

# Using digital technology in Design and Technology pedagogy to support the attainment of 21<sup>st</sup> century skills by senior secondary students in Botswana<sup>1</sup>

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## ABSTRACT

*Technology-based learning and the development of 21<sup>st</sup> century skills have the potential to transform the traditional teacher-centred approach into a more student-centred approach. Digital technology integration can be harnessed to foster effective learning and teaching. This study utilised the Technological Pedagogical Content Knowledge (TPACK) theoretical framework and explores the utilisation of digital technology in the learning and teaching of Design and Technology (D&T) in Botswana's senior secondary schools, with the aim of fostering the development of 21<sup>st</sup> century skills among students. The study adopted a case study that involves the collection of data from school heads, teachers and students through a survey. The findings indicate that 83.3% of school heads were somewhat satisfied with available digital technology resources in schools. The study reveals that 37.5% of the D&T students who perceive their teachers as possessing critical thinking skills are good at using digital technology resources during the lesson. This implies that it is imperative to recognise the importance of leveraging the pedagogical benefits of integrating digital technology to impart 21<sup>st</sup> century skills and competencies within Design and Technology teaching and learning contexts.*

**Keywords:** technology, pedagogy, 21<sup>st</sup> century skills, case study, design and technology

## INTRODUCTION

In today's digital era, proficiency with technology is essential for success in most fields. By incorporating digital technology into education, students can develop digital literacy skills through Technology Digital Literacy, which is crucial for navigating modern workplaces. Despite the advancement in technological innovations, the education sector has been slow in adopting technology to facilitate teaching and learning (Oke and Fernandes, 2020). However,

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the use of robots in education, particularly in teaching Science, Technology, Engineering, and Mathematics (STEM) subjects, has been around in countries such as Denmark and Estonia since the 1980s. Moreover, Kalyani (2024) explains that technology has emerged as a catalyst for innovation in education, enabling educators to adopt student-centric pedagogies that cater to diverse learning styles and abilities. In Education 5.0, dynamic technology surrounds the learner and provides options for the learner's core decisions of what, where, when, how, why and with whom to study (Melluso et al., 2020). Education 5.0 is a term used to describe the future of education, incorporating emerging technologies and innovative approaches to enhance learning experiences.

Indeed, integrating digital technology into education has become increasingly critical in preparing students, as well as the working population, to meet the demands of the 21<sup>st</sup> century workforce. Information and Communication Technology (ICT) is considered central to the development of 21<sup>st</sup> century skills. It serves both as a rationale for the necessity of these skills and as a tool to facilitate their acquisition and assessment. Moreover, the rapid evolution of ICT demands a fresh array of competencies pertaining to ICT and technological literacy. Overall, various frameworks concur in proposing that ICT offers the potential to facilitate the acquisition and evaluation of 21<sup>st</sup> century skills. Zain & Balakrishnan (2014) proposed the ASIE Model, which serves as an Integrated Instructional Design model that stands for Analyze, Strategize, Implement, and Evaluate. This integrated instructional design model functions as an alternative solution developed to the challenges for schools and institutions of higher learning in the 21<sup>st</sup> century learning environment (Zain et al., 2016). Since it has been developed in the midst of 21<sup>st</sup> century education, it meets the current educational trends and issues, such as flexibility, adaptability and effectiveness capabilities in almost every aspect of the instructional environment. According to Chukuwumeka (2020), the six-step instructional systems design model named ASSURE; (i) analyse learners, (ii) state objectives, (iii) select media and materials, (iv) utilise media and materials, (v) require learner participation and (vi) evaluate and revise, was developed by Smaldino et al. in 2008. The ASSURE model was designed to help teachers utilise technology and media in regular classrooms.

The SMAR model stands among modern technology integration models as one of the most frequently used today and was first developed by Peuntedura in 2006 (Hamilton et al, 2016). The model starts from the premise that technology modifies core educational activities to their core. The model proposed four possible levels of technology integration in the classroom: (i) Substitution, (ii) Augmentation, (iii) Modification and (iv) Redefinition. The programme intended to provide teachers with tools to integrate technology and media in their daily instructional practice. According to Puentedura (2013), *Substitution* occurs when either the teacher or the student uses technology to facilitate or access learning with no functional change. *Augmentation* extends teacher and student use of technology by offering a functional change afforded by the technology selected. *Modification* involves the use of technology, which allows for significant task redesign, and *Redefinition* involves a situation where technology is used to create new tasks. Furthermore, the remaining two stages educationists described as transformation levels where modification and redefining of learning activities is done using technology (Blundell et al, 2022).

