017:256, Partnership for 21st-Century Learning [P21] 2019; Abdillah et al. 2012:10; Triana et al. 2020:182). According to the Bialik (2015:4), advanced technology is a 21st-century technology, also referred to as "4Cs".

3.4.5.1 Critical thinking higher order skill

Critical thinking revolves around advancing knowledge using new ideas (Florea & Hurjui 2015:568). Critical thinking and problem solving can constitute higher-order cognitive skills (Shum & Crick 2016:7; Geisinger 2016:245; Germaine et al. 2016:19). According to several authors (Weaver et al. 2015:847; Karakoc 2016:81; Selman & Jaedun 2020:245) critical thinking is one of the most important skills students develop while teaching and learning. McGunagle and Zizka (2020:593) and Oliver and Jorre de St Jorre (2018:822) found that in the 21st-century global market, "employers are looking for graduates who can transfer critical thinking skills to work to solve problems". If 21st-century students can analyse problems, think critically, and solve problems, they will be effective in the 21st-century workplace. In this regard, students are expected to be able to identify/recognize, analyse, collect, interpret, evaluate/evaluate and summarize data from observations, experiences, reflections, judgements or interactions before making decisions (Brown B. 2015:40; Guo, 2016:12; Pardede 2020:75; Nurlenasari et al. 2019:2). Systems thinking is integrated into critical thinking and problem solving so that students make judgements and make decisions. A university study of students by Keinanen, Ursin and Nisseinen (2018:34) recognized that activities could be assessed, use different problem-solving methods and incorporate existing material. Furthermore, today's graduates without the ability to think critically or solve problems in STEM are considered unemployable because these are among the skills needed to innovate (Kaminska et al. 2017:1).

3.4.5.2 Communication higher order skill

Interpersonal communication skills are involved in communication and social interaction, from active listening and presentation skills to conflict resolution (Shum & Crick 2016:7; Geisinger 2016:245; Germaine et al. 2016:19). According to Nurlenasari et al. (2019:2), communication is the ability to relate the ideas contained in a conversation. A study by Keinanen et al. (2018:34) found that students value teamwork, listening to peers and active collaboration. Partnership for 21st-century Learning (2015:4) and Hasanah and Malik (2020:1297) state that students with good communication skills are those who can communicate clearly with peers and use digital technology effectively. Geisinger (2016: 245) and Germaine et al. (2016:19) argue that communication has changed in the 21st-century, as students are able to communicate with lecturers, peers and the outside world through telephones, mobile phones, email, learning management systems, WhatsApp, Twitter, Skype and LinkedIn. Zivkovi (2016:102-103) believes that students should actively learn oral communication through speaking, listening and written communication, especially writing and reading. This allows students to work collaboratively with peers, lecturers and the outside world. Blackley and Sheffield (2015:2-3) argue that communication in the 21st-century is now more important for effective performance. According to Bicer et al. (2015:69), communication advances and improves student learning outcomes in STEM programs.

3.4.5.3 Advanced technical cooperation

Interpersonal skills are a group of complex communication skills that generally prepare students and include cooperation, teamwork, cultural sensitivity and managing diversity (Shum & Crick 2016:7; Geisinger 2016:245; Germaine et al. 2016:19). Nurlenasari et al. (2019:3) discuss collaboration as the ability to work in groups related to collaboration, flexibility, responsibility, responsiveness reflection and initiative suitable leadership.

Collaboration also involves working as a team to achieve a common goal as students interact through networks (Keinanen et al. 2018:34; Pardede 2020:73; The Partnership for 21st-century Learning 2015:4-5; Bedir 2019:233; Rosen et al. 2016:684. Brown Z. (2015:41) argues that students who can collaborate are responsible and value one another's contributions. Students can participate in online collaborative discussions

and lecturers can self-assess (IGI Global 2019:48). According to Paschalis (2017:135) and Naila, Jatmiko and Sudiby (2019:616), students communicate and collaborate with their peers and lecturers. A study of cognition among college students found that they benefit from communication, albeit at a low rate and without any sign of creativity, collaboration, or critical thinking skills (Miranti, Abdurrahman & Hasnunidah 2020:8). Global 21st-century students communicate and enrich their ideas to solve complex STEM problems, improve accuracy and improve performance.

Several researchers have pointed out that STEM teaching methods can improve collaboration skills when students solve problems in groups and generally achieve better results (Ronfeldt et al. 2015:6; Sahin & Top 2015:28; Saenab et al. 2018:1). According to Bagarukayo et al. (2016:131), students engage in active learning and engage in group activities that develop collaborative skills with peers, lecturers and groups. the outside world. Through social interaction, students tend to present new knowledge in a new context and thus develop higher-level skills. Blackley and Sheffield (2015:2-3) argue that teamwork is becoming increasingly important due to the nature of work in the 21st-century, as diverse information is shared through collaboration between teams. Erdogan and Ciftci (2017:1056) report that collaboration between students, lecturers and the world is enabled and guided by influence through networks. They collaborate via e-mail, learning management systems and social media (Wiki, LinkedIn, Twitter, WhatsApp).

3.4.5.4 Creativity higher-order skill

Design-based learning in STEM programs develops and enhances students' creative skills as they explore the design process (Triana 2020:182; Milla, Jufri & Soepriyanto 2019:26). Creativity is one of the key skills for developing students' knowledge and skills (Egan et al. 2017:21; Mumford & Mcintosh 2017:3; Ritter & Mostert, 2017:243; Selman & Jaedun 2020:245). According to Yates and Twigg (2017:5), creativity means doing something original. Nurlenasari et al. (2019:2) state that creativity and innovation arise from the originality of ideas and designs or plans created. Students are asked to come up with ideas to do something in groups. Thus, STEM supports creativity in teaching and learning (Sulistiyowati, Abdurrahman & Jalmo 2018:90; Williams et al. 2018:5; Widayanti, Abdurrahman & Suyatna 2019:2). Keinanen et al. (2018:34) proposes what students call creative problem solving, because it includes new and

different ideas to support assignments and solve complex problems. Students also supported creativity because it helped them to make decisions and achieve their goals. Several STEM graduates have difficulty solving problems and innovating. This is because the minimal critical thinking skills and creativity of graduates hinder global participation (Kojmane & Aboutajeddine 2016:2; Uziak & Fang 2018:2; Talib & Aliyu 2019:775-776).

A study in Indonesia found that STEM learning activities helped students develop top-down skills in communication, collaboration, creativity, and ultimately critical thinking and problem solving, respectively (Trana et al. 2020:183). Therefore, these results can conclude that lecturers' teaching ability affects the learning outcomes of students' learning activities. UPI students at the Tasikmalaya campus in Indonesia ranked from highest to lowest in collaboration, critical thinking, communication, and creativity on the first test (Nurlenasari et al. 2019:6). A secondary test showed improvement from the highest to lowest in communication, collaboration, creativity and critical thinking (Nurlenasari et al. 2019:7). At Finnish universities, research measuring students' innovative capacities in teaching and learning has ranged from high to low levels of creativity and problem-solving, systems thinking, communication, and collaboration (Keinanen et al. 2018:34). However, this is in contrast to Tindowen, Bassing and Cagurangan (2017:2), who report low collaboration and communication skills. Ling and Loh (2020:62) report much lower creativity skills. In addition, Saputri, Sajidan and Rinanto (2018:2) rate critical thinking skills as satisfactory.

Previous studies involving United States of America, Canadian engineering students, and Malaysian chemical engineering students have shown that students benefit from courses/modules on creativity, critical thinking, communication, and teamwork (Keinanen & Oksanen 2017:57; Quintana et al. 2016:20; Rossano et al. 2016:19; Heath et al. 2017:18-19; Rusdin & Ali 2019:122).

In conclusion, the researcher believes that 21st-century skills are the key to solving economic, social, and global problems in STEM education. Project-based learning in STEM programs implements and reinforces the basic 4Cs, enabling students to think critically, work creatively, and communicate effectively to solve complex problems. Therefore, to engage effectively with changing curricula and evolving technologies, we

must act as a nation in the belief that “4C” technologies can be used to reshape our education system.

3.5 Student perceptions, attitudes and barriers on the of STEM learning technologies

Students are users of learning technologies and their perceptions are often considered one of the most important factors influencing technology (Razmak & Belanger 2018: 310). According to Adedokun et al. (2017:5) and Ali (2023:42), as well as research by Deaves et al. (2019:2) and Acosta-Gonzaga and Walet (2018:712), STEM students have positive attitudes about student acceptance of learning technologies. Students believed that technology had a positive impact on the learning climate and motivation.

According to Ling and Wah (2019:3), students' understanding of using educational software encourages collaboration, creativity, imagination, communication, and critical thinking skills. It is also interesting that among the 4C skills, students responded positively to three skills: collaboration skill (75%), creativity (69,3%) and communication (64%). Having said that, the implementation of 4C skills is considered good for students, Selman and Jaedoon (2020:253), Putri, Supardi and Sudibyo (2020:283) and Chai et al. (2015:397), in a study of Indonesian and Singaporean STEM students, recognized that STEM research had a positive impact on their 4Cs technology (Baran et al. 2016:15). A survey of Turkish education found that students perceive STEM as a craft skill, cognitive ability, technical ability, design capacity,; computer technology mathematics, science technology and future professions and occupations. According to Piper and Krehbiel (2015:40), students reported learning about problem solving, developing communication skills, collaboration, and research processes. A study by Bagarukayo et al. (2016:129) found that employers and students felt that colleges and universities did not prepare well for the world of work in many technological fields, including computer technology, entrepreneurial capacity, field practice, problem-solving skills, communication skills, general organizational skills, interpersonal skills, planning; and speed and precision of work. According to DiBenedetto and Willis (2020:51-52), students have tenacity/perseverance in agricultural mechanics, self-management, initiative, study skills, time management, responsibility, goal management, life skills, job search skills and career decision

reporting productivity technology. According to DiBenedetto and Willis (2020:57), vocational skills were one of the most-taught components in universities.

According to the 21st-Century Skills Partnership (2016:4) and Howlett and Wemusa (2019:80), mobile devices increase the creativity, communication, technical skills and general knowledge of lecturers and other students. According to Salonen et al. (2017:1346), Finnish/German students perceive STEM as creative, innovative, collaborative and well-oriented in implementing with technology.

According to Wu et al. (2019:484), students who engage in critical thinking and problem solving in STEM are inspired and motivated. According to Meyer (2015:79-81), at Minnesota State University, students' perceptions of life skills, are conducive to collaboration, communication, and creativity. Through collaboration, students engage in dialogue with lecturers and fellow students. Students identified communication as an important skill for interacting with lecturers and fellow students to improve their listening and speaking skills. Students define creativity as the ability to take ideas and create projects. According to Visalam et al. (2015:1), students' attitudes towards technology adoption have convinced them that they are willing to take many online courses.

Perceptions of ease of use and convenience had a greater impact on students' attitudes toward LMS use (Maposa & Dube 2020:175). Students believed that a successful LMS implementation required a stable network and constant bandwidth updates, and that network outages would impact Moodle use negatively. Lightner and Lightner-Laws (2016:227), Dziuban et al. (2018:5) and Harris et al. (2021:77) found that students can apply STEM learning skills to other subjects or modules to motivate educational results. In another study, Yau and Chan (2023:211) report that students who used simulation software such as FlexSim or Arena in their studies improved their academic performance.

Several studies have also shown increased student flexibility in terms of time, effort, increased student engagement, and a learning environment that provides more effective learning for students from all walks of life (Molnar 2017:6; Wang & Huang 2018:2; Mestan 2019:71; Vanslambrook et al. 2019:3; Thai, DeWever & Valcke 2020:2-3; Miguez-Alvarez et al. 2020:2; Xu, Yau & Reich 2020:2; Zimba, Cosa & Pillai 2021:2; Koprulu et al. 2022:69; Ali 2023:42). Cidrala et al. (2018:4), Gao, Jiang and

Tang (2020:2-3) and Ali (2023:42) report similar findings regarding students' perceptions of the use of technology in teaching and learning. These studies have shown that student satisfaction has a significant impact on acceptance and that factors such as system quality and the perceived interactions students have with their peers can explain course satisfaction. One study found that Chinese students' perceptions of lecturers' ICT skills were unsatisfactory (Shao et al. 2023:3). Another study in Zimbabwe found that LMS is not widespread and popular, because lecturers and students lack the knowledge and skills to implement LMS in teaching and learning (Chinamasa & Ncube 2023:91). On the other hand, several studies have shown that students are often, but not always, dissatisfied with the use of technology in teaching and learning (Spencer & Temple 2021:235; Tratnik, Urh & Jereb 2019:2; Van Wart et al. 2019:13). Additionally, many studies have reported much lower student satisfaction with laboratory work (Accettone 2022:655; Muheidat et al. 2021:87; Mistry & Shahid, 2021:1; Zhang, Al-Mekhled & Choate 2021:467). Some researchers have reported “empowerment” as one of the challenges of using technology (Choate Aguilar-Roca et al. 2021:311; Karaylan et al. 2022:879; Kelly 2021:2497). Another study from Indonesia found that higher academic achievement, ease of using technology, and motivation were achieved through the use of technology in teaching and learning (Akinoso 2023:85-87). According to the general perception of the students, there were various opinions about the use of digital technology in learning. These results are similar to previous findings showing that students are willing to use technology both inside and outside the classroom.

3.6 Extent of use of STEM learning technologies

The scope of STEM educational technology and applications in 21st-century universities is practice-oriented; therefore educational technology is essential for a better understanding of STEM subjects. Today's universities must adapt to the needs, wants and expectations of their students, and the university education system is constantly changing. As a result, universities are increasingly investing in learning technologies because they are perceived as necessary to accomplish their work (Mohammad et al. 2023:224). Although many universities integrate educational technology into teaching and learning without planning, it was initially introduced to support faculty development (Abhinandan, Yellinje & Bhat 2018:23). A study by Launi

(2023:49) found that the implementation of technology and the integration of universities in Morocco were not satisfactory. Therefore, in addition to setting goals and vision, Vice-Chancellors must prepare 21st-century universities for student management, education, innovation and technology leadership, operational creation, planning, and interpersonal relationships.

3.6.1 Extent of LMS use

Mohammed et al. (2023:224) found that many universities have signed up for LMSs such as Cicso Webex, Blackboard Collaborate, Canvas, Moodle Cloud and Edmodo LMS. Most students in the United States use and integrate learning technologies in teaching and learning (Molnar 2017:2741-2742). Most African universities have adopted learning management systems for blended learning to limit disruptions in teaching and learning (Namisiko, Munialo & Nyongesa (2014:132) and Chen et al. 2020:45). Isaacs and Hollow (2012:11) found that most African regions use learning management. Kwame Nkrumah University of Science and Technology and Accra University of Professional Studies have adopted the Moodle learning management system. This is to serve all interested potential candidates and people all over the world. Baber (2021:1), Tanjung and Utomo (2021:103) and Zhu and Zhang (2023:7632) conclude that lecturers play an important role in influencing the extent to which students' perceptions and learning management systems are integrated. According to Biney (2020:264), students implementing Sakai LMS showed great interest as it made learning to be interactive. External variables such as prior computer experience and level of computer literacy may affect the purpose and scope of the technology platform.

Arhinful (2016:59), Darko-Adjei and Ankrah (2020:11), and Odame's (2022:63) studies also looked into the experiences of Canadian and international students who used Sakai LMS. Participants responded that the Sakai platform was used by the majority of students to submit assignments, download course materials, read announcements, and view PowerPoint presentations, implying that the system is frequently used. In a study by Rafi, Samsudin and Hanafi (2015:370), the study also looked into the experiences of Canadian and international students who used Sakai LMS. Participants responded that the Sakai platform was used by the majority of students to submit

assignments, download course materials, read announcements, and view PowerPoint presentations, implying that the system is frequently used.

Espinosa, Estira and Ventayen (2017:25) undertook a study to examine Google Classroom's potential, as collaborative learning through assignments is thought to be very beneficial in improving student engagement. In addition, public universities in Mauritius have been using the Moodle platform for many years, as indicated by Ramkissoon, Belle and Bhurosy (2020:834). Another study from Mauritius found that students preferred to use WhatsApp over Moodle because they found it very useful and it had enhanced features that Moodle did not have (Ramkissoon et al. 2020:836). A Brazilian study found that students are willing to use learning management systems for teaching and learning (Cidrala et al. 2018:5; Ali 2023:47). Thus, it shows that the implementation of STEM educational skills is still low in developing countries. Another study in Zimbabwe found that 65% of lecturers and students used WhatsApp (Chinamasa & Ncube 2023:86). In the same study, 30% used Google Classroom and about 4% used Moodle. This was due to the availability and affordability of smartphones.

3.6.2 Extent of use of course/module software

There are studies on courseware/modules, but most of them are not clear about teacher-student integration in teaching and learning. A study by the University of Hong Kong investigated the use of simulation software by engineering faculty and students. 50% of students said that the software was easy to use, improved academic performance, increased academic efficiency and, most importantly, supported learning (Yau & Chan 2023:211). According to Syakdiyah, Iriani and Ibawa (2021:2), Indonesian students conducted laboratory activities for STEM courses/modules using a virtual chemistry laboratory (VLC). According to Morsch and Lewis (2015:1404) in a United States of America study found that organic chemistry students in classes enjoy using the ChemDraw iPad app to solve problems during teaching and learning. Gonzales (2022:5) indicates that Chinese students can use GAZEBO robot simulation software, Robologix logical design, Webbot 7, Robotics Developer Studio, and MATLAB for programming. A study conducted by Sambas et al. (2022:89) in Indonesia demonstrated the effective use of Proteus software by students and lecturers in working with LED circuits. MATLAB is an application tool used as a computer and can

also be used for modelling in various fields (Hutagalung 2018:31; Nugraha, 2020:52; Momox & De Maio, 2020:535; Utari et al. 2021:10721). Utari et al. (2021:108) show in a study that students use MATLAB in Indonesia for a physical thermodynamics course/module. Results showed that students were able to demonstrate calculated problems and answer solutions, as well as understand and memorize thermodynamic equations.