Covid-19 made the case for ICT education more urgent than ever before. The emergence of digital technologies transformed the education sector, reshaping the traditional model of

teaching and learning (Singh et al., 2023). Technology could provide access to vast amounts of educational resources and information, regardless of geographical location. Educational tools such as educational applications, multimedia presentations, virtual reality, and simulations engage students in immersive and interactive learning experiences, making complex concepts more accessible and understandable. Integrating technology into education provides students with an engaging learning experience, allowing them to remain more interested in the subject without being distracted (Haleem, 2022). Technology facilitates collaboration and communication among students, teachers, and working professionals. The rapid advancement of technology in recent years has led to an increasing dependence on mobile devices for communication, entertainment and access to information (Teodorescu et al., 2023). Online platforms, video conferencing tools, and collaborative software enable seamless communication, collaboration, and knowledge sharing, regardless of physical location.

Bećirović (2023) posits that using modern technologies in teaching effectively requires support, motivation, relevant knowledge, skills, competencies, and access to necessary technologies. According to Demissie et al. (2022), teachers' digital competencies have gained prominence in enhancing quality education in the 21st Century. If they cannot access these technologies due to poor infrastructure or lack of finances, they cannot create smart environments. Many studies (Bai et al., 2019; Hoyles, 2018; Rana et al., 2018; Rana et al., 2019) have acknowledged that it is essential to learn about ICT and how it can effectively be used and how new digital technology can enhance teaching and learning if it is used appropriately. In fact, ICT is considered a new set of competencies on how to effectively use, manage, evaluate, and produce information across various media types (Spante et al., 2018). This requires humans to master technology well. ICT-related competencies could be summarised into three parts, namely information literacy, technology literacy and ICT literacy (Hifzan et al., 2021; Shahrul et al., 2021; Helme et al., 2021; Mardiana., 2024). Information literacy is the ability to identify, locate, evaluate, and effectively use information for problem-solving, decision-making, and learning. Technology literacy is the ability to understand, use, and manage technology tools efficiently and effectively in everyday life, education, and work environments. ICT literacy is the ability to effectively use digital technologies, including computers, communication tools, and networks, to access, manage, integrate, evaluate, create, and communicate information. This article focuses on ICT literacy, which is a critical component of the strategic integration of digital technologies within D&T pedagogy. The availability of affordable ICT tools in classrooms increases the standard of education through ubiquitous and flexible knowledge and skill attainment (Rajendran et al., 2023). In essence, technology not only facilitates the sharing of thoughts and diverse thinking but also empowers students to engage meaningfully with the complex issues shaping our world. By harnessing the transformative power of technology, students are better equipped to navigate the uncertainties of the 21st century and contribute to the advancement of knowledge, creativity, and prosperity in the global economy. In addition, the Internet allows the merging of formal and informal learning, giving rise to blended teaching and learning and new pedagogies such as flipped classrooms.

In this study, ICT literacy is explored through the lens of how digital tools such as Computer-Aided Design (CAD) software, 3D printing, virtual simulations, and collaborative online

platforms are integrated into D&T classrooms to enhance students' learning experiences. These technologies not only support subject-specific knowledge but also foster critical competencies such as critical thinking, creativity, collaboration, communication, and digital literacy. Given this potential, there is a clear need to integrate digital technologies into D&T pedagogy to enhance the development of these skills. D&T is one of the subjects offered as an option in the Botswana senior secondary school curriculum, and it has the potential to equip learners with 21<sup>st</sup> century skills. An optional subject in an academic curriculum is a field that students can choose to take, but it is not mandatory for completing a particular programme of study. The Botswana senior secondary curriculum is a two-year programme intended to instil learner skills to assist them in solving technical and technological problems related to day-to-day life situations. The Senior Secondary Education Programme (Curriculum Blueprint, 2002) shows that subjects are grouped into core and optional subjects. Setswana, English and Mathematics are core subjects and compulsory for all candidates. Setswana and English are used as the official languages in Botswana. English and Mathematics are prerequisites to entry into tertiary institutions upon completing senior secondary education. The optional subjects are further subdivided into four sub-categories: Sciences, Humanities & Social Science, Creative, Technical and Vocational, and Enrichment. D&T is, therefore, in the Creative, Technical and Vocational optional bracket.

In Botswana, efforts to integrate ICT in education exist at a policy level. According to Mogwe and Balotlegi (2020), Botswana Vision 2036 has been designed to accommodate the integration of ICTs into the education system. This is done to produce globally competitive human capital relevant to the era of ICT and beyond. Apart from Vision 2036, there are various policies and strategies, such as the Botswana Education and Training Strategic Sector Plan (ETSSP 2015–2020), National Development Plan 11 (NDP, 2017-2023), National Human Resource Development Strategy (NHRDS, 2009), and Maitlamo (2012) designed to tackle the integration of ICT in education. The Botswana Education and Training Strategic Sector Plan (ETSSP 2015–2020) outlines strategies and objectives related to the integration and utilisation of ICT in education to improve teaching and learning and education management. The overarching theme of NDP 11 was: Inclusive Growth for the Realisation of Sustainable Development Goals. NDP 11 ended in 2023, and its outcomes have shaped Botswana's transition towards a diversified, knowledge-driven economy. It laid the groundwork for addressing post-COVID-19 recovery and resilience strategies. The implementation of NHRDS forms a fundamental component for creating a working nation where citizens achieve high-skill-high-value occupational positions. Maitlamo (2012) refers to Botswana's National ICT Policy, which was launched to guide the country's ICT development and digital transformation. The primary aim of Maitlamo was to transform Botswana into a knowledge-based society and an information-driven economy through the effective use of ICT. The former Ministry of Education and Skills Development has commenced the delivery of the school digitalisation project. This project aligns directly with the National Reset Agenda priority number three – 'digitalisation' – and the Education and Training Sector Strategic Plan (ETSSP) priority ten (10), which is the utilisation and integration of ICT in education. The school digitalisation project aims to develop ICT-based teaching and learning in schools. Digitalisation focuses on schools' internet connectivity, the use of ICT as a platform for teaching and learning, the development of e-content, capacity building of teachers, the

provision of the individual learner and teacher ICT devices and the introduction of ICT-related subjects at the basic education level.

Thus, the objectives of this study were to assess the effectiveness of incorporating digital technology into teaching methodologies and explore the impact of digital technology on attaining 21<sup>st</sup> century skills.

The study addresses the following research questions:

1. To what extent do digital technology resources affect the development of 21<sup>st</sup> century skills among students in Botswana's senior secondary design and technology?
2. How does the integration of digital technology in Botswana's senior secondary design and technology curriculum impact students' acquisition of 21<sup>st</sup> century skills?

### IMPORTANCE OF 21<sup>ST</sup> CENTURY SKILLS

Numerous educational and economic organisations have acknowledged the collective demand for 21<sup>st</sup> century skills (World Economic Forum, 2016; Van Laar et al., 2017). For example, data science, artificial intelligence, machine learning, and deep learning are essential skills for future jobs. Nevertheless, it is argued that developing these skills can be challenging (Verma et al., 2022). In this regard, students must be equipped with 21<sup>st</sup> century skills such as data literacy, problem-solving, programming, and creative thinking for them to remain competitive (Lavi et al., 2021). In the workforce, employees with these skills are more likely to be valued by employers (Habets et al., 2020; Rios et al., 2020). According to Rapitsenyane et al. (2023), educational learning institutions should align their learning programmes to 21<sup>st</sup> century skills as outlined by the World Economic Forum.

Global competition combined with task automation has made innovative capacity and a creative spirit essential for achieving personal success and workplace achievement. With the proliferation of applications such as file-sharing platforms (e.g., Dropbox), version control systems (e.g., Git), remote desktop software (e.g., TeamViewer), and many other tools for online collaboration and communication, a researcher can work seamlessly with a large, globally spread team. One of the major recommendations unique to the 21<sup>st</sup> century is the need to prepare students for the digital age (Kennedy & Sundberg, 2020). 21<sup>st</sup> century skills are no longer optional, they are fundamental to success in education, work, and society. By integrating these competencies into education systems, particularly through subjects such as Design and Technology (D&T), learners can be better prepared for the future.