3.7 STEM learning technology implementation skills for 21st-century skills and their effects

The successful implementation of STEM learning technologies relies not only on the technical and educational skills of lecturers, but also on the support and collaboration of technologists, ICT staff and university administrators (Shao et al. 2023:12). According to OECD (2016:2), the integration of technology in education and learning improves the quality of education in general and modernizes education systems, in particular, to keep pace with the rapid changes taking place in society. According to Matsun et al. (2021:21), few lecturers implement course/module software and LMS to teach and learn 21st-century skills. Sukisna and Suparvoto (2020) show the consequences of not implementing these learning skills as students become passive, disengaged and unable to cope with the demands of the 21st-century. Therefore, the lack of introduction of technology lowers students' academic performance (Azizah et al. (2023:515). A study for electronics students demonstrated the use of Proteus software in microcontroller-controlled sensors by Asparukhova, Shekhova and Lyubomirov (2019:63). Asparukhova et al. (2019:66) conclude that using Proteus software for modelling makes student learning more flexible, more effective and increases creativity. A study in Zimbabwe found that not all lecturers were able to use CSI in teaching and learning, except where the CSI was developed by faculty members (Muzari, Chasokela & Sithole 2022:50).

3.8 Chapter summary

STEM education aims to equip students and lecturers with 21st -century skills and academic outcomes. STEM has the potential to easily prepare a globally accepted and competitive future workforce. The universities' STEM learning capabilities are used to motivate, build positive attitudes and improve academic performance in the 21st-century. Technologies mentioned are courseware/modules and LMS. Course/module

software includes Chen draw, Matlab, CAD, Geogebra, Proteus, Simulink, Comsol and various programming programs. There are several LMSs, the most common being Sakai, Moodle, Blackboard, Angel, Edmodo, Canvas, Google Classroom, etc. Most local universities use free, open-source licences such as Sakai, Moodle and Google Classroom. Universities in South Africa use a suitable LMS such as licenced Blackboard. Students lack ICT skills, lack of internet access, unreliable power supplies, lack of technical support and use of inappropriate devices such as computers or laptops. The use of technology in student learning has a positive impact because it motivates, improves academic achievement and prepares students for 21st-century skills. The adoption of technology by lecturers and students remains low locally and regionally because lecturers lack knowledge and skills.

CHAPTER 4: METHODOLOGY

4.0 Introduction

The study focuses on how STEM learning technologies are used and how they affect students' ability to meet 21st-century issues at a technical university in Zimbabwe. In order to better understand how learning tools are used in STEM fields and how they affect students' ability to meet 21st-century challenges, a study was conducted at a university in Zimbabwe. The study also aimed to create a framework for the Zimbabwean University of Technology's adoption of STEM technologies in the 21st-century. According to Kumar (2019:4) and Leedy and Ormrod (2015:94), research methodology progresses from the underlying assumptions to research design and data collecting in order to address problems or find answers to the research questions of the study. According to Mertens (2015:453), dialogic technique respects cultural norms when conducting research. Mertens (2015:460) highlights that the researcher gains from receiving the essential instruction for compiling and organizing data as well as taking part in fieldwork. The study paradigm, approach, design, population, sample, and sampling techniques/processes, data collecting, instruments, procedures, data presentation analysis and validity, and finally ethical considerations/issues, are all covered in detail in this chapter. In order to triangulate instruments, the researcher used a technical framework for the paradigm.

The first main research question that needed to be answered is:

What framework can be developed to enhance the implementation of STEM technologies to alleviate students' learning challenges at a university of technology?

The study was guided by the following sub-research questions:

1. What are the STEM learning technologies that are used in the 21st century at the University of Technology in Zimbabwe?
2. What are the skills challenges faced by students in the 21st century?
3. What are the students' perceptions regarding the use of STEM learning technologies?

4. To what extent are STEM learning technologies implemented in Zimbabwean universities of technology by lecturers?
5. How are STEM learning technologies implemented for the 21st-century skills and their effect in Zimbabwe?

Semi-structured interviews for a qualitative study all employed the research questions (1, 2, 3, 4 and 5). The research questions (1, 2, 5) and (1, 2, 3, 4, 5) were the subjects of interviews with technicians, lecturers, and heads of departments (HODs). STEM learning technologies used in the 21st-century at the University of Technology in Zimbabwe, skills challenges faced by students in the 21st-century, and how STEM learning technologies are implemented for 21st-century skills and their effect in the university of technology are among the topics covered in the interview questions given to the technicians. The lecturers were also expected to discuss the 21st-century skills challenges faced by students and lecturers, the students' perceptions of the use of STEM learning technologies, the extent to which STEM learning technologies are implemented at universities of technology by lecturers, and how STEM learning technologies are implemented for the students in their relevant focus groups, including first-year and final-year undergraduates and postgraduates, who were also expected to provide input.

Utilizing study research questions 1, 2, 4 and 5, the researcher observed lessons and evaluated the resources available in STEM fields. In lesson observations, the researcher observed the STEM learning technologies used at Zimbabwe's university of technology in the 21st-century, the skills students and lecturers acquired and the challenges they faced, as well as the degree to which lecturers at Zimbabwe's university of technology are implementing STEM learning technologies. The qualitative study reiterate the hypotheses that correspond to the study questions from Chapter 1 and operationalize the variables. The problem of the statement and purpose is directly related to the research questions.

4.1 Research Paradigm

According to Kivunja and Kuyini (2017:26) and Hennink, Hutter and Bailey (2020:13), a research paradigm is a set of guiding ideas that affect how a researcher sees and understands reality in general. A paradigm is a pattern, structure, framework, or set of

beliefs that underpins academic and scientific thought. The research paradigm helps the researcher to create knowledge and gain a thorough understanding of reality in order to collect information regarding the use of STEM learning technologies. The transitive domain that creates an empirical domain that replicates actual events and real causes is the qualitative research approach. The researcher in this instance is aware of the interests, values, beliefs, and knowledge of the participants who are the subject of the study and are able to comment on prior research.

According to Kivunja and Kuyini (2017:30) and Heeks and Wall (2018:2), the three dominant research paradigms are positivist, interpretivist/constructivist and critical paradigms. The interpretivist/constructivist paradigm is one that the researcher hopes to apply, because it is part of people's everyday lives. The researcher attempted to question the participants in order to understand and interpret the problem being studied by incorporating the interpretivist/constructivist paradigm into the study. The researcher was able to comprehend each respondent and how they perceived events in their institutions in relation to the rest of the globe. According to Kivunja and Kuyini (2017:34), the interpretivist paradigm is characterized by key tenets, namely the researcher believes and listens to the participants; there is interaction between the researcher and participants; and context of knowledge that is created by the findings is also important.

According to Hinnink et al. (2020:16-17), a paradigm is a framework for understanding reality and includes concepts like epistemology, ontology and axiology.

4.1.1 Epistemology of a paradigm

According to Kivunja and Kuyini (2017:27) and Riese (2019:677), epistemology in qualitative studies explains how we know the truth, reality, and how specific behaviours affect and influence other people. It therefore depends on one's understanding, defence, and communication with other people. According to Maarouf (2019:8), the researcher is committed to achieving research goals based on the usefulness of dual-based information. It is concerned with the capacity to deepen, broaden, and extend understanding in the scientific area being studied. The importance of epistemology helps establish the researcher's faith in the data supplied.

4.1.2 Ontology of a paradigm

According to Kivunja and Kuyini (2017:27) and Heeks and Wall (2018:2), ontology is seen as an acceptance of some data as true or real. Thus, ontology helps the researcher to become familiar with, and establish concepts about the research problem, its significance, and how to approach the problem in order to come up with a solution. This paradigm is crucial, since it offers knowledge of issues in all spheres of life. In order to understand the meaning firmly embedded in research data, it also aims to ascertain the true nature, or the fundamental ideas that underlie the topics that the researcher analyses.

4.1.3 Axiology of a paradigm

Axiology concerns ethical considerations that the researcher carefully considers in the first stage of research proposal, including what the paradigm appreciates and what is not valued, in accordance with Kivunja and Kuyini (2017:29) and Heeks and Wall (2018:2). In doing the research and dealing with the participants and the data collected, the researcher is restrained by values or morals.

4.2 Research Approach

To obtain answers to the study research questions, in research studies there are three general research procedures that are used namely the quantitative/structured approach, the qualitative/unstructured approach, and the mixed methods approach (Kumar 2019:16). Therefore, the research methodology for the qualitative study approach are described in this work. This particular strategy was chosen since it reflects the participants' thoughts, attitudes, and viewpoints, as compared to the alternative approaches.

4.2.1 Qualitative Approach (QUAL)

According to Hammarberg, Kirkman and De Lacey (2016:498), a qualitative method typically seeks information on opinions, attitudes, perspectives, beliefs, or preferences (Karakaya et al. 2020:1047; Ostreika et al. 2021:72; Mahlangu & Makwasha 2022:1; Koprulu et al. 2022:68; Staddon 2023:31; Octaviani & Purnamaningsih 2023:10). Several studies on learning technologies at universities have used the qualitative

method. Therefore, the study observes the participants emotions, ideas, behaviours, and beliefs. The theoretical and practical components of the study are strongly related in qualitative research, as is the co-creation of knowledge (Riese 2019:670). QUAL gives the researcher flexibility in how they interact with the individuals. When gathering data, QUAL, which is based on the empiricist school of thought, becomes flexible and unstructured (Kumar 2019:16). According to Tracy (2019:4) and Leedy and Ormrod (2015:271), QUAL is a brief engagement with participants. The participants are aware that the relationship with them ends when the researcher is done working with them. In-depth interviews, observations, documents, focus groups, and context/textual analysis are examples of sources of QUAL data (Hennink et al. 2020:10; Tracy 2019:4). Focus-group talks or individual interviews are addressed, and paper or electronic measurements are used for the textual analysis. The researcher is able to focus on the experience, perceptions and sentiments of participants in social events that they understand and are involved in, while also exploring variety (Hennink et al. 2020:11). According to Tracy (2019:7) and Kumar (2019:16), the strategy makes use of analytical and descriptive communication to offer insight into cultural events and rich participant data. Emerging themes and a voice component are used to analyse the data.

4.3 Research Design

This section goes into great detail on the study's precise design and discusses why it is the best design for acquiring the data needed to address the study's research objectives. It specifies how the chosen design is used to facilitate data collection for each and every variable or precisely characterize the nature of the occurrences in a qualitative study . It defines the particular tools and data sources that will be used to collect all of the varied data required for the study. According to Flick (2022:148), a research design is a framework and structure for the inquiry created to find answers to specific research questions.

Gobo (2016:205) defines research design as a blueprint or plan of how the researcher wants to perform the research under study. This section goes into detail about the specific design for the study. The research design then serves as the glue that holds the various study components together. A plan of methods and processes for gathering material to address the research questions is included in this study's case

study research design. Descriptive, correlational, experimental, quasi-experimental, historical, case study, ethnographic, phenomenological, content analysis, exploratory, explanatory, and embedding are some of the research designs that can be utilized for the research studies. The best option for this study to examine the university of technology is the case study design. It involved gathering, analysing, and finally interpreting qualitative data. To evaluate practices management and, if necessary, capture any intricacies of the phenomenon in the use of STEM technologies, a case study methodology was used in the study.

The researcher chose the university as a case study as there was no conflict of interest. With no conflict of interest, therefore, the chances of obtaining sound data are high. The purpose of the study was to suggest and develop a framework for technology implementation and also to review recent research and establish how learning technologies are implemented in STEM disciplines in the 21st-century and their effects at Zimbabwean universities. The researcher used a case study of one university to gain in depth information about what framework can be developed. Through the use of the case study, the researcher was therefore able to collect information from the university STEM nine lecturers, three technicians and 18 students. The case of the university under study was good for understanding complex issues and was used to generate in-depth information from the students, lecturers and technicians. There was also room for the researcher to learn more about frameworks that has worked well and what might be changed in the future for the successful implementation of technologies. A case of the university under study also helps to identify solutions to potential technology implementation problems. The researcher can understand the students, lecturers and technicians as individuals by developing a detailed explanation of their experiences and perceptions on technology implementation. The case study is unique in that it offers insights and indicates broader issues to gain a better understanding of technology implementation in terms of frameworks to be used, STEM learning technologies, skill challenges faced by students in the 21st-century and their perceptions, extent of STEM learning technologies implementation by lecturers and how STEM learning technologies are implemented for the 21st-century skills and their effects in in the university of technology. The researcher is able to explore the case of the university of technology under study with the ability to analyse the data within the case analysis. This then gave the researcher the power of ability to look at sub units

that are located within a case and repeatedly engaging with the students, lecturers and technicians can be achieved as it is the same location.

4.4 The Population and Sample

The setting, general population, target demographic, and study sample are all covered in this section. The sample is discussed along with the sample population and the final sample's protection measures. The sample discussion also contains research language particular to the study's kind of sampling.

4.4.1 Population

Population is a term used to refer to a group of participants in any geographical area from which the researcher extracts data or findings for generalization. A sample is taken from the population, which is the overall collection of study participants (Chivore et al. 2015:5). Zimbabwe has a total of eighteen universities and four universities of technology. Six of these universities offer STEM subjects and have opportunity to use STEM technologies for teaching. All lecturers, technicians, and undergraduate and graduate students (first and final years) in the STEM fields were included in the study.

4.4.2 The Sample

Participants or responders chosen from a population make up a sample. An effective, trustworthy, and adaptable sample is chosen to provide the field of study with abundant information. There is only one Zimbabwean University of Technology included in the study sample. Students were asked to volunteer to participate in the research study, along with three technicians and nine STEM lecturers. The sample include first-year and final year STEM undergraduate and postgraduate students in four focus groups. First year and final undegraduates were 5 in each group and the first and final year postgraduates were 4 in each group. Total sample was thirty participants including students, lectuerrs and technicians. The single case study is unique as the researcher had no conflict of interest and it was conducive to collect data at the same location repeatadly so as to justify the experiences and perceptions of students, lecturers and the technicians in the technology implementation

4.4.2.1 Sampling Procedures

Anarb (2017:4) defines a sample as a group chosen from a vast population with the aim of producing information or data on the study's participants. The population under research is therefore said to be represented by the sample, allowing for a more thorough knowledge of how the two universities are utilizing STEM learning technology. The researcher collected data from a university of technology that is 1 606.4 kilometers from the university that is the subject of the investigation. Therefore there is a wide geographic distance between the two, which could make it challenging to travel between them. Several sampling techniques can be utilized, including convenience, purposive, snowball, and random. To account for the qualitative approach, the researcher used purposive sampling on students, lecturers, and technicians. This is because the students, lecturers and technicians were scattered all over the university. Students who attend STEM classes regularly and are reasonably versed with/ attuned to, or have a vested interest in the use of STEM technologies for learning purposes were purposively sampled and put into focus groups according to their study levels separately. The researcher utilized simple random sampling to choose STEM lecturers and technicians who were free to take part and had an idea on STEM technologies.

4.5 The Data Collection Research Instruments

The specific tools and sources that were utilized to collect each type of data are identified and described in the data-collecting research instruments. Tests, surveys, interviews, data banks, media, and observations are just a few examples of data collection tools. Three main sources or instruments for gathering data for qualitative research, according to Daniel (2016:92), Merriam and Grenier (2019:14), and Denny and Weckesser (2022:1166), are interviews, focus-group discussions, and observations. For this qualitative study, these sources were used to gather data for each variable or group. A study's texture and depth are captured and represented by the use of interviews, focus-group discussions, and observations (Rossman & Rallis 2017:147). The researcher's tools for data collecting on the use of STEM learning technologies at the university under investigation are known as research instruments. By examining a research issue from several angles, the instruments can be triangulated to evaluate and establish the validity of qualitative findings (Merriam & Tisdell 2016:368). Lesson observations, focus groups, and interviews were employed

to provide the results of the qualitative approach research. Professors, students, and parents now face a new situation of social withdrawal and crowd avoidance due to lockdown in the majority of countries (Huber & Helm 2020:238). Due to Covid-19, the transition to online distribution of study equipment to participants was unanticipated and quick (McFarlane 2019:1126). The researcher used appropriate tools that encouraged social distance to gather data. To assess the availability of STEM learning resources, the researcher used semi-structured interviews, focus groups, and instructional observation schedules. At the University of Technology, face-to-face semi-structured interviews with professors, technicians, and focus groups were conducted. The face-to-face platforms utilized for lessons allowed for the observation of lessons. The data generated from these data sets were corroborated to assess and establish the trustworthiness of the findings.

4.5.1 Semi-structured interviews

The researcher introduced herself to the participants and explained why the study was being done. The researcher informed the participants that they were free to end the interview when they felt like doing so. The participants received a guarantee of privacy from the researcher. An interview guide with several questions that address the qualitative research questions served as the research's direction. Lecturers and technicians and students from STEM were the targets of the interviews. This is due to the fact that they were few and there was enough time to talk to them one on one to gather data for the study. The participant's nonverbal cues could be read by the researcher to indicate happiness or negativity. Closed-ended and open-ended questions were both used in case-study interviews. The interviews were anticipated to last at least 30 minutes. In order to ask pertinent questions about the study, the researcher pre-structured the interview questions and provided interview guides. It was taken into account that participants' cultural origins could have an impact or influence on their responses. Technicians had different interview guidelines, albeit some of the questions may have been somewhat similar. This is true because the group of participants may not be aware of certain facts. In order to eliminate distractions, participants were invited to identify the convenient research interview location of their choosing. Questions about biographies, beliefs, attitudes, motivations, behaviours, and explanations for certain study-related circumstances were also

posed. The researcher enquired about their knowledge of and use of STEM learning technology for the department's courses, modules, and disciplines. The frequency with which STEM learning technologies are used was also significant. The researcher also examined the student-to-STEM technology ratio. The researcher was a wonderful listener and gave participants the freedom to respond in any way they wanted. To obtain correct data, the researcher made an effort to suppress her feelings.

4.5.2 Focus-group discussions

Focus groups are gatherings of people who have been carefully chosen with the intention of taking part in a predetermined conversation (Krueger & Casey 2015:506; Denny & Weckesser 2022:166). The discussion(s) were meant to spark ideas and analysis regarding the subject matter, promoting positive participation. Focus-group talks involve member interaction as they build upon one another's ideas. Individual responses to formal questions are also improved, producing qualitative data (Technological University of the Shannon 2022:4). These conversations involved two focus groups for first-year undergraduate and postgraduate students as well as two focus groups for students in their final years of undergraduate and postgraduate STEM programs. All levels and not just the final year students only were part of the study because both the first years and final years attend STEM classes regularly and are reasonably versed with / attuned to or have vested interest in the use of STEM technologies for learning purposes. The two different levels can show if the technologies are still the same, are being used in different levels and views on their experiences and perceptions on technology implementation. The number of participants in focus groups varies between 4 and 8 (Busetto, Wick & Gumbinger 2020:3; Robinson 2020:338). Therefore, the focus groups were held in-person and lasted for at least an hour. The researcher entertained the students with brief introductions that described the focus-group discussion's goals and objectives. First-year undergraduates, first-year postgraduates, final-year undergraduates, and final-year postgraduates were the groups that the researcher had invited volunteers from various STEM programs to form. As a result, the researcher asked these students in these groups certain questions on the subject of the study, and they were free to respond without being nominated. The researcher posed some questions and gave the students some time to contribute, allowing for the recording of every student's

input. The researcher probed further after the students had responded to elicit more detailed information and noted the comments on a notebook as the students responded. The researcher scheduled interviews with various groups, speaking with at least two groups each day.