### THEORETICAL FRAMEWORK

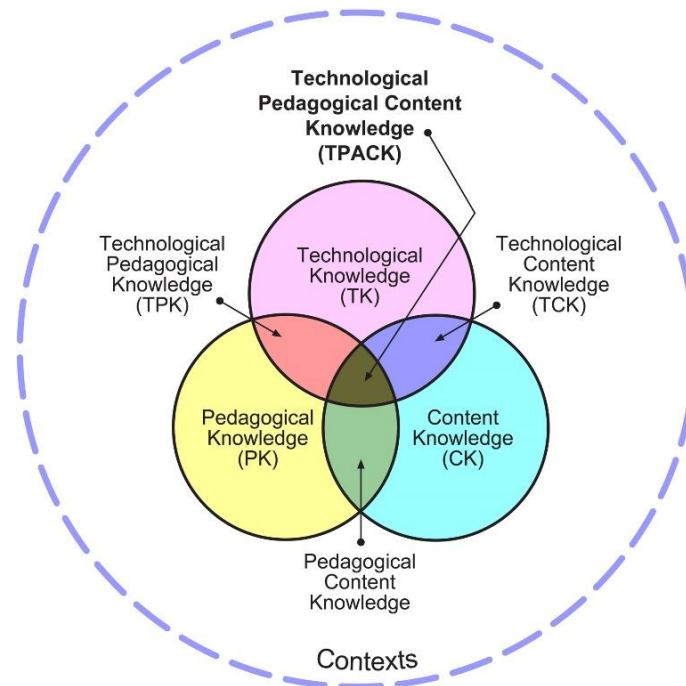
This study utilised the Technological Pedagogical Content Knowledge (TPACK) theoretical framework, as depicted in Figure 1. TPACK is a theoretical framework that emerges from the addition of technology knowledge (TK) to the concept of pedagogical content knowledge (PCK), which Shulman put forward in 1986 (Mishra & Koehler, 2006). TPACK emphasises three key components: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). Scholars such as Mishra and Koehler (2006) and Kurt (2018) argue that the TPACK framework provides a constructive approach to addressing the challenges teachers encounter when integrating educational technology (edtech) into their teaching

practices. Given that a technology-assisted method of teaching has a positive effect on student achievement, the technology integration knowledge of teachers who are practitioners of this method may have an important influence on academic achievement (Akturk & Ozturk, 2019).

Figure 1:

*TPACK Theoretical framework model*

(Source: image ©2012 by tpack.org)



The TPACK framework elucidates that effective integration hinges on the alignment and synergy between content (what is being taught) and pedagogy (how the teacher imparts that content). Content Knowledge (CK) comprises knowledge of the field's best practices and established methodologies for effectively conveying this information to students. CK provides educators with the foundational understanding necessary to teach a subject comprehensively and facilitate meaningful learning experiences for their students. For example, CK for teaching D&T subject in Botswana encompasses knowledge of various design processes, techniques, materials, and technologies used in designing and creating products or solutions to real-world problems.

Pedagogical Knowledge (PK) empowers educators with the skills and insights needed to create engaging and supportive learning environments, tailor teaching to meet diverse student needs and assess learning outcomes effectively. D&T pedagogical knowledge refers to the understanding of effective teaching strategies, teaching methods, and approaches specific to the field of D&T. The Design and Technology-Resistant Materials Syllabus (2020) is delivered using different teaching and learning strategies that will inculcate in learners the environmental, social and economic implications of various technologies. Furthermore, for learners to achieve learning outcomes, learner-centred approaches are highly recommended to cater to each learner, including those with special educational needs (Design and Technology-Resistant Materials syllabus, 2020). The learner-centred approach has been built



into the syllabus to keep learners abreast with changing technologies as well as making learners become better users and creators of technology. Some of the instructional methods of D&T include differentiated learning, project-based learning, expeditionary learning, and provide anytime, anywhere and on-demand support.

Technological Knowledge (TK) enables educators to integrate technology into their teaching practices effectively, select appropriate digital tools to support learning objectives and leverage technology to enhance student engagement and achievement. Design and Technology educators with TK possess the technical skills and expertise necessary to integrate technology effectively into their teaching practices and support student learning.

Educators with Technological Content Knowledge (TCK) expertise can strategically integrate technology into their teaching practices to enhance their students' learning experiences and facilitate a deeper understanding of the content being taught.

Technological Pedagogical Knowledge (TPK) empowers educators to incorporate technology thoughtfully into their teaching strategies. By aligning technology with pedagogy, educators can create engaging and interactive learning experiences that enhance student understanding and promote meaningful learning outcomes.

Technology Pedagogical Content Knowledge (TPACK) enables educators to seamlessly blend their understanding of subject matter, pedagogical practices, and technology tools to create engaging and impactful learning experiences for their students. Through TPACK, educators can harness the potential of technology to enhance teaching and learning, promote a deeper understanding of content, and foster critical thinking and problem-solving skills in students. Overall, Design and Technology TPACK empowers educators to effectively integrate technology into their teaching practices, enhance student learning experiences, and prepare students for success in their future careers.

### **Digital technology resource availability and integration in education**

The ICT is an umbrella concept that includes any communication device or application, encompassing radio, television, cellular phones, computers, network hardware and software, satellite systems, and so on, as well as the various services and applications associated with them, such as video conferencing and distance learning. ICT consists of the internet, Wi-Fi, and other mediums of communication, consisting of audio-visible structures and middleware that allow users to connect, store, transfer, and manage data (Talukder et al., 2015). When technology is effectively integrated into the curriculum through the TPACK framework, technology tools can extend learning in powerful ways. TPACK emphasises the intersection of TK, PK and CK to ensure meaningful and effective digital integration.