4.5.3 Observation schedules

The main focus of the lesson study is actually noted in the observations, which concentrate on the lecturer, student teaching and learning behaviour, events, and recording physical characteristics (Ekka 2021:17; Wood, Cajkler & Jakobsen 2020:76; Fitriati, Rosli & Iksan 2022:676). Investigating the phenomenon that is directly observed requires using a checklist of materials that is available for use in the lesson and observation. Although the participants may frame a lesson if they are aware that they are being watched, resource integration and implementation are rigorously watched. The researcher attended the lecture from just before it began till the very end in order to collect rich observations. Direct observations gave the researcher a firsthand picture of the lesson, the events, and the characteristics. The observer only documented the occurrences in an attempt to control and manipulate the situation (Kumar 2022:7). During the observational sessions, the researcher adopted a passive attitude and avoided making eye contact with the subjects. In order to focus and not disrupt the lesson, the researcher did this. The use of technology in the lessons by the lecturer and the students were covered in the observation guide. Both the professor and the students were able to observe the skills level and difficulties encountered when implementing the STEM learning technology. We noted the problems the lecturer and students encountered when using the technologies, as well as the availability of the STEM learning resources, infrastructural conditions, and skills. The researcher evaluated the attitudes of the students and lecturers towards implementing technologies, as well as the ratio of students to technologies. The researcher observed the technologies available for STEM learning for their condition/lifespan and the state of the infrastructure checking suitability to the STEM learning. Observations were based on:

- the availability of laboratory or classroom;
- availability and adequacy of Course/module software or LMSs;

- STEM learning technologies used in the 21st-century at universities of technology;
- broadband internet connectivity; availability of electricity;
- ratio of technological devices/tools to student; lecturer competencies during lesson delivery;
- lecturing strategies used;
- lecturer-to-student interaction during lessons; lecture duration;
- number of students in the class; relevancy of technological gadget or tools used;
- possession of basic digital skills by students and lecturers;
- extent of course/module software or LMS implementation;
- 21st-century skills observed from students; skills challenges faced by students in the 21st-century;
- availability of technician;
- technical support from the technician;
- lecturers and students' knowledge and skills in the integration of software and LMSs;
- lecturers and students' attitudes in the integration of course/module software or LMSs; students' perceptions regarding the use of STEM learning technologies;
- extent of STEM learning technologies implementation at the University of Technology by lecturers;
- challenges encountered by the students;
- lecturers and technicians during the lessons; and
- implementation of STEM learning technologies for the 21st-century skills and their effect at the University of Technology.

4.6 Data collection procedures

This is a crucial component of the study, since it captures what was heard and seen during the QUAL approach of data collecting. In order to enable replication of the study by another researcher, the QUAL methodology gives a full account of the data gathering process. This description includes data sources and methods employed,

including interviews, focus group discussions and lesson observations. The information gathered was comprehensive and in-depth enough to address the research question(s), and it was accurately evaluated and presented according to the theme, research question, and/or instrument. Semi-structured interviews with technicians and lecturers in their work environment. (Research question 1, 2, 5; 1, 2, 3, 4, 5; and 1, 2, 3, 4, 5, respectively). The interviews give room for clarification and further discussion with the participants so that relevant and pressing issues are ironed out. Individual interviews with lecturers and technicians were preferred for privacy. The researcher introduced herself and explained the reasons for the area under study. All research questions were assessed in lesson and resource availability observations. The researcher observed the implementation of relevant course/module software and LMSs in the teaching and learning process by both the lecturers and students. Lesson and resource availability was observed based on prolonged engagements with the lecturers, technicians, and students for credibility and reliability.

4.7 Data Analysis and Presentation Techniques

This technique is also vital as what is heard, observed, and experienced is then reported about the investigation.

4.7.1 Data analysis technique

This section describes the techniques that were used to analyse the data step by step. The procedure through which was prepared raw data for analysis and then analysed that data is one of the most important aspects of this part. This section outlines how the data for each variable or group were gathered (qualitative study). It identifies the descriptive, thematic, inferential, and/or non-statistical analysis performed on the data. This section illustrates that the research analysis is in accordance with the study design.

Coding of participants was suggested so as to increase validity of results for the study (Rossman & Rallis (2017:23). Participants were allocated coding for the university under study. Coding for the participants were as follows: Lecturers (**L1, L2, L3, L4, L5, L6, L7, L8 and L9**); technicians (**TECH 1, TECH 2 and TECH 3**). Students in focus groups were coded as follows: focus-group postgraduate first year – **FGRP PGRAD FIRST YR**, focus-group postgraduate final year – **FGRP PGRAD FINAL YR**, focus-

group undergraduate first year – **FGRP UNGRAD FIRST YR**, and focus-group undergraduate first year – **FGRP UNGRAD FINAL YR**. Lesson observations were coded as **OBSER 1, OBSER 2, OBSER 3, OBSER 4, OBSER 5, OBSER 6, OBSER 7** and **OBSER 8**. **OBSER 1 & 2** are undergraduates first-year students, **OBSER 3 & 4** are for postgraduates first-year students, **OBSER 5 & 6** are for undergraduate final-year students and **OBSER 7 & 8** for postgraduate final-year students. If the participants had to answer the same questions, then their response is inserted under the same sub-title for easy flow of data management.

Emerging themes are used to analyse the study topics. As the researcher divided each research issue into many questions, the quantity and quality of data are adequate for providing answers to the research questions. The research tools that are included as given appendices to this document contain the questions. All research tools include some questions that are repeated in order to get rich data from various participants.

4.7.2 Technique for data presentation

In the study of qualitative data, replies are presented using emerging themes with an element of voice aspect. Participants are quoted in an anonymous manner using codes.

4.8 Ethical issues

The study design, sample techniques, theoretical framework, research problem, and research questions all show commitment to the fundamental principles and values of respect, fairness, and beneficence in this section (Johnson et al. 2020:142). To avoid possible ethical problems with the study, including human volunteers and data would be protected by the researcher. It details how any potential ethical concerns have been and are addressed, along with how the study's findings are disseminated. Implementation of ethical issues focuses on principles like privacy, accuracy, property, and accessibility, claim Kivunja and Kuyini (2017:28-29). Before beginning data collecting, the researcher requested an ethical clearance letter from the ethics committee of the Central University of Technology, the study institution. Ethical clearance was also sought from the university where the researcher is employed for sourcing of data collection funds. Additionally, a letter of ethics from the university under investigation was obtained, and permission to conduct the research was

requested from the Ministry of Higher Education in the nation under investigation. The participant was assured that their comments would be kept confidential and that they would remain anonymous when the researcher asked for their permission to participate. The data analyses made use of a coding of responses. These safeguards are in place to safeguard the study's subjects, participants, and participating institutions. The researcher keeps the interview guides and observations with scrawled responses in a secret file that is sealed in a desk drawer for proper security. After the thesis has been approved for final submission, the file must be destroyed. However, there must be a grace period in case the supervisors or the examiner need to double-check something. Thereafter it should be destroyed using an office paper shredder machine. Additionally, participants were asked for their informed consent throughout interviews and observational sessions, confirming their agreement to participate in the study.

4.8.1 Principle of privacy

In this scenario, the researcher took into account what details participants are willing to share about themselves, their connections, or their organizations. The researcher also gave consideration to the procedures and security measures used in data collection and analysis.

4.8.2 Accuracy principle

Information accuracy, veracity, and authenticity are the responsibility of the researcher. By re-interviewing the participants, it was possible to confirm with the participants that the data recorded is accurate.

4.8.3 Property principle

The researcher also gave ownership of the data and requests for payment from participants some thought.

4.8.4 Accessibility principle

Who will have access to the data is taken into account by the accessibility principle. The researcher stored the material on her laptop in a secure location and made a backup using a USB flash drive and an additional hard drive.

The criteria for authenticity and trustworthiness took the place of the interpretative paradigm for validity and dependability. Regarding credibility, it is important to be honest and precise about the research's goals, methods, decision-making processes, and the specifics of data creation and administration (Hammarberg et al. 2016:500). Dependability, conformability, credibility, and transferability are the requirements for authenticity and trustworthiness.

4.9 Chapter Summary

The study methodology shows how the problem statement, methodology, design, instrumentation, data collecting, procedures, and data analysis approach were in line with the study questions, showing a thorough awareness and command of the methods used in data analysis as well as the general study strategy. The study adopted a constructivist perspective, a case study design, and a qualitative methodology. The researcher talked with the participants throughout the survey, taking note of their values, flaws, and respectfully stepping into their personal spaces. STEM lecturers, technicians, undergraduates, and postgraduate first- and final-year students make up the study's sample. The research questions were used to guide the data collection processes. Participants' coding enabled analysis and presentation of the data. Additionally, data were presented with emergent themes and a voice aspect. Instruments for gathering data for the study include semi-structured interviews administered to lecturers and technicians, focus group discussions administered to a group of students and lesson observation guides. The researcher obtained authorization from the university under study, the Ministry of Higher and Tertiary Education, Innovation, Science and Technology Development in Zimbabwe, and the university where data were collected to conduct the study. The researcher also obtained consent from the participants and participants, as well as an assurance that the information they supplied would be kept confidential. The identities of the participants were concealed. Semi-structured interviews, focus-group talks, observation schedules for the availability of STEM learning resources/environments, and a lesson observation check list were all used. The study's participants comprised technicians, lecturers, and first- and final-year (undergraduate and postgraduate) students from the university under study. In the study field, ethical issues were

investigated. The responses were analysed with the help of emerging themes with element of voice for qualitative study.

CHAPTER 5: DATA PRESENTATION, ANALYSIS AND INTERPRETATION

5.0 Introduction

This chapter discusses, analyses and present the findings of data collected from the participants through data collection instruments. The data collection instruments were semi-structured interviews, focus-group interviews, and lesson observation and evaluation of available resources. This chapter responds to the research questions found in Chapter 1. The main research question was to investigate what framework can be developed to enhance the implementation of STEM technologies to alleviate students' challenges at a university of technology. The researcher collected data for a STEM university in Matabeleland South. Lecturers were coded as **L1, L2, L3, L4, L5, L6, L7, L8** and **L9**. The technicians were coded as **TECH 1, TECH 2** and **TECH 3**. Postgraduate and undergraduate students focus groups for first year and final year were coded as **FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR** and **FGRP UNGRAD FINAL YR**.

Grounded theory analysis was employed in this qualitative research study to identify and summarize data acquired through semi-structured interviews, focus-group discussions, and lesson observations. These theoretical viewpoints on data analysis influenced my approach and attempted to understand the data. The data acquired was used to answer the research questions established in the study, and the findings were reported. The data were analysed according to STEM technologies implemented at Zimbabwean universities of technology; STEM learning technologies that are used in the 21st-century at the University of Technology Zimbabwe; skills challenges faced by students in the 21st-century; students' perceptions regarding the use of STEM learning technologies; the extent to which STEM learning technologies are implemented at a Zimbabwean university of technology by lecturers; and how STEM learning technologies are implemented for the 21st-century skills and their effects in Zimbabwe. The data retrieved from the instruments were thoroughly analysed. The data were collected from lecturers, students and technicians as they are directly involved in the teaching and learning. The technicians assist both the lecturers and students with the installation and understanding of learning course/module software and the implementation of the learning management systems.

5.1 Distribution of participants and their biographical data

Critical information was extracted from the biographical data. Thus the academic and professional qualifications assisted in getting to know the calibre of participants the researcher dealt with. The teaching experience of participants also assisted in determining the knowledge they have in the integration of technologies in the teaching and learning. The distribution of the participants was as follows: 9 lecturers, 3 technicians and 18 students (postgraduate first-year and final-year students and undergraduate first-year and final-year students) involved in STEM through interviews, focus groups and lesson observations.

5.1.1 Gender range of the participants

The study comprised 6 males and 3 female lecturers; 2 males and 1 female technician and postgraduate first-year (2 males and 2 female) and final-year (3 males and 2 females) students and undergraduate first-year (2 males and 3 females) and final-year (2 males and 2 females) students. More males than females participated in the study. Note that it does not mean that the institution has more males than females. Only the technicians comprise more males than females. The gender for lecturers and students therefore suggested the participants who had an interest in being interviewed.

5.1.2 Academic and professional qualifications

All the **L1** to **L9** and **TECH 1** to **TECH 3** hold the minimum academic qualification, which is Ordinary Level Certificate. Eight lecturers hold an Advanced Level Certificate and two technicians hold an Advanced Level Certificate. The assumption is that all students hold the Ordinary Level Certificate, because it is one of their entry requirements when they are enrolled for a programme at the institution under study. The educational background of participants is good, as they were able to interpret the interview guides.

5.1.3 Highest professional qualifications

All lecturers and technicians hold a Bachelor of Technology or a Bachelor of Science, which is a university first degree. All lecturers and **TECH 2** hold a master's degree. **TECH 1** and **TECH 3** hold a bachelor degree. This gave an impression that the

participants could give valued responses, based on their relatively high academic and professional qualifications.

5.1.4 Teaching and laboratory experience for the lecturers and technicians respectively

L2, L3, L4, L7 and L9 have teaching experience of 10 years and above. **TECH 1** have 7 years of laboratory experience; **TECH 2** have 13 years of laboratory experience; and **TECH 3** have 5 years of experience as a laboratory technician. Most lecturers had extensive teaching experience of more than 10 years, with technicians having 5 years or more as laboratory technicians.

OBSER 1, 2, 3, 5 & 8 indicated that lecturers seemed to engage with students. In **OBSER 2, 3, 5 & 8** the lecturers presented the information in the lesson with less probing and in **OBSER 1, 4, 6 & 7** the lecturers facilitated student learning in groupwork presentations. In **OBSER 7** the lecturers managed to use a trial-and-error mechanism on the integration of LMS and course/module software with students.

5.2 STEM technology implementation at universities of technology

Technologies are implemented at universities of technology, as it is evolving rapidly. Therefore, it is important to prepare the lecturers, technicians and students for the outside world to facilitate smooth collaboration and a future workforce.

5.2.1 Availability of institutional ICT/Technology policy

Lecturers and technicians were asked if the institution concerned has an ICT/technology policy. **L1, L6, L7, L8 and L9** stated that their institution has an ICT policy. **L2, L3, L4 and L5** were not sure if an ICT policy existed. The rest of the lecturers answered as follows:

TECH 1, TECH 2 and TECH 3 agreed that the institution has an ICT/technology policy. The majority of the lecturers and all technicians confirmed that the institution has an ICT/technology policy, which gave hope that they knew the requirements of the policy.

5.2.2 Staff development on ICT/technology implementation with rapidly evolving technology

Lecturers and technicians were asked if they received staff development on ICT/technology implementation, as technology was revolving rapidly. All the lecturers agreed that they regularly received staff development on ICT implementation at their institution but not everyone is keen to attend the trainings. The rest of the lecturers replied as follows:

- L1:** *“We receive staff development especially with this Covid-19 e-learning seminars were held to promote learning and avoid spread of Covid-19.”*
- L3:** *“Regularly, but attendance is not pleasing at all”.*
- L4:** *“Staff development are there but the power cuts are a challenge when one wants to attend virtually.”*
- L5:** *“Yes. Online learning training workshop. Use of moodle workshop.”*
- L6:** *“I have received staff development programme invitations but there is no room for one on one scaffolding when one needs assistance.”*
- L8:** *“There has been so many staff developments but we tend to shun them as technology is revolving and we cannot catch up with it.”*

TECH 1, TECH 2 and TECH 3 said that they had never undergone regular staff development on ICT/technology integration. The majority of the lecturers received staff development on ICT/technology integration. The technicians also lack adequate staff development on ICT/technology integration, as they have to support lecturers, students and other staff members involved in the teaching and learning set-up.

5.3 STEM learning technologies (course/module software and LMSs) used in the 21st-century at the university

In STEM, various technologies are used, depending on the programme that the students are enrolled for. Different programmes can have similar technologies used. Lecturers, technicians and students were asked about the STEM learning technologies that they integrate in the teaching and learning. **L3, L4 and L7** indicated

using moodle at their institution as a learning technology LMS. **L9** indicated that they used nothing at all. The rest of the lecturers replied as follows:

L1: *“Design of structures and hydraulic design.”*

L2: *“Moodle, Visual Programming Computer Networking Simulation and Modelling Object Oriented Programming Databases All programming courses.”*

L5: *“Software: SPSS, Mathematica, Geogebra and LMS: moodle.”*

L6: *“Proteus, moodle.”*

L8: *“Mat lab/ python, moodle.”*

The technicians replied as follows:

TECH 1: *“Pcs, laptops, tablets, phones.”*

TECH 2: *“Projector, moodle.”*

TECH 3: *“Moodle, projectors laptops mobile phones.”*

The students in the focus group replied as follows:

FGRP PGRAD FIRST YR: *“Auto CAD and moodle for resources, assignments and discussions.”*

FGRP PGRAD FINAL YR: *“Packages in maths, auto cad, virtual lab.”*

FGRP UNGRAD FIRST YR: *“moodle.”*

FGRP UNGRAD FINAL YR: *“moodle, mat lab, Auto Cad, PowerPoint; Proteus 8.”*

Lesson **OBSER 1-5 & 7** use moodle as an LMS through online lessons and the lecturers posted resources and assignments. Students referred to the resources and posted comments/questions on the discussion forum and also posted assignments. **OBSER 6** uses Moodle here and there to relate the course/module resources and assignment submission. **OBSERV 8** showed no trace of using any LMS. **OBSER 4, 6 & 7** used course/module software for the lessons. It emerged in the study that the LMSs and course/module software used are relevant, though there is need to vary them.

The implementation of course/module software and LMSs under **OBSER 6** reflected that moodle was used for submission of assignments, checking for course resources and announcements and the lessons to be learnt for the course/module. Lesson observations for the implementation of course/module software from lessons indicated use of packages in Maths, Virtual Lab; Auto CAD; MATLAB, Proteus 8 and SPSS. Principles of the theoretical framework explained in chapter two are seen on the technology use. Social interaction of students and peers and students with their lecturers was observed in the implementation of the course/module software and moodle interactions. ZPD was also observed as the lecturers probed the students on the information they know. Scaffolding of students by lecturers was satisfactory so that they had the matching knowledge and skills like the rest of the students on the use of course/module software and moodle. Nachmias model in Figure 1 is also consolidated by the interpretation of learning, infrastructure, the roles of the lecturer and roles of students. There is learning taking place as there is use of course/module software and the moodle. If students and lecturers can implement the course/module software and the moodle then it shows that the computers and internet though limited are available. The lecturers' and students' roles are satisfactory as there is interaction in the use of the course/module software and the moodle LMS.

5.4 Understanding what 21st-century skills are

Lecturers, technicians and students were therefore asked if they had any knowledge on 21st-century skills. The lecturers, when asked about what they understood about 21st-century skills, replied as follows:

- L1:** *“The current hands-on knowledge applied to current digital environment. There is communication, digital literacy, creativity, problem solving”*
- L2:** *“Skills which are a requirement for one to be productive and employable in the 21st-century like being creative, good communication, computer literacy, management skills.”*
- L3:** *“Turning academic knowledge into goods and services, creativity, leadership, critical thinking, skills in computer use, communication”*
- L4:** *“Skills relevant to the 21st-century like critical thinking, problem solving, life skills and entrepreneurship.”*

- L5:** *“These are skills essential for someone to be relevant in the 21st-century. They are a necessity and they include the four Cs like collaboration, creativity, critical thinking and communication.”*
- L6:** *“These are learning skills that both lecturers and students in this generation must all possess. These may include among other things issues like critical thinking, creativity, collaboration, information and technology literacy, leadership, social interaction, productive, etc.”*
- L7:** *“21st-century skills refer to the knowledge, life skills, professional skills, habits, and attitudes that are vital to student success in today’s environment, particularly as students progress to college, the workforce, and adulthood, are referred to as 21st-century skills.”*
- L8:** *“Skills based on the use of computer programming and related technologies.”*
- L9:** *“Skills that are needed so that everyone fits well in the 21st-century.”*

TECH 1 and **TECH 2** indicated that they did not know what 21st-century skills are. **TECH 3** replied as follows:

“I remember critical thinking, collaboration, digital literacy and problem-solving.”

FGRP PGRAD FIRST YR and **FGRP PGRAD FINAL YR** students all understood well what 21st-century skills are. Most **FGRP UNGRAD FIRST YR** and **FGRP UNGRAD FINAL YR** students understood what 21st-century skills are.

Generally, all lecturers knew what 21st-century skills are. Basically the two technicians did not have an idea what 21st-century skills are and the third technician knows the skills.

5.4.1 21st-century skills lecturers, technician and students are familiar with

Lecturers, technicians and students were asked about the 21st-century skills they were familiar with. The lecturers replied as follows:

- L1:** *“communication, digital literacy, creativity, problem solving”*

- L2:** *“being creative, good communication, computer literacy, management skills.”*
- L3:** *“creativity, leadership, critical thinking, skills in computer use, communication”*
- L4:** *“critical thinking, problem solving, life skills and entrepreneurship.”*
- L5:** *“the four Cs like collaboration, creativity, critical thinking and communication.”*
- L6:** *“These may include among other things issues like critical thinking, creativity, collaboration, information and technology literacy, leadership, social interaction, productive.”*
- L7:** *“communication, problem solving, life skills, professional skills.”*
- L8:** *“Computer literacy.”*
- L9:** *“Computer literacy, innovation, collaboration, communication, creativity, enquiry.”*

TECH 1 and **TECH 2** were not familiar with 21st-century skills and **TECH 3** indicated that 21st-century skills are to be able to use technology gadgets and different software. **Tech 3** went on to name critical thinking, communication, collaboration, and creativity as 21st-century skills. **FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR** and **FGRP UNGRAD FINAL YR** students mentioned collaboration, creativity, communication, critical thinking, information literacy, work skills, leadership, innovation and life skills.

Lecturers **L4, L5** and **L9** were familiar with all the 21st-century skills. Only one technician was familiar with the 21st-century skills. Almost all students were familiar with most of the 21st-century skills, especially collaboration, creativity, communication, critical thinking, information literacy, work skills and leadership.

It was noted that for students' 21st-century skills observations in lessons **OBSER 1 - 7** posed similar 21st-century skills like communication and digital skills. **OBSER 4 & 7** students were creative, could collaborate. **OBSER 6** was creative, could collaborate and managed to solve problems. It emerged in the study that the students lack 21st-century skills and there is a need to work on this, as technology is evolving rapidly.

5.4.2 Important 21st-century skills in STEM

21st-century skills are of great importance in STEM. Lecturers and students were asked which 21st-century skills are important in the teaching and learning of STEM. Lecturers therefore replied as follows:

- L1:** *“Design and innovation via innovation hubs, they solve day to day challenges of the economies of most states.”*
- L2:** *“ICT because technology is the backbone on all developments.”*
- L3:** *“Embracing Technology and effectively implementing it into teaching and learning.”*
- L4:** *“Critical thinking, problem solving, entrepreneurship because these directly lead to the achievement of education 5.0 goals of industrialization and economic recovery.”*
- L5:** *“Innovation, communication, digital literacy, and Creativity. These are key since we are living in a digital age.”*
- L6:** *“Critical thinking: because must be able to think beyond the obvious and come up with new inventions. Creativity: this helps in bringing innovations in ways of doing things and catch up with hanging circumstances world over. Collaboration: teamwork is a necessity, thus coming together can sharpen an invention for the good of all (networking in global village). Productivity: put what is learnt into practice and produce.”*
- L7:** *“Critical thinking, information and technology literacy. To inspire innovative thinking and hence innovative inventions beneficial for the relevant communities.”*
- L8:** *“Mathematics and Programming. The use of logics is the foundation of programming.”*
- L9:** *“Innovation-collaboration; computer literacy and creativity.”*

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR
and **FGRP UNGRAD FINAL YR** students indicated collaboration; creativity;

communication; critical thinking; information literacy; work skills; leadership; innovation and life skills as important 21st-century skills.

L4; L5; L6; L7 and L9 knew the 21st-century skills that are important in STEM. The majority of the students indicated most 21st-century skills as important.

5.4.3 Skills needed by STEM students for future workplace

21st-century skills are needed by the STEM students for future workforce and they need to be prepared accordingly. Lecturers, technicians and students were asked about the skills needed by students for future workplace. The lecturers replied as follows:

- L1:** *“Creativity, designs and construct, modelling the prototype to real object, because those are the demands of society.”*
- L2:** *“ICT skills because you won’t any job that does use ICT creativity leading to technological inventions.”*
- L3:** *“It is difficult to predict. I think they need skills that are more generally applicable, critical thinking, the ability to work ethically, the ability to manage teams and themselves.”*
- L4:** *“Critical thinking and entrepreneurship to be able to create businesses and solve societal problems.”*
- L5:** *“Innovation, creativity, critical thinking, problem Solving.”*
- L6:** *“All of the above skills cCollaboration; creativity; communication; critical thinking; Work skills; and Leadership, they will make them more relevant in the workplace and become more productive. In another dimension, these skills will not only make students fit for purpose in working environments, but can even invent new ways of doing business thus creating own employment and others.”*
- L7:** *“Problem solving to effect change and solve available problems in communities.”*
- L8:** *“Good foundation of Mathematics and Physico-Engineering principles. Programming and modelling require a sound understanding of them.”*

L9: *“Creativity – to be able to create new inventions collaboration-to be able to get ideas from others innovation computer literacy – to be able to do research.”*

Technicians replied as follows:

TECH 1: *“Soft personal computer skills search and locate on web.”*

TECH 2: *“To be able to use technological gadgets and different software.”*

TECH 3: *“ICT skills to integrate new methods of learning.”*

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR and FGRP UNGRAD FINAL YR students strongly indicated collaboration; creativity; communication; critical thinking; information literacy; work skills; leadership; innovation and life skills as skills needed for future workforce.

Only two lecturers seemed to know the skills needed by students for future workforce. All technicians were not sure of the skills needed by students for future workplace. The majority of the students indicated the above 21st-century skills as important.

5.4.4 21st-century skills that students benefit when implementing course/module software and LMSs in the teaching and learning

When implementing the course/module software, students tend to benefit several 21st-century skills. Lecturers; technicians and students were asked which 21st-century skills students benefit in lessons when implementing course/module software and LMSs. The lecturers replied as follows:

L1: *“Designing to solve real-life problems from their workplaces like water challenges in community caused maybe by hydraulic problems.”*

L2: *“ICT skills.”*

L3: *“The ability to use ICT.”*

L4: *“Students benefit problem solving and critical thinking.”*

L5: *“There is creativity, innovation, communication, collaboration, critical thinking skills.”*

L6: *“Critical thinking; Collaboration; Social interaction; Productivity; information & technology literacy.”*

L7: *“Yes.”*

L8: *“Computer literacy is a benefit for learning in 21st-century.”*

L9: *“Collaboration.”*

TECH 1, TECH 2 and **TECH 3** indicated that both the lecturers and students possess and benefit 21st-century skills.

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR and **FGRP UNGRAD FINAL YR** students indicated benefiting 21st-century skills such as collaboration; creativity; communication; critical thinking; information literacy; work skills; leadership; innovation and life skills as the 21st-century skills in the learning process.

In **OBSER 1, 3** and **4** under observation reflected that the students benefited communication, critical thinking, collaboration, computer literacy and creativity. In **OBSER 2**, it was observed that communication and collaboration amongst the students was excellent as they worked in groups sharing knowledge, skills and good attitudes. It emerged in the study that **OBSER 5, 6, 7** and **8** students benefited from collaboration, creativity, communication, information literacy, work skills, leadership and computer literacy 21st-century skills. In the lessons that were observed, it was observed that students collaborated with their peers, communicated well and were critically thinking and solving problems when implementing course/module software and LMSs. All students possessed the basic digital skills, as they could switch on and off the computers and tried to manipulate some features of the LMS and course/module software. **OBSER 4, 6 & 7** had better skills compared to other students in some observations.

Only two lecturers managed to state several 21st-century skills that the students benefited when implementing course/module software and LMSs in the teaching and learning process. The technicians mentioned that both the students and lecturers benefited the 21st-century skills during the teaching and learning sessions. The majority of students indicated benefiting 21st-century skills.

5.4.5 Lecturer possession to be excellent in 21st-century skills

Lecturers and technicians were asked what one needs to possess to be an excellent lecturer of the 21st-century. **L3**; **L4** and **L5** stated that they needed excellent ICT skills to foster and implement STEM-based solutions to societal problems. The rest replied as follows:

- L1:** *“One individual lecturer need to equip himself or herself with technology skills to be relevant in the stem learning and teaching eg auto cad/cam arch cad use.”*
- L2:** *“Lecturers need to be innovative so that they may come up with ways to promote each skill.”*
- L6:** *“A clear mind-set and be prepared to learn even from the students as knowledge is no longer singly possessed as yester year educators used to think. Some students are even advanced and quick to embrace and understand technology, thus a clever educator can swallow pride and even learn from such students.”*
- L7:** *“Passion, hard work and resilience.”*
- L8:** *“Good foundation of Mathematics and Physical-Chemical Sciences, together with their application in Engineering and Technology.”*
- L9:** *“Exposure and staff development programmes.”*

TECH 1 mentioned soft skills as skills a lecturer should possess; **TECH 2** and **TECH 3** replied as follows:

- TECH 2:** *“Be able to integrate theory, practical, and application in a course.”*
- TECH 3:** *“ICT gadgets, internet connectivity.”*

OBSER 1 reflected that the lecturer had technology, communication and innovative skills. In another lesson, **OBSER 2** indicated that the lecturer lacked all the 21st-century skills. It was also established that only two lessons observed had sound use of Google classroom for classroom activities. It emerged in the study that lecturers from **OBSER 5** lacked excellency in terms of 21st-century skills. It was established that the lecturers in all lessons had basic digital skills, though they need to possess adequate skills so as to be more competent on the integration of course/module software and LMS.

5.4.6 Skills challenges faced by students in the 21st-century

21st-century skills in STEM programmes are very essential to lecturers, technicians and students at large, as students are prepared for a future workforce. It is therefore wise to understand what these skills are, and the ones needed for everyday life. Students may face challenges because of lack of knowledge and practice and in adequate learning gadgets or technologies. Lecturers and students were therefore asked about the skills challenges faced by students in 21st-century teaching and learning.

All **L1** to **L9** mentioned inadequate devices, lack of practice, lecturers with minimal knowledge how to spell out and teach the skills and minimal time to teach a large group of students. **FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR** and **FGRP UNGRAD FINAL YR** students indicated sharing of computers with software as personal laptops reject the pirated software, minimal time for practice, lecturers with minimal knowledge on how to spell out and teach the skills and lack of one-on-one procedures as one has to try and study after class.

It emerged in all the study observations that students and lecturers had skills challenges in the integration of Google Classroom in the teaching and learning. In all the lessons that were observed, it was observed that all lecturers had the minimum knowledge on how to integrate course/module software. Through trial and error students had to assist the lecturers for the lessons to be achieved.

5.4.7 Ranking and valuing the importance of 21st-century skills by students

21st-century skills are valued in STEM teaching and learning as they prepare the students for collaboration and a future workforce. Lecturers and students were asked on how the students rank and value the 21st-century skills. The lecturers replied as follows:

- L1:** *“Students value and rank skills acquired via technology highly but have challenges of internet and gadgets.”*
- L2:** *“Very high.”*
- L3:** *“Some are not aware of them, such that they just flow with the rest. However, some have shown innovative skills and energy.”*

- L4:** *“Some understand the importance of STEM and rank it highly, some are sceptical.”*
- L5:** *“They value them since they are essential in the 21st-century era.”*
- L6:** *“They rank them highly as seen by the way they envy to put them into practice.”*
- L7:** *“Both in the listed frameworks and in the students' free comments, social skills and collaboration are ranked first. Males place a higher value on technical skills, while females place a higher value on social skills.”*
- L8:** *“I am convinced that students highly value digital skill.”*
- L9:** *“Most students are not aware of these 21st-century skills.”*

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR and **FGRP UNGRAD FINAL YR** students indicated that they rank and value the importance of 21st-century skills highly, though they said that there is need for them to improve those skills.

The majority of the lecturers shared the same sentiments that the students highly rank and rank 21st-century skills. Almost all/the majority of the students indicated the above 21st-century skills as important.

5.5 Gender differences in the teaching of STEM

Gender differences in the teaching of STEM vary from time to time. Lecturers and students were therefore asked if there are any gender differences in the teaching of STEM. **L5** and **L9** spelt no gender differences in the teaching of STEM. The rest of the lecturers replied as follows:

L1 and L8: *“Gender differences are marginal with few female students participating in stem.”*

L2, L4, L6 shared the same sentiments as following:

- L2:** *“Males used to dominate, but many initiatives have levelled the playing fields.”*
- L4:** *“Traditionally more males have been appreciating STEM, of late many females are now enrolling in STEM based disciplines.”*

L6: *“Of late more males were taking up STEM programmes compared to female counterparts, however do to encouragements from local and international role models, more females are now taking such studies.”*

L3: *“Currently there are more females than males.”*

L7: *“Men are more likely to be literate on a global average, although higher literacy scores for women are prevalent in many countries.”*

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR and **FGRP UNGRAD FINAL YR** students indicated having males as the majority in their STEM classes.

Most lecturers indicated that nowadays females are enrolling in STEM. The students indicated having more males than females in their programmes. It was established that in lessons for Computer Science, Chemistry, Biology, Mathematics and Physics female representation was overriding that of males. In the engineering programmes like Civil and Construction, Electrical & Electronics and Mechanical, the number of males as compared to females was still low.

5.6 Frameworks useful in determining skills and competences for excelling in teaching STEM programmes

Lecturers were asked about the frameworks that are useful in determining skills and competences for excelling in teaching STEM programmes. **L2, L8** and **L9** were not familiar with what frameworks are. The rest of the lecturers replied as follows:

L1: *“The 5.0 education framework is the way to go in stem teaching.”*

L3: *“Precise knowledge of the practical work and research techniques for the particular stem subject.”*

L4: *“A mixture of Positivist and Interpretivist philosophical frameworks.”*

L5: *“Blended Teaching.”*

L6: *“Integrated framework with a socio-constructivism approach (mixed methods approach). School-Home link approach where school activities are supported by home activities to foster learning.”*

L7: *“The STEM Education Framework developed by the Global STEM Alliance strives to identify best practices in science, technology, engineering, and mathematics (STEM) education. It is based on current educational research and draws on creative and effective approaches used all over the world.”*

5.7 STEM resource and skills challenges faced by lecturers, technicians and students in the implementation of course/module software and LMSs

In the implementation of course/module software and LMSs lecturers, technicians and students may face some challenges like inadequate computers, network connectivity challenges and many more. The lecturers, technicians and students were asked about the challenges they face in the implementation of course/module software and LMSs. The lecturers replied as follows:

- L1:** *“Lack of personal gadgets for day to day teaching and learning.”*
- L3:** *“Limited data, inadequate computer skills.”*
- L4:** *“Lack of modern tech gadgets and software. Many students based in rural areas have limited or no access to the internet.”*
- L5:** *“Power outages, internet challenges and failure to customise the learning material to suit the online learning environment.”*
- L6:** *“The unavailability of institution provided gadgets to staff such that some learning material can end up being shared even on social media platforms like WhatsApp rendering it difficult to have checks and balances on desired quality of education outcomes.”*
- L7:** *“Unavailability of equipment for both students and staff and power outages, poor computer skills.”*
- L8:** *“Internet challenges, Need to effectively train staff to adapt to new technologies.”*
- L9:** *“Inadequate digital skills, Power outages, in staff development is needed on current software.”*

Technicians replied as followed:

TECH 1: *“Power outages, challenge of lack of equipment (funding).”*

TECH 2: *“Funding, power outages and internet challenges and poor digital skills.”*

TECH 3: *“Power outages, network interruptions and lack of financial computer skills and human resources.”*

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR and FGRP UNGRAD FINAL YR students indicated minimum access to laboratories; laboratories not well equipped, power outages, internet challenges, no access to module software in the computer labs, computer not sufficient, interface learning tools supporting LMS such as chats, Wikis, feedback, podcasts are not effectively utilized in learning as challenges faced in the implementation of software and LMSs.