Some essential 21<sup>st</sup> century skills include critical thinking, creativity, communication, collaboration, adaptability, problem-solving, global awareness, social responsibility, digital literacy, and cultural awareness (Hidayatullah et al., 2020). This study examines the following skills: critical thinking, creativity, collaboration, communication and digital technology. Incorporating digital technology into D&T education within the TPACK framework may enhance students' ability to interact with subject content (CK) through well-structured teaching methods (PK) supported by appropriate digital tools (TK). This integration enables students to develop communication skills in both digital and traditional contexts while ensuring that digital

tools align with pedagogical strategies and content requirements. Digital technology allows greater interactivity in learning, increased possibilities for collaboration, and improved communication between teachers and students, facilitating deeper engagement and better knowledge retention (Mora et al., 2018). By leveraging TPACK, educators can make informed decisions about selecting and integrating ICT tools that align with learning objectives, ensuring that technology enhances rather than merely supplements traditional teaching methods.

Digital technology helps students focus on higher-level concepts rather than less meaningful tasks (Sharma and Singh, 2023). Through digital technology platforms, students can share ideas, provide feedback, and work together on design projects, fostering teamwork and interpersonal communication skills. According to Molinillo et al. (2018), Collaborative Learning and skill development can be enhanced through digital technology, such as online forums, blogs, and other web-based tools. Digital technology also stimulates innovation, and creativity enables individualisation and flexibilisation of education and makes knowledge acquisition more accessible (Lei et al., 2007; Meroni et al., 2015).

In today's rapidly evolving technological landscape, adaptability and digital literacy are essential skills. By incorporating digital technology into D&T education, students become familiar with various digital tools and platforms, preparing them to navigate and adapt to new technologies in their future careers. Digital technology tools such as Computer-Aided Design (CAD) software and graphic design applications empower students to create precise and visually appealing representations of their design ideas. Digital technology tools can unleash students' creativity by providing them with the means to explore and express their ideas in innovative ways. For example, multimedia software (Photoshop) enables students to create digital presentations, animations, and videos to showcase their design concepts creatively. Chatwattana and Wanglang (2023) argues that digital technology enhances blended learning, gamification, and project-based learning, so it is relevant in new pedagogies and develops relevant 21<sup>st</sup> century skills, such as digital literacy.

### **Impact of digital technology in teaching and learning D&T**

The role of digital technology is widely acknowledged, and its impact has fundamentally transformed practices and procedures across various domains, including education, business, governance, and personal life. Das (2019) argues that quality education depends on the development of information technology in several ways, such as enlarging the motivation of learners, enriching essential skills, and increasing teacher training in technology. Digital technology standards keep learning more accessible for students (Parveen and Ramzan, 2024). D&T involves the development of complex skills, such as problem-solving, critical thinking, design thinking, and hands-on craftsmanship. When these skills are supported by digital tools that align with pedagogical goals, students benefit from guided, scaffolded learning experiences that promote skill acquisition and retention. For example, computer-assisted instruction (CAI) programmes, used in simulation or tutorial modes, can supplement rather than replace traditional instruction, enhancing student learning (Timotheou et al., 2023). Within the TPACK framework, such technologies are not merely added to the curriculum but are strategically integrated to align with instructional objectives and pedagogical strategies. The use of ICT within TPACK also results in positive student outcomes,

including increased attention, engagement, motivation, communication, teamwork, and improved attitudes toward learning.

Moreover, effective ICT integration supports the development of computer-based competencies, which enhance students' organisational behaviours in practical fields. TPACK ensures that digital tools are selected and implemented not for their novelty but for their pedagogical efficacy, reinforcing constructivist learning environments where students actively seek, construct, and represent knowledge using digital platforms (Falck et al., 2018). Beyond its impact on students' academic performance, TPACK-driven ICT integration influences several school-related aspects, such as equity, social integration, teaching practices, and stakeholder engagement. By leveraging digital technology within the TPACK framework, educators can personalise instruction, track student progress more effectively, and promote learner autonomy while maintaining pedagogical coherence (Alderete et al., 2017; Humbhi and Tareen, 2021). Teachers use digital tools not only to enhance course content but also to create engaging, interactive lessons that align with both content and pedagogy (Comi et al., 2017). Countries such as Sweden, Italy and Germany have reported significant ICT adoption in education in recent years, driven by strategic, pedagogically informed integration rather than mere technological advancement (Comi et al., 2017; Falck et al., 2018). This demonstrates that when TPACK principles guide ICT adoption, students achieve higher educational outcomes, and institutions experience long-term cost savings in education (De Witte & Rogge, 2014).