It emerged in the study that in the observed lessons, all lacked inadequate computers, network connectivity, and lecturers' had minimal knowledge or skills in the integration of course/module software. It was noted that lecturers in all observations, except in **OBSER 7** were able to use the LMS up to a certain extent. **OBSER 4, 6 & 7** integrated the course/module software, but with minimal skills. **OBSER 1, 2, 3 & 4** had to do trial and error using the knowledge they had in order to integrate either the software and LMS. **OBSER 5, 6 & 7** were better than the rest of the observations and they need adequate technical support for them to excel. **OBSER 8** had no trace of use as the lesson was mostly done theoretical. It was observed that in **OBSER 1, 2, 5 & 6**, internet connectivity was fast during the lesson. In **OBSER 4, 7 & 8** there was no WiFi at all. **OBSER 1, 2, 5 & 6** had electricity; for **OBSER 3** electricity was on and off and there was no electricity during **OBSER 7 & 8**. **OBSER 1 & 2** had a highly discouraging ratio of computer to student as 1:4 & 1:5, respectively. **OBSER 3 & 8** had a ratio of 1:3. **OBSER 4, 5 & 6** had a ratio of 1:2. In another lesson, **OBSER 7** indicated 1:1 as some students brought their own laptops. It emerged that in low ratios like 1:1; 1:2 and 1:3 students brought their laptops so they could minimize sharing for easy practice and grasping of skills. It emerged that there was satisfactory lecturer to student interaction during the lesson observation for **OBSER 1, 2, 3, 4, 5, 6 & 8**. Student to student interaction was observed in **OBSER 7**, as students assisted one another in brainstorming on how to manoeuvre with LMSs and course/module software features. **OBSER 1, 2, 5 & 6** were scheduled for 2 hours and **OBSER 3, 4, 7 & 8** were scheduled

for 4 hours and this was adequate to implement the LMS and course/module software. Based on student class numbers ranging between 17 and 32, all the STEM classes had many students and resources were not adequate.

L1, L4 & L6 shared the same sentiments that the institution has inadequate gadgets. Overall, the lecturers, technicians and students indicated that there is minimal implementation of software and LMSs because of unavailability of devices and software, limited internet connectivity, power outages, and lack of knowledge on the integration of the software and LMSs.

5.8 Students' perceptions regarding the use of course/module software and LMSs in STEM learning

Students' perceptions of course/module software and LMS integration were based in terms of its features and usability on both the desktop computers and laptops. The lecturers and students were asked about the students' perception. The lecturers replied as follows:

- L1:** *“Students feel they will benefit from use of course/module software and LMSs since this has lessened manual efforts in designs.”*
- L2:** *“Students look forward to and are excited about course/module software and LMSs however are let down by lack of a variety of course software.”*
- L3:** *“Most students do not subscribe to the LMS due to their lack of technical skills and poor connectivity.”*
- L4:** *“Some are sceptical, some are enthusiastic and experimented, showing ability for innovation if well tutored and motivated.”*
- L5:** *“Students have attitude towards LMS as they prefer WhatsApp, which is cheaper. The course/module software motivates the students.”*
- L6:** *“Because of some technological gaps among and between students the perceptions vary. However, it is to some extent generally agreed that LMSs are not all that user friendly to the general populace of the students based on their backgrounds where some will be meeting such technologies for the first time.”*
- L7:** *“The course software and LMS are very useful for their work.”*

L8: *“They like using such facilities in learning, however, few of them think about the engineering principles governing their efficient function.”*

L9: *“They do not want to use mobile interfaces due to internet challenges.”*

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR and FGRP UNGRAD FINAL YR students indicated that the LMS features and usability are user friendly, though they mentioned challenges of data to log onto the system. Therefore, they preferred using WhatsApp as an alternative. The students also indicated that most course/module software is pirated; therefore difficult to install onto their devices. The students went on to say that a semester is never enough to learn and use the course/module software adequately.

It was established in lesson observations for five lessons that technicians had a great challenge in installing pirated software onto the computers. Some students in the seven lessons who are outside the country because of Covid-19 restrictions failed to log onto Google Classroom because of internet connectivity.

5.9 Beliefs, knowledge and attitude in the implementation of course/module software and LMSs in the teaching and learning of STEM

Lecturers and students may have beliefs, knowledge and attitudes in the implementation of course/module software and LMSs in teaching and learning of STEM. The lecturers and students were therefore asked about their beliefs, knowledge and attitudes. The lecturers replied as follows:

L1: *“I believe stem teaching and learning should be moved so swiftly to get to where the global population to promote global village.”*

L2: *“I fully support it and i support all the efforts.”*

L3: *“It's now the new normal, more training is required in the use of LMSs, and the attitude should that of positivity for the use of ICT is here to stay.”*

L4: *“I believe that the modern world needs STEM based solutions to its problems.”*

L5: *“Online learning should complement face to face.”*

L6: *“Be adaptive; Be Innovative; Be flexible to issues of technology.”*

- L7:** *“A teaching model based on the assumption is personalized learning. Each student receives accelerated learning depending on their learning style, knowledge, and skills and interests. It is the polar opposite of the one-size-fits-all strategy adopted in most schools. This procedure encourages students to take charge of their education.”*
- L8:** *“I believe in building good foundation in Mathematics.”*
- L9:** *“If materials are provided it will be easy to implement teaching of STEM.”*

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR and **FGRP UNGRAD FINAL YR** students indicated that they could integrate the course/module software and LMSs in the teaching and learning of STEM up to a certain extent. The **FGRP PGRAD FIRST YR** students also said that during their undergraduate course they never implemented the course/module and LMSs therefore they are facing challenges and need to catch up.

All eight observations, **OBSEER 1-8** reflected that there were attitudes in the use of Google Classroom, as most students did not manage to log onto the system and could not work without assistance. In the eight lessons that were observed, it was observed that use of course/module software was a challenge to both the lecturers, students and the technician to a large extent. Students in **OBSEER 1, 2, 3 & 4** had challenges in using the course/module software and LMS, but were willing to learn from their peers and lecturers. It was noted that students in **OBSEER 5, 6 & 7** could use the software and LMS with no problems and carrying out task through trial and error, where possible. **OBSEER 8** had no trace of use of the software and LMS.

5.10 Perceived usefulness of technologies to alleviate students’ 21st-century skills

With technology revolving rapidly, technologies are useful to gain knowledge and 21st-century skills. Lecturers, technicians and students were asked how they perceived usefulness of the integration of technologies. The lecturers replied as follows:

- L1:** *“The skills learnt by students have been modified to a greater extent due to technology.”*

- L2:** *“Technologies assist to make 21st-century skills more accessible and students can easily use technologies to develop these skills.”*
- L3:** *“Technology is the vehicle and tool for 21st-century skills.”*
- L4:** *“Use of ICT is inevitable.”*
- L5:** *“Technology is at the heart in the development of 21st-century skills.”*
- L6:** *“Technology can be used to promote critical thinking, evaluate accuracy of some online content through online surveys. Also through use of technologies, students and educators can even collaborate in such issues like research work and publications, seminar and conferences presentations.”*
- L7:** *“It promotes inclusion and the development of digital literacy skills.”*
- L8:** *“The technology will quicken the learning process.”*
- L9:** *“Gadgets should be available.”*

TECH 1, TECH 2 and TECH 3 indicated that technologies are very useful and effective for modern learning.

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR and FGRP UNGRAD FINAL YR students indicated that technology is evolving rapidly and there is need to keep abreast because of its significance.

The lecturers, technicians and students agreed that technology is useful to master 21st-century skills.

5.11 Perceptions, practices and comfort with teaching and learning STEM programmes

Lecturers and students were asked on perceptions, practices and comfort with the teaching of STEM programmes. The lecturers replied as follows:

- L1:** *“Teaching of stem has become a better move towards current environment of technology.”*
- L2:** *“Teaching STEM programmes is essential and should be prioritised as there is a shortage in the market.”*

- L3:** *“They the way to self-sustainable, and I teach them implementing technology.”*
- L4:** *“I am passionate about STEM teaching. I believe the modern world requires STEM based solutions to its problems.”*
- L5:** *“They are key in the advancements of the nation.”*
- L6:** *“Experts must be consulted when crafting these programs to make sure all requirements are taken aboard from onset. Students and educators must complement each other, changing some aspects together as they go with learning. Learning area clubs must be formed to promote exchange programs.”*
- L7:** *“I favour STEM education; yet, identified hurdles such as pedagogical challenges, curricular challenges, structural challenges, student worries, assessment concerns, and a lack of lecturer support have an impact. Collaboration with peers, quality curriculum, district support, prior experiences, and good professional development would all help to strengthen attempts to incorporate STEM education.”*
- L8:** *“Teaching STEM programmes require a lot of means in terms of infrastructures and equipment. The comfort lies in equipping students with skills necessary for future industrial development.”*
- L9:** *“Gadgets to be provided to both lecturers and students.”*

The majority of **FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR** and **FGRP UNGRAD FINAL YR** students indicated that lecturers are able to teach the STEM programmes effectively. It was established that in **OBSER 1 - 7** except **OBSER 8** students had an interest in implementing the LMS and are willing to learn more on all the features the LMS possessed. From all lesson observations lack of skill to teach STEM programmes was seen in minimal use of the course/module software.

5.12 Gadgets/software availability and extent of use in the teaching and learning of STEM programmes

In the teaching of STEM, it is assumed that institutions have adequate course/module software, effective integration of LMSs and availability of sound technology equipment like computers, good internet connectivity, availability of electricity and many more. Lecturers, technicians and the students were asked about the extent to which STEM learning technologies are implemented in their institution by lecturers. Regarding the extent of use of the gadgets/tools and software, lecturer **L1** to **L6** were very positive and replied as follows:

- L1:** *“Regularly integrate gadgets to cater for Covid-19 spread we resort to use of software and computer tools.”*
- L2:** *“Due to COVID we are forced to use software almost 90% of the time.”*
- L3:** *“Always.”*
- L4:** *“About 80% ... personal gadgets.”*
- L5:** *“To a larger extent I integrate the ICT tools and use relevant Maths software.”*
- L6:** *“Due to the Covid-19 pandemic, face-to-face lectures are now done for few days and online interactions between lecturers and students are becoming more pronounced. It is now against this background that gadgets/tools/software are now frequently used for interaction between students and lecturers.”*
- L7:** *“Teaching and assessments.”*
- L8:** *“30%.”*
- L9:** *“I have not seen any gadgets in my institution. Software I do not know where to get them.”*

TECH1 indicated availability of personal computers, laptops, tablets and phones and on extent of use its medium use. **TECH 2** mentioned Google Meet being used in lessons. **TECH 3** mentioned availability of Teams and Zoom and to a lesser extent due to a limited availability. **FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR** and **FGRP UNGRAD FINAL YR** students indicated that lecturers were implementing the course/module software and LMSs adequately for class activities and assignments. Google Classroom is integrated for viewing

resources; lessons; assignments; uploading presentations; e-mailing; course outline and assignments.

It was also established that Google Classroom was used in the teaching and learning of all the observed lessons. In the lessons that were observed, it was observed that few course/module software is available at the institution. Implementation of the course/module software and LMS in **OBSER 1, 2, 3, 5 & 6** was minimal. **OBSER 4** and **7** showed satisfactory implementation, whereas **OBSER 8** had no trace of implementation as nothing was referred to any software or LMS in the lesson.

5.13 Extent of STEM learning technology implementation

STEM learning technologies in the study are divided into course/module software and LMSs. Lecturers, technicians and students indicated that they use Google Classroom as the LMS for the teaching and learning. Students also indicated that they used Google Classroom to access learning resources, to view and send assignments and for discussions with peers and the lecturers. The students also indicated that some tools and features for the Google Classroom are not utilized because of lack of skill and knowledge.

Lecturers indicated that course/module used are visual programming, SPSS, Mathematica, Geogebra, Matlab, Proteus and Python. The technicians seemed lost on course/module software. The students mentioned using course/module software like CAD, packages of mathematics, virtual laboratory software, Matlab and Proteus software.

From observations, the lecturers referred to the learning resources, assignments viewing and sending to be done on the LMS. Only two observations had any trace of using the course/module software, though it was just for a short time and the lecturers had no skill or knowledge in using the tools or features.

5.14 Implementation of STEM learning technologies for the 21st-century skills and their effects in the teaching and learning

Implementation of technologies in STEM is essential for 21st-century skills, as technology is evolving rapidly. All stakeholders the lecturers, technicians and students should be able to collaborate, be creative, communicate, critically think and solve

problems and be ready for the outside world. The lecturers, technicians and students were asked how STEM learning technologies are implemented for 21st-century skills and their effect at the university. Lecturers **L1** to **L9** generally mentioned the following in relation to implementation of technologies and their effects to the university:

“Technical support is minimal, as the technician is overloaded having to service quite a number of students and lecturers at a given time. Students fail to log on to the Google Classroom because of poor connectivity, poor bandwidth, power cuts or challenges of data. Implementation of technologies is a great challenge. We are using pirated course/module software which is sometimes rejected in most computers. Sharing of computers amongst students with a computer to student ratio of 1:5 is another challenges that leads to minimal implementation of technologies as students have minimal hands on. Some students fail to log on to Google Classroom and resort to sending their assignments through emails. There is need to effectively train us regularly as lecturers to adapt to new technologies so as to keep abreast. Most of the course software is new and to study it at the same time trying to teach students is a challenge. With the minimal implementation the effect on the students that graduate is not fully baked and this lowers the standard thus killing the brand of the institution.”

TECH 1, TECH 2 and **TECH 3** indicated that lecturers and students possess basic computer skills in the integration of course/module software and LMSs. **TECH 1, TECH 2** and **TECH 3** went on to say that devices are used to a lesser extent by both lecturers and students, due limited availability. **TECH 1, TECH 2** and **TECH 3** also shared the same sentiments on the need of funding and increase internet bandwidth for effective implementation of technologies in teaching and learning so as to impart the students with relevant 21st-century skills needed for future workforce.

When the technicians were asked on their expertise in the integration of course/module software or LMSs they replied as follows:

Tech 1: *“I am very good.”*

Tech 2: *“I have limited knowledge on integration of course software but have no problem with LMSs.”*

Tech 3: *“I am average because there is lack of training.”*

FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR
and **FGRP UNGRAD FINAL YR** students replied as follows:

“We face challenges in using LMS due to data, internet connectivity, inadequate gadget and power cuts. Some lecturers try to figure out the operation of course software as they teach. We tend to waste time during lessons and as we collaborate will fellow students thus doing trial and error with no assistance and at the end of the day benefit nothing. This has an effect on that, we learn and finish some courses with minimal or no benefits at all this in turn affects us when we are given a piece of work to work on outside the institution. Generally, we have minimal implementation technologies and it has massive effect on the university as it tarnishes its image to the outside world.”

It was also established that some in all lessons observed, students failed to log onto Google Classroom because of poor connectivity, poor bandwidth and power cuts. Regarding the challenges of installing software to a number of computers during the lessons, lecturers had minimum knowledge and skills of how to integrate the course/module software.

5.15 Technical and financial support

Emotional/instructional/technical support is important to lecturers, technicians and students in STEM teaching and learning. Lecturers, technicians and students were asked about the support they get from one another as a whole. The lecturers were therefore asked about the support they give to their students and they replied as follows:

- L1:** *“We offer them lesson online and video lectures recorded for them to revisit.”*
- L2:** *“We have a faculty technician available for support.”*
- L3:** *“Emotional is through encouragement and use of teaching methods that are student centred.”*
- L4:** *“I encourage students to embrace and implement STEM in their lives and jobs. I collaborate with technicians in offering technical support to students.”*

- L5:** *“Encourage them to their work in time, giving them learning support documents.”*
- L6:** *“Let’s work, learn or fail together as we foster meaningful teaching and learning”. “Never give up, when one method fails, try another one till learning objectives me met.”*
- L7:** *“Creating an inclusive environment and provide mentorship.”*
- L8:** *“STEM is useful for industrial development.”*
- L9:** *“To be provided with gadgets and data for internet.”*

Technicians were also asked about the support they give to lecturers and students and they replied as follows:

- TECH 1:** *“Hardware maintenance and provision software installation, profile maintenance.”*
- TECH 2:** *“I always refer them to student support”*
- TECH 3:** *“Through training end user support demonstrations” “software and hardware maintenance, access profile provision and maintenance.”*

Students in focus groups were asked about the support they get and they replied as follows:

FGRP PGRAD FIRST YR: *“There is inadequate support from the lecturers and technicians. You find one technician trying to assist quite a number of students which sometimes disturb lessons.”*

FGRP PGRAD FINAL YR: *“The lecturers try their best to teach us on how to use the course software and LMSs, unfortunately time is limited and in some mass lessons the ratio of students to lecturer is unbearable. The technician is reliable and makes sure that he assists tirelessly.”*

FGRP UNGRAD FIRST YR: *“The technician assists by installing software in our personal laptops before or after lessons. Sometimes when we get class codes for Google Classroom lessons and we fail to log in the technician assists us. During lessons there is no technical support.”*

FGRP UNGRAD FINAL YR: “Lecturers and technicians’ support is minimal and fellow students who have known how on how to use the software try to assist. The technician installs software for us and other technical problems like signing into institutional WiFi.”

It emerged in the study that technicians were available for technical support in only three lessons. In some lessons students were forced either to lose some lesson time looking for assistance, or to find the technician after lessons. In the lessons that were observed, it was observed that most lecturers try to give support to the students up to a certain extent, as lessons seemed to be too short and they lack knowledge and skills in implementing the technologies.

5.15.1 Responsible office/personnel for the technical support

Institutions must have a particular office that support lecturers and technicians technically to facilitate smooth teaching and learning. Adequate technical support reduces frustration from end users, in this case the lecturers, technicians and students at large. Lecturers and technicians were asked who is responsible for technical support and how they are supported. **L1** said that the research and innovation hub department, supported via the research centre for innovations, is responsible for the technical support. **L2, L4, L5, L6, L7, and L8** mentioned technical support by ICT technicians. **L3** said the university is responsible but no support has been given technically. **L5** said that he faculty technician is responsible for the technical support when they have challenges in connection with Google Classroom LMS. **L9** revealed that no-one has ever supported them technically. **TECH 1** indicated that the administration of the institution and the state are responsible for the technical support. **TECH 2** mentioned the Information Communication and Technical Service department as one responsible for the technical support.

5.15.2 Adequacy of technical support

Lecturers, technicians and students were asked how adequate the technical support was. **L1, L2, L3, L5, L6, L7 and L8** said that technical support is not adequate due to resources constraints. Either the technician will be alone and support over 300 people at a given time, however they try their best to assist. **L4** said that the technical support is satisfactory and the technicians have little influence on people's personal devices.

L9 was not sure. **TECH 1, TECH 2 and TECH 3** mentioned that they receive minimal support from the administration. **FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UNGRAD FIRST YR and FGRP UNGRAD FINAL YR** students shared the same sentiments that technical support is not adequate as few technicians service each faculty and it takes days to be assisted, especially if it is a mass class. Minimal technical support was established from all the observed lessons as there was no back-up for power cuts, few computers functioning properly and pirated course/module software.

5.15.3 Sources of funding for STEM programmes

Institutions have sources of funding for their ICT/technology like internet connectivity, devices, maintenance, and staff development. Lecturers and technicians were asked about the sources of funding for the STEM programmes. **L1** mentioned the university research and innovations funds as a source of funding. **L2** said that there is no source of funding. **L4, L7 and L9** were not sure about the sources of funding. **L3, L5 and L6** stated that sources of funding are from the University Coffers. **L8** mentioned Government budget as a source of funding. **TECH 1** said that he is funding himself, **TECH 2** said that the source of funding is the university and **TECH 3** indicated that the source of funding is from the government and student fees.

5.15.4 ICTS/technologies with adequate funding

Lecturers and technicians were asked whether ICTs/technologies have adequate funding. **L1, L2 and L5** stated that no ICTs or technologies have adequate funding. **L3, L7 and L8** had no idea on the ICTs or technologies with adequate funding. **L4, L6 and L9** were not sure which ICTs or technologies have adequate funding. **TECH 1, TECH 2 and TECH 3** said there are no ICTs/technologies with adequate funding.

5.15.5 ICTs/technology funding sustainability by the university

L1 mentioned research and innovations as means how the university sustains funding. **L4 and L2** shared the same sentiment that no funding for procuring of gadgets for lecturers but pays full-time ICT personnel for technical support. **L3 and L6** believed that the university sustained funding through tuition fees collected from students. **L5** said that the university sustains funding by providing data bundles. **L7 and L9** had no

idea on how the university sustains funding. **L8** stated that the university provides computers, laptops, internet connectivity and technician per faculty.

5.15.6 Challenges in technical and financial support of ICTs/technologies faced in teaching and learning

The lecturers and technicians were asked about the challenges they face technically or financially in the support of ICT/technologies. The lecturers replied as follows:

- L1:** *“Hardware and software gadgets are not adequate for teaching.”*
- L2:** *“Assistance is normally unavailable, no money available.”*
- L3:** *“Lack of efficient gadgets and data.”*
- L4:** *“Modern tech gadgets are very expensive and not affordable by individuals.”*
- L5:** *“Poor internet connectivity, Lack of functional Laptops, few projectors.”*
- L6:** *“Should provide lecturers with gadgets like laptops than let lecturers source their own gadgets for university business.”*
- L7:** *“Not much technical and financial support.”*
- L8:** *“Lack of sufficient technicians to assist students and staffs”.*

TECH 1, TECH 2 and **TECH 3** mentioned funding, lack of accessibility to the technicians, and lack of financial and human resources, respectively.

5.15.6.1 Challenges encountered by the students during the lesson

Students in **OBSER 1, 2, 3** and **8** had concerns on the computer to student ratio. There was no technical support from the technician in **OBSER 1, 3, 6, 7** and **8**. It was observed that technical support was minimal from the technicians and lecturers in **OBSER 2, 4** and **6** and technicians were overloaded in assisting quite a number of students and lecturers at a given time. The lecturers had minimal skills in the integration of the software and LMS used in the lessons. There was a shortage of functioning computers and course/module software. The course/module software sourced was pirated; therefore it was difficult to install onto some computers with old

versions. Time was wasted on computers that froze as students were working and some data were lost, giving students a hard time.

5.15.6.2 Challenges encountered by the technicians during the lesson

The technicians were only available in **OBSER 2, 4 and 5** and had a challenge in assisting the students, as they were many and it took time to install the software. Challenges encountered by the lecturers during the lesson The lecturers faced challenges in implementing some of the software and LMS as they did not know how to use some features.

5.16 Promotion of STEM to students

Promotion of STEM is important as a way of encouraging upcoming students on knowledge and 21st-century skills. Lecturers and students were asked how they promote STEM to students. The lecturers replied as follows:

- L1:** *“Stem is promoted through the enhancement of mathematics and use of technology software like AUTO CAD/ CAM.”*
- L2:** *“In all subjects taught, STEM examples are always used.”*
- L3:** *“Extending my community services to high schools teaching stem education.”*
- L4:** *“By presenting a positive attitude towards STEM disciplines and talking about STEM on social media.”*
- L5:** *“By STEM teaching and showing relevance of STEM subjects to everyday life.”*
- L6:** *“By giving as many STEM oriented projects as possible that bring curiosity among and within students. Be good role model to students by sharing experiences, achievements and expectations. Give exciting hands-on problems whose outcomes can even be answers to students' own problems.”*
- L7:** *“Participating in a variety of projects and activities fosters love and interest for STEM. Hands-on experiences, positive role models, and interesting problems inspire students to learn and flourish.”*

L8: *“Encouraging students to focus on Mathematics and Physics knowledge.”*

L9: *“Encouraging students on doing STEM subjects at their secondary education.”*

Technicians promote STEM to students by:

TECH 1: *“Mandatory usage.”*

TECH 2: *“By involving other lecturers and students.”*

TECH 3: *“Through demonstration of tutorials and labs.”*

5.17 Possible solutions to the challenges faced in teaching STEM programmes

Lecturers and technicians were asked for any possible solutions to the challenges that they face in teaching STEM programmes. L3 stated internet connectivity as challenge in lecturing STEM. L2 and L9 went on to say that the university had to fund lecturers with equipment. L4 said that the university should avail technical infrastructure. L7 mentioned possible solutions as technical and financial support. The rest replied as follows:

L1: *“STEM lecturers need to be fully equipped with digital equipment for them to be relevant to their teaching.”*

L5: *“For gadgets. The Institution can subsidise the lecturing staff when buying laptops.”*

L6: *“Funding should be set aside for the purchase of ICT gadgets for use by lecturers with centralised management system and for provision of smart classrooms and laboratories.”*

L8: *“Decrease of teaching load and number of students per lecturer will enable lecturer to better assist weak students in STEM. This will also enable lecturer to learn about new trends in the use of Technology in teaching and learning.”*

TECH 1 indicated that donor funding, greater enrolment and changes in budgetary allotment policy are possible solutions to the challenges face in teaching STEM programmes. **TECH 2** and **TECH 3** indicated that they did not have possible solutions.

5.18 Any other information shared in regard to the implementation of technologies in STEM learning

Lecturers, technicians and students were asked for any other information in the implementation of technologies in STEM learning to improve students' 21st-century skills in the institution. The lecturers replied as follows:

- L1:** *“More laboratories and more resources should be challenged towards researches and viable innovations.”*
- L2:** *“Technologies need to be availed to students bearing in mind students' needs differ, and hence must be on case by case basis, some students are in urban areas, while some in rural areas.”*
- L3:** *“More funding, building laboratories and ensuring connectivity and availability of data.”*
- L5:** *“University should assist students in accessing online lessons.”*
- L6:** *“Work-based learning (industrial attachment) should be widely spread to all programmes so that students will have the to implement and evaluate what they would have learnt before exiting the university.”*
- L7:** *“Provision of adequate funding and resources for proper implementation.”*
- L8:** *“The university shall have licence for Math Type software for all staffs and students in the Faculty of Engineering.”*
- L9:** *“Staff development programmes should take place because some lecturers do not have the knowledge of these skills.”*

TECH 1 indicated that donor funding, greater enrolment and changes in budgetary allotment policy are the way to go for the effective implementation of technologies in STEM learning to improve students' 21st-century skills. **TECH 2** and **TECH 3** had no more information to share. **FGRP PGRAD FIRST YR, FGRP PGRAD FINAL YR, FGRP UGRAD FIRST YR** and **FGRP UGRAD FINAL YR** students shared the following information:

FGRP PGRAD FIRST YR: *“The university must invest and purchase the original software as pirated software is rejected by most laptops. Improve LMS*

interfaces to be improved for usability such as chats, wikis, feedback, podcasts were not effectively utilized in learning.”

FGRP PGRAD FINAL YR: *“Ratio of students to computers is 5:1 for a mass class which makes it difficult for hands-on therefore the university should purchase more computers. Integrate LMS with adequate interface learning tools.”*

FGRP UNGRAD FIRST YR: *“The university to organize and offer data to students when they are off campus. Lecturers are able to implement the course/module software and LMSs efficiently.”*

FGRP UNGRAD FINAL YR: *“need to have workshops of some sort on how some course software or LMSs are used so that as students we are not left out.”*

It was established that there was minimal implementation of software and LMS and it affected the learning, as technology is evolving rapidly and lecturers and students may not be on par with the outside world. In the lessons that were observed, it was observed that there is a challenge regarding the number of computers, electricity outages, and poor WiFi connectivity. There is a skills challenge among the lecturers, technicians and students. Students are willing to learn more, but technical support from both the lecturers and technicians is minimal. Implementation of the course/module software and LMS is minimal, as both the students and lecturers have no skill in using some features.

5.18 Chapter summary

This chapter's goal was to analyse, present, and interpret data from interviews, focus-group interviews, and lesson observations. To increase trustworthiness, every effort was made to convey the research findings as factually as possible. Each study question addressed the core research question problem of determining how STEM technologies are implemented at the University of Technology. Relevant quotes from responders were obtained, with the goal of presenting a clear, disciplined, defensible, and scientifically sound argument. The chapter examined how STEM technologies are

implemented; challenges faced by students; students' perceptions; extent of STEM learning technologies implementation and their effect at a university of technology.

The chapter therefore authenticated some of the contributions from other scholars in the same fields of the study. It then surfaced that STEM learning technologies that are used in the 21st-century at the university are SPSS, Mathematica, Geogebra, MATLAB and AUTO CAD and the LMS used was Google Classroom. On STEM learning technologies implementation for 21st-century skills and their effects in Zimbabwe, lecturers and students mentioned the minimal implementation of technologies, which has massive effect on the university, as it tarnishes its image to the outside world. It also emerged that the skills challenges faced by students in the 21st-century were trial and error on the use of moodle LMS and manoeuvring on the course/module software, as the lecturers also had minimal skills. It was further established that students' perceptions regarding the use of STEM learning technologies are challenges of data, few shared computers and the use of pirated software, which was sometimes rejected by some of their laptops. The study also established that the extent of the implementation of technology by lecturers at a Zimbabwean university is minimal, as they have minimal skills and lack technical support.

There is a negative correlation between adequacy and reliability of course/module software and LMS technologies and implementation of these technologies from what emerged from the study. It was brought to the researcher's attention throughout the data analysis that there are various challenges lecturers, technicians and students face in the implementation of course/module software and LMSs. These have also been supported by the literature in Chapter 2. The main challenge that was established is inadequate technologies like the lack of computers, small internet bandwidth, and inconsistent power supply required for operation of the technologies. There was an issue of some lecturers lacking the appropriate skills in the integration of course/module software and the technician overloaded by the numbers of students and lecturers needing help at a given time. With these observations, the research now proceeds to the next chapter, which focuses on the discussion of the findings. The discussion seeks to put the findings in the mainstream of the body of knowledge on implementation of technologies in the institution to improve students' 21st-century skills.

CHAPTER 6: SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

After data collection, presentation and analysis, it is of paramount importance for the researcher to provide a summary of the findings, draw conclusions from the findings of the study and to make recommendations and suggestions for further research. This chapter gives an in-depth analysis of the results obtained by highlighting the gaps that exist in the implementation of STEM technologies (course/module software and learning management systems). Having analysed and presented the research findings in Chapter 5, the study hereunder discusses the findings, summarising, concluding and recommending with respect to the major research questions that were raised in Chapter 1. The main objective of this chapter was to bring the findings into the fold of the existing knowledge in what framework can be developed to enhance the implementation of STEM technologies to alleviate students' learning challenges at a university of technology.

6.1 Summary

The study aimed to design a framework for implementing STEM learning technologies to alleviate students' challenges in respect of 21st-century skills at a Zimbabwean university. The analysis was from the data collected from a sample of 9 lecturers, 3 technicians and 18 students in 4 focus groups. More males than females participated in the study for the STEM disciplines. All the lecturers and technicians hold minimum academic qualifications. Furthermore, all lecturers and technicians who responded have extensive teaching or laboratory experience of 5 years or more. Lecturers and technicians agreed that there is an institutional ICT/Technology policy, but it is not adequately enforced. The literature therefore indicates that ICT policies are vital in influencing universities' ICT/technology implementation (Koh et al. 2015:536; Njui 2018:112). Unwin (2005:123) and Wastiau et al. (2013:2) point out that the implementation of technologies is vital and must be prioritized in teaching and learning. Only two lecturers in the research have undergone staff development. No technicians have ever undergone staff development.

Pertaining to STEM learning technologies used in the 21st-century at universities of technology, the findings of the study indicate that lecturers use course/module

software like visual programming, SPSS, Mathematica, Geogebra, Matlab, Proteus and python. Technicians seemed lost when asked about the course/module software used by the lecturers and students in the teaching and learning. Students mentioned using course/module software like CAD, packages in maths, virtual laboratory simulations, Matlab and Proteus software. The lecturers and students stated the same LMS as Moodle being used in their teaching and learning. It emerged that little course/module software was implemented in the lessons. Most lecturers mentioned 21st-century skills as critical thinking, problem solving, creativity, collaboration, life skills, career skills and leadership skills. Of the three technicians who responded, only one regards 21st-century skills as collaboration, digital skills, critical thinking and problem solving.

Skills challenges faced by students in the 21st-century are creativity, problem solving and collaboration. The students went on to say that there was inadequate computers, as they have to share with peers, making it difficult for them, as well as power outages, internet challenges, inadequate course/module software, LMS tools or features not fully utilised. Time for practice is minimal. The students also mentioned that they lacked skills and knowledge on the implementation of the technologies. Lecturers themselves mentioned that there were inadequate devices, lack of practice, minimal knowledge, limited data, power outages, internet challenges, skills and knowledge to teach the students effectively and no staff development to boost their knowledge and skills. The technicians indicated lack of funding for the technologies to be used in the teaching and learning, as well as power outages and internet challenges. The findings point out that Zimbabwean universities only have intermittent electricity, resistance to change, computer shortages, insufficient internet bandwidth, with ICT/technology policies not being enforced and inadequate funds as challenges of LMS implementation in the teaching and learning (Mtebe & Raphael 2017:109-110; Dube 2018:305; Jegede et al. 2019:34-35; United Nations 2021:8-9; Kuteesa et al. 2021:26; Pondiwa et al. 2022:7; Snoussi 2019:666; Koprulu et al. 2022:73; Akah et al. Neji 2022:2; Chinamasa & Ncube 2023:90; Bolaji & Jimoh 2023:102-103; Nungu et al. 2023:17; Mohammad et al. 2023:228).

Students' perceptions regarding the use of STEM learning technologies indicated that most lecturers shared the same sentiments that students were interested in the implementation of LMS. Some lecturers mentioned that some students did not use the

LMS due to lack of technical skills to use it and they faced internet connectivity challenges. The lecturers went on to say that the students preferred to use WhatsApp which is a social networking site instead of Moodle. Students indicated that they used LMS, but faced data challenges so they preferred WhatsApp for their lessons. The students also indicated that the pirated course/module software was difficult to install onto their laptops as the software were not compatible with it. Time to master the course/module in the lessons was not enough. Students mentioned that use of course/module software and learning management systems in their teaching and learning motivated them and their academic performance also improved. The findings agree that the technologies improve student experience, can increase students' motivation and promote a positive attitude (Markova et al. 2017:686; Loughlin 2017:336; Akcayir & Akcayir 2018:334; Awidi & Paynter 2018:269; AlYakin et al. 2022:1054; Setyani & Susilowati 2022:504; Akinoso 2023:80). Another finding also mentions that technologies improve students' motivation, knowledge and skills, and academic performance (Lightner & Lightner-Laws 2016:225; Dziuban et al. 2018:3; Harris et al. 2021:71; Hew et al. 2020:4; Hu & Xie, 2019:29). Students mentioned that technical support from the lecturers and technicians is minimal and the lecturers had no skill or knowledge of the implementation of course/module software and LMS. During most lessons the technicians were absent and when they were present it was impossible for all students to be assisted. Some installations took a very long time to load onto the computer system.

The extent of STEM learning technologies implementation at the University of Technology by lecturers indicated that lecturers only referred students to the LMS to check the learning resources, and to view and submit assignments. Only two lessons indicated the use of the course/module software, although it was used for a very short time as the lecturers had no skill or knowledge on the implementation thereof. The students had to assist one another, in some cases through trial and error, on how to use the course/module software. The literature agrees with findings that at a Zimbabwean university it appears that setting up a conducive environment that promotes students' use of digital technologies in the learning process to have failed to (Dube & Scott 2018:306).

The implementation of STEM learning technologies for 21st-century skills and their effect at the university of technology are essential, as technology is revolving rapidly.

Students and lecturers gain 21st-century skills through the implementation of the course/module software and LMSs. This keeps the lecturers and students abreast with technology, thus making them acceptable to the industry and outside world. From the findings it transpires that students' preparation for the workforce needs a variety of skills including analysis, critical thinking, decision-making, and problem solving (Bagarukayo et al. 2016:130; Akbaba 2017:4; Chitate 2016:31; Erdogan & Ciftci 2017:1056; Gulhan & Sahin 2016:603). According to Harman (2023:1), students' chances of getting employed at a research unit and getting better career opportunities at globally recognized industries is minimal. Another finding indicated that STEM teaching and learning allowed students to gain more experience and their motivation escalates ,thus giving positive results (Triana et al. 2020:182; Suvarma et al. 2015:373).