### **Challenges of using digital technology in teaching and learning**

Hurdles to effectively integrating digital technology into students' education include inadequate investment in ICT infrastructure, insufficient professional development for teaching and non-teaching staff, teachers' reluctance to embrace digital technology, inconsistent power supply, and minimal administrative support for optimal utilisation of digital technology resources (Johnson, 2021). When educators lack professional development in technological pedagogical strategies, they may struggle to integrate ICT effectively into their instructional practices, reinforcing reluctance toward digital adoption. Additionally, concerns regarding student distractions (Spiezia, 2010; De Witte & Rogge, 2014) and the potential undermining of discipline and work ethic (Falck et al., 2018) underscore the importance of aligning technology use with pedagogical goals to maintain engagement and learning focus. Through TPACK-aligned instructional design, educators can mitigate these risks by employing structured digital tools that support learning without compromising student discipline or attentiveness.

The Fourth Industrial Revolution (4IR) and 21<sup>st</sup> century skills necessitate pedagogical adaptations that align with technological advancements. 4IR integrates physical, digital, and biological systems, reshaping work, education, and social interactions (Jiang et al., 2017). The TPACK framework plays a crucial role in ensuring that teachers can effectively teach 21<sup>st</sup> century competencies such as critical thinking, creativity, and emotional intelligence by leveraging digital tools that enhance these skills rather than replacing them. However, infrastructural challenges such as limited access to high-speed internet, digital technology disparities between urban and rural areas, and inadequate broadband penetration hinder the widespread adoption of 4IR technologies in education. Botswana's insufficient digital

infrastructure is a major obstacle to equitable ICT access, particularly in marginalised rural communities. The After-Access ICT survey by Research ICT Africa (2020) found that only 9% of Botswana use the internet, with urban residents being the primary beneficiaries of digital connectivity. Among the few households with internet access, mobile 3G (44.4%) remains the most widely used connection type, followed by ISDN dial-up (23.5%), wireless broadband (17.3%), and ADSL (6.2%).

To bridge this digital divide, education systems must adopt TPACK-informed strategies that effectively use the available digital tools while developing pedagogical models that work within infrastructure limitations. Offline digital resources, mobile-compatible learning platforms, and blended learning approaches can ensure that students in underprivileged areas still benefit from technology-enhanced education. By aligning technological investments with pedagogical and content objectives, TPACK provides a roadmap for ensuring that digital technology adoption in education is both impactful and sustainable, fostering inclusive access to 21<sup>st</sup> century learning opportunities despite infrastructural constraints.

## RESEARCH METHODOLOGY

This study employed quantitative method to investigate the research problem. According to Rana et al. (2021), the quantitative method is used to summarise, average, find patterns, make predictions, and test causal associations as well as generalising results to wider populations. In this study, counts, percentages and correlations were used to analyse data. The study adopted a case study approach because it provides a contextual understanding of issues or phenomena and enables researchers to gain practical insights and lessons learned from real-world experiences. According to Gustafsson (2017), a case study is described as an intensive, systematic investigation of a single individual, group, community, or other units in which the researcher examines in-depth data relating to several variables.

A total of 412 senior secondary D&T students, 31 teachers, and 15 school heads were selected to participate in the study using simple random sampling. The primary aim of sampling was to obtain a representative sample composed of small units or instances drawn from a much larger group or population. The simple random sampling method took care of bias through the random selection of participants, meaning that every individual stood a chance to be selected to take part in the study.

Questionnaires were used for data collection. Questionnaires were developed from the study objectives, which assessed the effectiveness of digital technology incorporation into teaching methodologies and explored the impact of digital technology to assist in attaining 21<sup>st</sup> century skills. Taherdoost (2022) defines a questionnaire as an important instrument in a research study to help the researcher collect relevant data regarding the research topic. Krosnick (2018) argues that a questionnaire can ensure a faster and more accurate data collection process and facilitate data processing as well.

The questionnaires underwent pilot testing to ensure content validity at two senior secondary schools. Both the students' and teachers' questionnaires were the same and had 84 items while the school head questionnaire had 18 items. A reliability test was conducted on the items, yielding a Cronbach Alpha Index of .986, implying the instrument would yield the same result if applied on a different occasion. According to Johnson (2021), Cronbach's alpha was developed by Lee Cronbach in 1951 to measure reliability and determine the internal

consistency or average correlation of items in a survey instrument to gauge its reliability. Sutton (2021) posits that scales with alpha levels equal to or above  $\alpha = .70$  are acceptable. The best scales have values of  $\alpha = .9$  or higher.