6.2 Conclusion

The aim of this study was to design a framework for implementing STEM learning technologies to alleviate students' challenges regarding 21st-century skills at a Zimbabwean university. The conclusion of the study findings are based on the relationships that were established from the different objectives. From the forgoing summary of findings, it can be concluded that course/module software and learning management systems are not adequately implemented in the teaching and learning and there is need to vary them. The study established that both the lecturers and students faced a lack of 21st-century skill challenges, which yield the minimal implementation of the course/module software and learning management systems. The lecturers and students' technical support from the technicians was a disappointment, as either the technician was there to assist, but lacked knowledge and skills on how to use the software, or he was absent. The technicians were also overwhelmed with the number of students, as it was difficult to assist them on a one-on-one basis. Another finding was that in integration of LMSs and course/module software, students are motivated and their academic performance is improved.

The challenges faced were inadequate course/module software, which is either available, but not compatible with their computers/laptops, or not available at all, poor internet connectivity, power outages, and lack of knowledge and skills on how to use the software, inadequate computers/laptops. It was also established the that

implementation of course/module software and learning management systems was minimal because of the time allocated for the lessons. In most cases the lecturers referred lesson resources, assignments and further discussions to the learning management system, which had its own challenges. Technology is revolving rapidly and lecturers and students need to stay abreast with it so that they do not face challenges in the global work force. Africa is still far behind globally and something should be done (Lashayo & Johar 2018:76).

6.3 Recommendations

- a) The study recommends that the University of Technology under study incorporate budget on STEM learning technologies and purchase all relevant technologies. This will facilitate a sound teaching and learning for STEM preparing students for the 21st-century workplace.
- b) The study recommends staff development refresher courses, workshops or seminars for technician and lecturers on integration of various course/module software and LMSs. This will facilitate effective demonstrations to students in lessons.
- c) The study recommends the University of Technology under study to alert the lecturers to the 21st-century skills and their significance to students to eliminate skills challenges by students.
- d) Further research, therefore, can explore user perceptions across the levels of the university; that is, lecturers, technicians and the administrators, to better understand the effect of perceptions of all the stakeholder groups for institutional implementation. In addition, to understand the perceptions, a mixed-method approach with in-depth interviews can be helpful to investigate in several universities of technology.
- e) It is further recommended that the lecturers implement the STEM learning Technologies in their daily teaching and learning.

6.4 Suggestions for further study

The researcher urged to have another comparative study of universities of Technology in Zimbabwe so as to find out what is happening at other institutions in terms of

technology implementation and gain knowledge and skills. Also the researcher to study universities of technology in developed countries and in Africa at large.

CHAPTER 7: PROPOSED TECHNOLOGY FRAMEWORK

7.0 Introduction

Technology framework is one of the components that are very important to educational technology planning and implementation (Ogunode et al. 2021:138). It is therefore planned continuously so as to meet the revolving changes of technology in the outside world. The researches focuses mainly on what framework can be developed to enhance the implementation of STEM technologies to alleviate students' learning challenges at a university of technology. There are a number of factors that should be considered when implementing a framework for technologies. It is therefore important to consider the purpose of the technology and how it will be used. The framework is also designed to support the intended use of the technology and align it with the universities' overall goals, objectives and principles. The framework also takes into account the infrastructure and capabilities of the university. The technologies are implemented in a way that takes advantage of the existing infrastructure and makes the best use of the universities' available resources. Above all the framework considers the needs of the students, lecturers and technicians who are directly involved with the teaching and learning.

The technologies should be easy to use and meet the needs of the students, lecturers and the technicians. The technology should be easy to use, accessible and compatible with other systems. It is important to consider the needs of students, lecturers and technicians in order to ensure that the technology is implemented in a way that is effective and user friendly. Additionally the framework takes into account the level of technical expertise of the students, lecturers and technicians and ensures that the technology is not complicated or difficult to use. Finally the framework considers the universities' security needs and make sure that the technology is secure and protected from people that do not have rights to use it like students or any other person who are not enrolled in this university under study universities and system hackers.

7.1 Technology implementation framework

The proposed implementation framework is shown below in Figure 3.

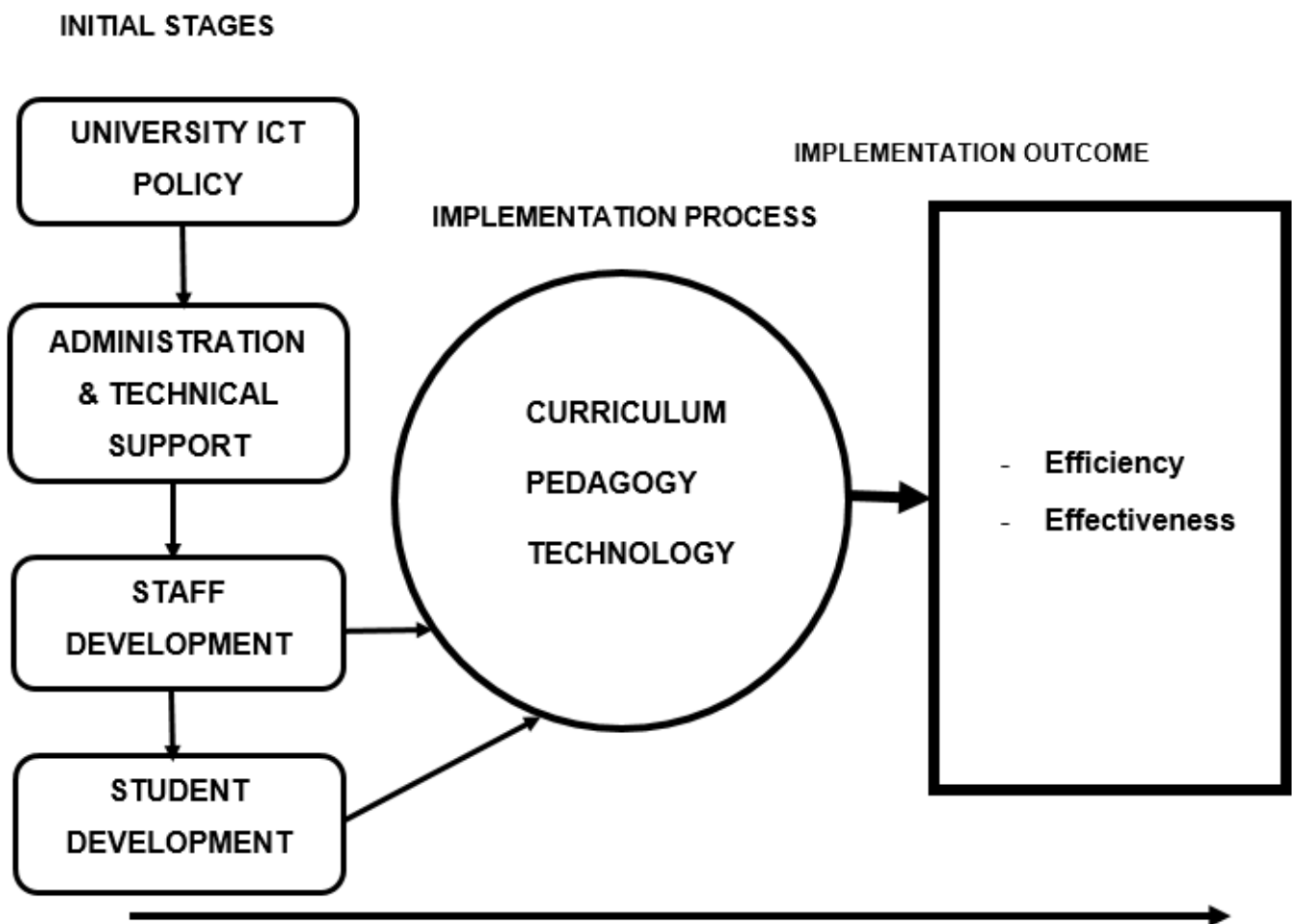


Figure 3: Technology implementation framework
(Designed by Doris Chasokela 2023)

7.1.1 Key elements of technology implementation framework

Utilizing technology in learning keeps students interested in what they are studying while allowing them to do it anywhere and wherever they want. Additionally, it gives students a head start on 21st-century abilities. There are several important components that go into implementing technologies in a university setting. The ICT/technology policy; administration and technical support; staff development, student development, implementation process and the implementation outcome are the proposed elements.

7.1.1.1 ICT/technology policy

A university ICT/technology policy should be in black and white so that everyone concerned has information about it. It should be enforced by the administrators and a follow-up is necessary to check for its implementation.

7.1.1.2 Administration and technical support

Support from an administrative perspective is referred to as technical and administrative support. Allocating responsibilities and authority for various educational levels and ensuring that lecturers and students in general receive the most technical support while implementing technology are both aspects of administrative planning and support in the field of education. Administration and technical support are also important factors that can impact the successful implementation of ICT at a university. On the administrative side, it's important to ensure that there is a clear chain of command, with designated staff members responsible for overseeing the project and communicating with other stakeholders. It's also important to have systems in place for tracking progress and resolving any issues that arise. On the technical side, it's important to have a team of experts who can provide support and troubleshooting for the new systems. This team should be able to respond quickly to any issues, and work with other departments to ensure that the systems are running smoothly. In accordance with the proficiency of various educational administrators in administrative educational planning and technology implementation, the administrative responsibilities and powers are planned phase-wise. The planning and implementation of technologies have made it possible to structure and organize higher education with such precision at various levels, including general, technical, and professional. According to Olatunde-Aiyedun and Ogunode (2021:145), this technological implementation and planning prepare for planning the length of an educational program, the planning and organization of educational programs, the budget or financial support for the program, the participation of educational authorities in the program, and the effective administration of the program. With the aid of technicians, administrators must conduct research, plan, budget, and generate funds to account for high internet bandwidth, a backup in case of power outages, and enough data. To keep lecturers and technicians up to date with the quickly evolving technologies, workshops and refresher short courses have to be planned. Programs for staff development can be created in conjunction with organizations or establishments that provide a range of options, or they can be especially created to satisfy the institution's requirements. This will provide

technological support for the entire university. A registration deadline for lecturers must be established, and the workshops or refresher courses must recognize outstanding lecturers and technicians.

The implementation process should also include careful consideration of the technology itself. The university should conduct a thorough needs assessment to determine which systems are needed, and how they can be integrated with the existing infrastructure. The implementation team should also consider the hardware and software requirements of the new systems, as well as any training that will be needed for staff and students to use them effectively. It's also important to consider issues such as data security, network capacity, and disaster recovery planning. By carefully considering the technology, universities can avoid costly and time-consuming mistakes during implementation.

Availability of infrastructure and technology resources include: STEM awareness; adequate computers, software, and laboratories and high internet bandwidth. Technology resources include computers, course/module software and Moodle LMS. The institution ought to purchase computers that can accommodate a sufficient number of students using them simultaneously. Students should have software loaded onto their computers and even personal laptops so they can still use it to edit data even when they are not in the labs at the institution. In order to keep up with the rest of the world, at the very least the institution needs to integrate a learning management system in its teaching and learning processes.

7.1.1.3 Staff development

Staff development is another important factor that can influence the success of ICT implementation at a university. The staff members who will be using the new systems should be provided with appropriate training and support to ensure that they are able to effectively use the technology. Training should be tailored to the needs of the individuals and groups involved, and should be ongoing to ensure that staff members are able to keep up with any changes or updates to the systems. Staff development should also include regular feedback sessions to identify any areas where additional support is needed. By investing in staff development, universities can ensure that their ICT lecturer/technician 21st-century skills are necessary so as to be able to support the students technically. Given how rapidly technology is developing, it is necessary

to provide training workshops and refresher courses to lecturers and technicians. Collaboration with other institutions or organizations may also close the knowledge and skills-exchange gap. It becomes simpler for the students to utilize trial and error and they tend to find more methods to do things if the lecturers have a basic understanding of how to use course/module software and LMSs. There is need for lecturers and students to be aware of the importance of implementation of technologies in the teaching and learning. Universities can have posters in faculty offices and also have workshops or seminars as awareness programmes when the students are first years. This can be done to exhibit the importance of the technologies as technology is changing rapidly and to indicate its importance globally.

7.1.1.4 Student development

Just as staff development is important for successful ICT implementation, so too is student development. Students are the end users of the new systems, and it's important to ensure that they are able to effectively use them. To do this, universities should provide students with training on how to use the new systems, as well as ongoing support to help them troubleshoot any issues they encounter. Students should also be given the opportunity to provide feedback on the systems, so that they can be further improved to meet their needs. In addition, universities should consider how the new systems can be integrated into the curriculum to enhance student learning. Students' development of basic computer literacy, course/module software, and Moodle use can be measured using a variety of methods. For basic computer literacy, one way to measure it is to conduct a pre- and post-survey to assess students' comfort and familiarity with using computers. For course/module software, students can be given a quiz or test to assess their ability to use the software. Finally, for Moodle use, lecturers can monitor students' activity on the platform and assess how they are using the features, such as discussion forums, quizzes, and chat. When students complete the first-year Level 1, information and communication technology courses or modules should always be included in the curriculum so that they can learn about and practise using computers. The fundamentals of the course/module software that will be used in teaching and learning must further be covered by lecturers. This will help the students to be well-prepared to manipulate the software and LMSs independently without much remote guidance.

7.1.1.5 Implementation process

Curriculum, pedagogy, and technologies are integrated in the teaching and learning by the students and lecturers. These process factors can impact the implementation outcomes, such as efficiency and effectiveness of the course/module software and the Moodle used for the lectures. Curriculum is another important factor to consider when implementing ICT in a university setting. The new systems should be designed to support the curriculum and the learning objectives of the institution, rather than dictating what is taught and how. This means carefully considering how the systems can be used to support existing courses, and how they can be integrated into the curriculum in a way that enhances the learning experience. The curriculum should also be adapted to take advantage of the new technology, such as by incorporating more interactive and collaborative learning activities. By considering the curriculum, universities can make the most of the ICT systems they are implementing. There are several steps that can be taken when implementing a curriculum. First, it is important to conduct a needs assessment to determine the specific needs of the school or district. Then, the appropriate curriculum should be selected based on these needs. Next, professional development should be provided to lecturers to ensure that they are able to effectively implement the new curriculum. Finally, the curriculum should be evaluated to determine its effectiveness and any necessary changes should be made. In general, the implementation process should be a collaborative effort between all stakeholders, including lecturers, administrators, and the community.

In the context of the pedagogy factor, the implementation process can be broken down into three main stages: preparation, delivery, and reflection. During the preparation stage, lecturers should be trained on the new pedagogical methods and materials, and they should have the opportunity to practice using them. During the delivery stage, lecturers should be supported as they begin to use the new pedagogical methods in their classrooms. Finally, during the reflection stage, lecturers should have the opportunity to discuss their experiences using the new methods and materials, and they should be given feedback on their performance. When implementing ICT in a university setting, it's important to consider how it will affect pedagogy, or the teaching methods used. The new systems should be designed to support and enhance the pedagogical approach of the university, rather than replacing it entirely. This means considering how the systems can be used to support active learning, collaboration, and other key pedagogical approaches. The implementation process should also

include opportunities for faculty to experiment with the new systems and develop new ways of using them in the classroom. By taking a pedagogical approach to ICT implementation, universities can ensure that the systems are used in the most effective way.

The implementation process for the technological factor should take into account the needs of both lecturers and students. The trained lecturers on how to use the new technology, and they should have the opportunity to practice using it in their classrooms. Secondly, students should be introduced to the technology and given the opportunity to become familiar with it. Thirdly, the technology should be integrated into the curriculum in a way that supports student learning. Finally, lecturers and students should have access to technical support if they encounter any problems while using the technology. The lecturers and students gain the 21st-century skills through communication, collaborations, creativity and critical thinking.

7.1.1.6 Implementation outcome

The implementation process factors can impact the implementation outcomes and output efficiency and effectiveness of the course/module software and Moodle used. Efficiency is splilt out on how well the course module software and Moodle LMS systems increases productivity and efficiency. Effectiveness of the course/module and Moodle LMS is how well the systems meets the needs of the lecturers and students. The outcome of the implementation process for any of the four factors - curriculum, pedagogy, technology, and professional development - can be measured using a variety of methods. One way to measure the outcome is to survey lecturers and students about their experiences using the new curriculum, pedagogical methods, technology, or professional development opportunities. Another way to measure the outcome is to analyze student achievement data before and after the implementation process. Finally, interviews with lecturers and students can also provide insight into the success of the implementation process.

The technology implementation process is an ongoing cycle. The initial stages of the process - needs assessment, selection, and planning. The cycle therefore should be repeated on a regular basis in order to ensure that the technology is still meeting the needs of lecturers and students. Additionally, the evaluation stage should be used to identify areas for improvement, which can then be addressed in future iterations of the

cycle. This cyclical process helps to ensure that the technology is constantly evolving to meet the ever-changing needs of the curriculum and pedagogy used at the university.

7.2 Operation of the proposed framework

Implementation of technology framework in Figure 3 indicate the university ICT policy that is spelt out in the goals. Then there are the administrators who offer the technical support assisted by the technicians who in turn scaffold the students and lecturers. The implementation of ICT at a university is likely to be affected by the ICT policy of the institution. This policy will outline the overall vision and goals for the use of technology, as well as the responsibilities and procedures for managing the implementation. The policy should cover funding like how the ICTs will be funded, and who will be responsible for ensuring that the funds are used effectively. Security is also considered on how will the security of the new systems be maintained, and who will be responsible for monitoring and enforcing security policies. Data management on how will the data generated by the new systems be managed is sort.

The administrators put in place a budget to cater for the ICT resources. Technology infrastructure should be in place like adequate computers, good internet connectivity, laboratories, back up for power cuts, adequate and relevant course/module software as per module requirements and an LMS to be used by the university. Administrators have a role to play on timing on the amount of time available for technology implementation in modules. When the infrastructure is in place, the technicians are supported by having workshops so that they get to know how the software functions in preparation of assisting the students and lecturers.

There are a number of staff development activities that can be undertaken to support the implementation of ICT at a university. These might include:

- Training: This can involve both technical training to ensure that staff are familiar with the new systems, and soft skills training to help staff adapt to the changes that the new technology brings.
- Mentoring: Pairing new users with experienced staff members can help to smooth the transition to the new system.
- Communication: Keeping staff informed about the progress of the implementation.

Lecturers are staff developed through workshops or seminars by technicians or invited MKOs outside the university. There is need for the lecturers to be imparted with skills and knowledge on how the course/module software and the moodle LMS functions. There is need to teach all degree beginners at first year the basic digital literacy as a module for easy navigation when using computers.

In turn, the students are also developed by holding workshops with them on how to use the course/module software and moodle LMS. The lecturers get to know what the students know at hand and scaffold those who need assistance. After the training, the students and lectures can be asked to give feedback to check their acceptance of the technologies. When user acceptance is satisfactory then the course/module software and the moodle LMS are implemented in teaching and learning. There is integration of the specific curriculum, pedagogy, and technology for each module according to its requirements.