### Instrument

The quantitative data collection tool utilised in this study was a Likert scale questionnaire for students and teachers. According to Moser and Kalton (2017), Likert scales are widely used in survey research to measure attitudes, opinions, and perceptions across various domains. These scales offer a structured approach to gathering quantitative data by presenting respondents with a range of options, typically ranging from strongly disagree to strongly agree or, as in this study, from basic to proficient skills.

- Basic (1): I do not know the existence of the skill, and I do not possess it.
- Aware (2): I know the existence of the skill, but I do not possess it. I am inclined to apply myself to improve.
- Practised (3): I know this skill exists and have the basic knowledge, sometimes needing an external supervisor. I work hard to improve myself.
- Competent (4): I possess this skill, and I master it almost automatically. In an innovation-oriented way, I can manage complex and unforeseen activities, even in contexts other than every day.
- Proficient (5): I possess this skill, and I master it automatically. In an innovation-oriented way, I can manage complex and unforeseen activities, even in contexts other than every day, and teach them to my colleagues.

The school head questionnaire used a Likert scale of 5 = Very satisfied, 4 = Somewhat satisfied, 3 = Neither satisfied nor dissatisfied, 2 = Somewhat dissatisfied, and 1 = Very dissatisfied.

The following section describes the variables descriptions of D&T pedagogy from student and teacher questionnaires:

- Critical thinking skills: Students can freely create solutions to problems their way, be given a chance to troubleshoot problems, promote the generation of innovative solutions, entertain possibilities other students may miss and prompt interest and curiosity.
- Creativity skills: using and applying various ideas and methods in the learning process so that classroom learning is not monotonous, stimulating student motivation in learning, and demonstrating practical skills by connecting things to the realities of daily life.
- Collaboration skills: These involve occasionally engaging students in society projects, allowing students to form groups in some activities and submit their work as groups, and asking students to do assignments in groups so that they can discuss the content amongst themselves.

- Communication skills: The ability to teach from simple to abstract activities, process and interpret both verbal and non-verbal information from others, negotiate positive outcomes with others through negotiation and instructing, convey information in the classroom to be easily understood by students and use relevant instructions.
- Digital technology skills: Effective usage of digital technology/the Internet, online applications such as Yahoo, Google, etc., during learning and teaching D&T; setting up a meeting using Google, Microsoft Teams or WhatsApp for virtual meetings; usage of software applications such as Microsoft Office during the D&T teaching and learning process; applying Computer-Aided Design/Computer-Aided Manufacture (CAD/CAM) computer software and graphic design software when teaching.

The school head questionnaire comprised of the following themes: professional development, enrolling in online programmes, staff situation in schools, allocating reasonable D&T budget, available digital technology resources in schools, and use of available digital technology resources in schools.

### Data analysis

Variables were computed using Statistical Package for the Social Sciences (SPSS) Statistics 25.0 based on items from the questionnaires completed by D&T students, teachers, and school heads. Descriptive analysis was conducted to determine variable means, percentages, frequencies, and standard deviations. Inferential statistics were used to determine associations between variables.

## RESULTS

### Demographics

A total of 15 senior secondary schools were selected to participate in the study. Table 1 reflects the demographic data of the study's participants.

*Table 1:  
Demographic data of participants*

Students	Teachers	School heads
<b>Target 485</b> <b>412 students (346 form 4s, 66 form 5s)</b> <b>350 males</b> <b>60 females</b> <b>Response rate 84.95%</b>	31 teachers (8 regions) 21 males, two females 28 Degree holders Three Master's holders <i>77.5% response rate</i>	Target: 15 13 school heads responded. <i>86.7% Response rate</i>

As reflected in Figure 1, 412 D&T students, 31 teachers, and 15 school heads who took part in the study.

## THE EXTENT TO WHICH DIGITAL TECHNOLOGY RESOURCES AFFECT THE DEVELOPMENT OF 21<sup>ST</sup> CENTURY SKILLS AMONG STUDENTS

### Research question 1

*To what extent do digital technology resources affect the development of 21<sup>st</sup> century skills among students in Botswana's senior secondary design and technology?*

To answer this research question, the following variables were computed and analysed: available digital technology resources in schools, use of available digital technology resources in schools and effective facilitation of a lesson by a D&T teacher using digital technology. The following were the findings.