After these initial stages, there is the implementation process where the lecturers give lectures to the students. The set curriculum and pedagogy are implemented with the correct technology. The curriculum is according to the programmes offered at that particular semester/stage/year of instruction. Course/module software and Moodle LMS are implemented for the offered programmes facilitating social interactions between students and their peers; students and lecturers; students and technicians; students and MKOs. During social interactions 21st-century skills are visible through communication, collaborations, critical thinking, and being creative. Through communication students exchange ideas with their peers, lecturers and MKOs. Students also collaborate in coming out with models, write articles with lecturers and MKOs. Students have to look at the objectives of a project or assignment think creatively drafting ideas on how to carry it out. As thinking is taking place then the students find ways of being creative on their models or circuits by inserting a variety of components or devices. During and after implementation the outcomes should prove the effectiveness and efficiency of the course/module software and Moodle LMS. The lecturers and students must be able to implement the course/module software and maneuver on the Moodle LMS with minimal assistance.

There is need to consult and find out perceptions of the lecturers, students and technicians on the implementation of the course/module and Moodle LMS on any

improvements to be done. This assists in the implementation effectiveness so that the teaching and learning is improved.

7.3 Chapter summary

Careful planning and implementation of educational technology are essential for the realization of the technology framework. Educational planning is the foundation of the educational system when implementing technologies. The successful implementation of new technology depends on careful planning. The technology planning and implementation framework, a running program, ensures that educational policies and programs are developed to keep up with the various changes occurring in the external educational system. The researcher makes the following recommendation in order to prepare for the future and to ensure that technology planning and execution continue even in the midst of technology planning: All educational planners and industrialists in the country should have access to ICT facilities in order to provide top-notch STEM education. Industrialists, MKO, and educational planners in the education sector should all receive training on how to use ICT tools for planning activities.

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APPENDICES

APPENDIX 1: PERMISSION LETTER: FROM CENTRAL UNIVERSITY OF TECHNOLOGY TO COLLECT DATA



FACULTY OF HUMANITIES

FACULTY RESEARCH AND INNOVATION
COMMITTEE (FRIC)

To: The Research Project Promoters
(Dr Masoabi C, Prof AH Makura)

OUTCOMES OF FRIC APPLICATIONS (REF: FRIC 19/02)

Dear Promoter

The application for the approval of research proposal (LS262a form) for student Chasokela D, was presented at the FRIC meeting, which was held on Wednesday, 06 March 2019, and was discussed as follows:

Chasokela D _Doctor of Education (Dr Masoabi, Prof AH Makura)

RESOLUTION: FRIC 07/19/02

Thesis Title:

A FRAMEWORK FOR IMPLEMENTING STEM LEARNING TECHNOLOGIES TO ALLEVIATE STUDENTS' CHALLENGES OF THE 21st CENTURY SKILLS IN UNIVERSITIES OF SOUTH AFRICA AND ZIMBABWE

The FHUM FRIC approved the LS262a for student Chasokela D. She can now collect data from the relevant institutions in Zimbabwe and South Africa.

Kind regards,

Signature:



Dr Modise, M A
Assistant Dean: Research, Innovation, & Engagement:
Faculty of Humanities
Chairperson of the FRIC

N.B: This letter is issued for ethical clearance purposes and it should only serve as evidence of the approval of the submission from the FHUM FRIC Committee.

APPENDIX 2: PERMISSION LETTER: TO THE Ministry of Higher and Tertiary Education, Science and Technology Development (MoHTESTD) TO COLLECT DATA

Central University of Technology

Faculty of Humanities

Bloemfontein, Free State

South Africa

The Permanent Secretary

Ministry of Higher and Tertiary Education, Science and Technology Development

P.O. Box

Causeway

Harare

Dear Sir,

REF: APPLICATION TO CARRY OUT RESEARCH ON, “Framework for implementing STEM learning technologies to alleviate students’ challenges of the 21st-century skills in a Zimbabwean university”

I, Doris Chasokela, is applying to be allowed to carry out research on the above reference. I am a PhD student at the Central University of Technology, Bloemfontein, Free State Province in South Africa and a lecturer at the National University of Science and Technology, Bulawayo Zimbabwe. The data collected will be used for the purpose of framework for the implementation of technologies to alleviate students’ challenges at 21st-century. I assure you that the data collected will be mainly used for this research and will be confidential. I also promise that the participants will remain anonymous.

Thank you


.....

Doris Chasokela

Mobile: +263774315106

Email: dchasokela@gmail.com/doris.chasokela@nust.ac.zw

APPENDIX 3: PERMISSION LETTER: TO CHINHOYI UNIVERSITY OF TECHNOLOGY

Central University of Technology

Faculty of Humanities

Bloemfontein, Free State

South Africa

The Vice Chancellor

Chinhoyi University of Technology

Dear Sir,

REF: APPLICATION TO CARRY OUT RESEARCH ON, “Framework for implementing STEM learning technologies to alleviate students’ challenges of the 21st-century skills in a Zimbabwean university”

I, Doris Chasokela, is applying to be allowed to carry out research on the above reference. I am a PhD student at the Central University of Technology, Bloemfontein, Free State Province in South Africa and a lecturer at the National University of Science and Technology, Bulawayo Zimbabwe. The data collected will be used for the purpose of framework for the implementation of technologies to alleviate students’ challenges at 21st-century. I assure you that the data collected will be mainly used for this research and will be confidential. I also promise that the participants will remain anonymous.

Thank you

.....DChasokela.....

Doris Chasokela

Mobile: +263774315106

Email: dchasokela@gmail.com/doris.chasokela@nust.ac.zw

APPENDIX 4: PERMISSION FROM THE Ministry of Higher and Tertiary Education, Science and Technology Development (MoHTESTD) TO COLLECT DATA

All official communications should be addressed to
"The Secretary"

Telephone: 795891-5, 796441-9, 730055-9
Fax: 792109
E-mail: eduniversity2011@gmail.com
Telegraphic Address "EDUCATION"



MINISTRY OF HIGHER AND
TERTIARY EDUCATION,
INNOVATION SCIENCE AND
TECHNOLOGY DEVELOPMENT
P.BAG CY 7732
Causeway
HARARE

REF: P/CHASOKELA D. (MRS)

STAFF CONFIDENTIAL

09 September 2021

Mrs. D. Chasokela
C/o Chinhoyi University of Technology

Dear Mrs. Chasokela,

REQUEST FOR AUTHORITY TO CARRY OUT RESEARCH AT THE CHINHOYI UNIVERSITY OF TECHNOLOGY: MRS. DORIS CHASOKELA: PHD STUDENT: CENTRAL UNIVERSITY OF TECHNOLOGY, BLOEMFONTEIN, FREE STATE, SOUTH AFRICA: MINISTRY OF HIGHER AND TERTIARY EDUCATION, INNOVATION, SCIENCE, AND TECHNOLOGY DEVELOPMENT

Reference is made to your application in which you requested for authority to carry out research at the Chinhoyi University of Technology.

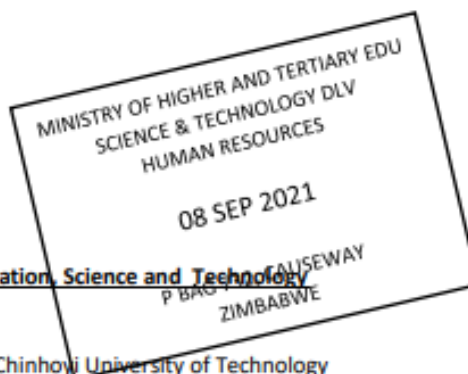
Please note that the Head of Ministry, has granted you authority to carry out your research entitled, 'A Framework for Implementing STEM learning Technologies to alleviate student's challenges of the 21st Century Skills at a University of Technology in Zimbabwe'.

Please be advised accordingly.

E. Yesaya (Mrs)

FOR: Secretary

Higher and Tertiary Education, Innovation, Science and Technology Development



C.c The Vice Chancellor - Chinhoyi University of Technology
File

APPENDIX 5: PERMISSION FROM CHINHOYI UNIVERSITY OF TECHNOLOGY TO COLLECT DATA



CHINHOYI UNIVERSITY OF TECHNOLOGY

☎: P. Bag 7724, Chinhoyi ☎: 263-67-22203-5 📠: 263-67- 27214 E-mail : vicechancellor@cut.ac.zw

Vice-Chancellor's Office: Prof. D. J. Simbi - PhD, BSc, MIM, CEng, FZ'welE, FICorr, FZAS, Hons FZ'wel

HUMAN RESOURCES DEPARTMENT

31 August 2022

Ms. Doris Chasokela
C/o National University of Technology
Cnr Gwanda Road and Cecil Avenue
P.O Box AC 939 Ascot
BULAWAYO

Dear Ms. Chasokela

RE: REQUEST TO CARRY OUT A RESEARCH PROJECT AT CHINHOYI UNIVERSITY OF TECHNOLOGY

We acknowledge receipt of your application letter seeking permission to undertake research study at Chinhoyi University of Technology for Research entitled: *"A framework for implementing STEM learning technologies to alleviate students' challenges of the 21st Century skills in*

Zimbabwe

You are kindly advised that permission to undertake your study is hereby granted. However, you are reminded to observe the University Official Secrecy Oath.

The University would also expect results of your research upon completion. *

Thank you


M.C. Makaza (Mr)
Deputy Registrar- Human Resources



APPENDIX 6: LETTER OF CONCENT FOR ALL PARTICIPANTS

I am Doris Chasokela, a PhD student at the Central University of Technology, Bloemfontein, Free State Province in South Africa. I am carrying out research on: **Framework for implementing STEM learning technologies to alleviate students' challenges of the 21st-century skills in Zimbabwe**

I am kindly requesting you to participate in the interviews and focus-group discussions of the study. I guarantee you that all the information you provide will be confidential and will be used for this study only. I also promise that you will remain anonymous.

Thank you



Doris Chasokela

Date:....13/02/2023...

Ihereby give my consent to participate in the above study.

.....

Date:.....

Respondent signature

APPENDIX 7: INTERVIEW SCHEDULE FOR LECTURERS

TOPIC: Framework for implementing STEM learning technologies to alleviate students' challenges of the 21st-century skills in Zimbabwe

1. What are your academic and professional qualifications?
2. What are your highest professional qualifications?
3. What is your teaching and laboratory experience?
4. Does the university have institutional ICT/Technology policy?
5. Does the university offer staff development on ICT/technology integration with rapidly evolving technology?
6. What are the STEM learning technologies (course/module software and LMSs) used in the 21st-century at the University?
7.
 - (a) What do you understand by 21st-century skills?
 - (b) Which 21st-century skills are you familiar with?
 - (c) Which 21st-century skills are important in STEM?
 - (d) Which skills are needed by STEM students for future workplace?
 - (e) Which 21st-century skills do students benefit when integrating course/module software and LMSs in the teaching and learning?
 - (f) What does a lecturer need to be excellent in 21st-century skills?
 - (g) Which skill challenges are faced by students in the 21st-century?
8. How do you rank and value the importance of 21st-century skills by students?
9. State any gender differences in the teaching of STEM.
10. Which framework is useful in determining skills and competences for excelling in teaching STEM programmes?
11. What are the challenges faced by the lecturers, technicians and students in the implementation of course/module software and LMSs?
12. What are the students' perceptions regarding the use of LMS integration in STEM learning technologies?
13. What are the beliefs, knowledge and attitude in the implementation of course/module software and LMSs in the teaching and learning of STEM?
14. Perceived usefulness of technologies to improve students' 21st-century skills
15. What are the perceptions, practices and comfort with teaching and learning STEM programmes?

16. Which gadgets/tools/software availability and extent of use in the teaching and learning of STEM programmes at the institution?
17. How are STEM learning technologies implemented for the 21st-century skills and their effects in the university of technology?
18. Does the university offer technical and financial support to lecturers and students?
19. How is STEM promoted to students?
20. a) Who is responsible office/personnel for the technical support?
b) Is the technical support adequate?
21.
 - a) What are the sources of funding for STEM programmes?
 - b) Are the ICTS/technologies with adequate funding?
 - c) How does the university sustain funding of ICTs/technologies?
 - d) What are the challenges in technical and financial support of ICTs/technologies faced in teaching and learning?
22. What are the possible solutions to the challenges faced in teaching STEM programmes?
23. Any other information shared in regard to the implementation of technologies in STEM learning to improve students' 21st-century skills in the institution?

APPENDIX 8: INTERVIEW SCHEDULE FOR TECHNICIANS

TOPIC: Framework for implementing STEM learning technologies to alleviate students' challenges of the 21st-century skills in Zimbabwe.

1. What is your academic and professional qualifications?
2. What is your highest professional qualifications?
3. What is your teaching and laboratory experience?
4. Does the university have ICT/Technology policy?
5. Which staff development have you been offered by the university on ICT/technology integration with rapidly evolving technology?
6. Which STEM learning technologies (course/module software and LMSs) are used in the 21st-century at the University?
7.
 - a) What do you understand by 21st-century skills?
 - b) Which 21st-century skills are you familiar with?
 - c) Which are the important 21st-century skills in STEM?
 - d) Which skills are needed by STEM students for future workplace?
 - e) Which 21st-century skills that students benefit when integrating course/module software and LMSs in the teaching and learning?
 - f) What does a lecturer need to possess to be excellent in terms of 21st-century skills?
 - g) What are the skill challenges faced by students in the 21st-century?
8. What challenges do lecturers, technicians and students in the implementation of course/module software and LMSs?
9. What are the perceived usefulness of technologies to improve students' 21st-century skills?
10. Which gadgets/tools/software are available and extent of use in the teaching and learning of STEM programmes at the university?
11. Which STEM learning technologies are implemented for the 21st-century skills and their effects in the university of technology?

12.

- a) How are the lecturers and students technical and financial supported?
- b) Who is/are responsible office/personnel for the technical support?
- c) How do you rate the adequacy of technical support?

13.

- a) What are the sources of funding for STEM programmes?
- b) Is funding adequate for ICTS/technologies?

14. What are the challenges in technical and financial support of ICTs/technologies faced in teaching and learning?

15. What are the possible solutions to the challenges faced in teaching STEM programmes?

16. Do you have any other information shared in regard to the implementation of technologies in STEM learning to improve students' 21st-century skills in the university

APPENDIX 9: FOCUS-GROUP DISCUSSION SCHEDULE FOR STUDENTS

TOPIC: Framework for implementing STEM learning technologies to alleviate students' challenges of the 21st-century skills in South Africa and Zimbabwe.

1. What are the STEM learning technologies (course/module software and LMSs) used in the 21st-century at the University?
2.
 - a) What do you understand by 21st-century skills?
 - b) Which 21st-century skills are you familiar with?
 - c) Which 21st-century skills are important in STEM?
 - d) Skills needed by STEM students for future workplace
 - e) 21st-century skills that students benefit when integrating course/module software and LMSs in the teaching and learning
 - f) What are the skill challenges faced by students in the 21st-century
 - g) How do you rate ranking and valuing the importance of 21st-century skills?
3. What are the gender differences in the teaching of STEM?
4. What challenges are faced by the lecturers, technicians and students in the implementation of course/module software and LMSs?
5. What are the students' perceptions regarding the use of LMS integration in STEM learning technologies?
6. What are the beliefs, knowledge and attitude in the implementation of course/module software and LMSs in the teaching and learning of STEM?
7. What are the perceived usefulness of technologies to improve students' 21st-century skills?
8. What are the perceptions, practices and comfort with teaching and learning STEM programmes?
9. Which gadgets/tools/software are available and extent of use in the teaching and learning of STEM programmes at the university?
10. How is STEM learning technologies implementation for the 21st-century skills and their effects in the university of technology?

11. How is STEM promoted to STEM to students?

12.

- a) Who is/are responsible office/personnel for the technical support?
- b) Is the technical support adequate?

13. Any other information shared in regard to the implementation of technologies in STEM learning to improve students' 21st-century skills in the institution

**APPENDIX 10: LESSON OBSERVATION SCHEDULE FOR (AVAILABILITY OF
STEM LEARNING COURSE/MODULE SOFTWARE AND LEARNING
MANAGEMENT SYSTEMS)**

**TOPIC: Framework for implementing STEM learning technologies to alleviate
students' challenges of the 21st-century skills at a Zimbabwean university**

OBSERVATIONS	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8
Availability of laboratory or classroom								
Availability and adequacy of Course/module software or LMSs								
Equipped Laboratory or classroom, arrangement of furniture and technological gadgets								
Internet connectivity broadband								
Availability of electricity								
Software or LMSs used								
Ratio of technological gadget/tools to student								
Lecturer competencies								

during lesson delivery								
Lecturing strategies used								
Lecturer to student interaction during lessons								
Lecture duration								
Number of students in the class								
Relevancy of technological gadget or tools used								
Possession of basic digital skills by students								
Possession of basic digital skills by lecturers								
Course/module software or LMSs implemented in the lesson								
Extent of Course/module software or LMSs implementation								
21 st -century skills observed from students								
Availability of technician								

Technical support from the technician								
Lecturers' knowledge and skills in the integration of software and LMSs								
Students' knowledge and skills in the integration of software and LMSs								
Lecturers' attitudes in the integration of Course/module software or LMSs								
Students' attitudes Course/module software or LMSs								
Challenges encountered by the students during the lesson								
Challenges encountered by the technician during the lesson								
Challenges encountered by the lecturer during the lesson								

APPENDIX 11: EDITOR'S LETTER

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24 September 2023

TO WHOM IT MAY CONCERN

Herewith I, **Cornelia Geldenhuys (ID 521114 0083 088)** declare that I am a qualified, accredited language practitioner and that I have edited the following doctoral thesis:

**FRAMEWORK FOR IMPLEMENTING STEM LEARNING TECHNOLOGIES
TO ALLEVIATE STUDENTS' CHALLENGES OF THE 21ST-CENTURY
SKILLS AT A ZIMBABWEAN UNIVERSITY**

BY

Doris Chasokela

STUDENT NO: 218011498

All changes were indicated by track changes and comments **for the author to verify, clarify aspects that are unclear, make the necessary adjustments and finalise.** The editor takes no responsibility in the instance of this not being done. The document remains the final responsibility of the author.



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C GELDENHUYS

MA (Lin) cum laude, MA (Mus), BA Hons (French), HED, HDL, UELM

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