#### **Available digital technology resources in schools**

This variable is about available digital technology in the school. To determine the availability of digital technology, school heads were asked to indicate their level of satisfaction with the availability of each of the following: computers/laptops for D&T students and teachers, e-content for D&T and internet availability. A Likert scale of 5 = Very satisfied, 4 = Somewhat satisfied, 3 = Neither satisfied nor dissatisfied, 2 = Somewhat dissatisfied, and 1 = Very dissatisfied was used. The researcher then used SPSS to compute a variable named (available digital technology resources in schools). Analysis of the results for this variable reflects that 83.3% of school heads were somewhat satisfied with available digital technology resources in schools. In comparison, 16.7% of the school heads were somewhat dissatisfied with the available digital technology resources in their schools. Most of the school heads (84.8%) were satisfied with computers/laptops for D&T students. A substantial percentage (58.4%) of School heads were dissatisfied with e-content for D&T.

#### **Use of computers/laptops by D&T teachers during a lesson**

Students (28.4%) perceived the level of skill in the use of computers by D&T teachers during a lesson as proficient, while 14.5% of students perceived the teacher's skill in the use of computers as competent. A substantial 25.8% and 14.8% found the teacher's skill in the use of computers to be basic and aware, respectively. This is an alarming percentage to note that students perceive the level of skill of teachers in the use of computers to be at a basic and awareness level, primarily when the world revolves around technology. There is a need for appropriate measures to increase teacher's level of knowledge in the use of technology.

#### **Effective facilitation of a lesson by a D&T teacher using digital technology**

This variable is about digital technology applications or demonstrations during a D&T lesson, such as the usage of software applications, Photoshop, Computer-Aided Design/Computer Aided Manufacture (CAD/CAM), Microsoft Office, search engines, WhatsApp, and virtual lessons. The findings indicate that 54.6% of students found effective facilitation of a D&T lesson using digital technology. Most of the students (67.1%) indicated that teachers could connect to the internet, and (51.9%) indicated that the application of CAD/CAM software is hardly used to facilitate a D&T lesson. CAD/CAM is covered under the fundamentals of design. The emphasis of this module is on understanding and applying design elements and principles to present and interpret ideas through sketching and modelling. Upon completion of this

module, learners can explore and apply computer-aided design (CAD) to generate design ideas.

### Effective facilitation of a D&T lesson using available digital technology resources in school

Table 2 reflects that the results of a test on the association between the effective facilitation of D&T lessons using available digital technology resources and the use of computer/laptop variables using Chi-square.

*Table 2:*

*Effective facilitation of a lesson using digital technology and the use of computers/laptops*

	Value	df	Significance (2-sided)
Pearson Chi-Square	108.212	16	.000
Likelihood Ratio	108.170	16	.000
Linear-by-Linear Association	88.511	1	.000
N of Valid Cases	316		

Table 2 demonstrates that there is a statistically significant association between the use of computers/laptops and effective facilitation of a lesson by D&T teachers using digital technology: Pearson Chi-Square is  $\chi^2(16) = 108.212, p = .000$ . A Chi-Square Test is a statistical test used to determine if there is a significant association between categorical variables (Beukelman and Brunner, 2016). According to Kirana and Suranti (2022), if the significance value (p value) was .000, which was a number that was lower than 0.05, then there is a statistical significance. That is, there is evidence that D&T teachers are more likely to use computers and laptops based on their knowledge of digital technology.

### Student perceptions of teacher's digital technology skills level and their use of computers/laptops

Further analysis using Custom tables highlights the connection between the teacher's technology skill level and students' perceptions of their use of computers/laptops. Table 3 summarises the underlying data on which the Pearson Chi-Square test in Table 2 was done. The results show that 66.7% of students perceived D&T teachers' skill level on the use of computers/laptops as basic, and 38.2% also reported the teacher's digital technology level as basic.

Table 3:

*Student perceptions of teacher's digital technology skills level and use of computers/laptops*

		Effective facilitation of D&T lessons using digital technology					
		Basic	Aware	Practised	Competent	Proficient	Total
Laptops or Computers	Basic	34	34	18	3	0	89
	Aware	8	20	16	4	0	48
	Practised	4	16	27	4	0	51
	Competent	3	12	25	10	1	51
	Proficient	2	11	32	29	3	77
	<b>Total</b>	<b>51</b>	<b>93</b>	<b>118</b>	<b>50</b>	<b>4</b>	<b>316</b>

It can also be noted that D&T students (27.1%) perceived the teacher's level of skill in using computers/laptops as proficient, and 15.3% of students have indicated the teacher's digital technology skill level as practised. It can be concluded that where the level of skill in using computers/laptops was basic, the level of skill in digital technology also tends to be basic.

#### Student perceptions on teacher's digital technology skills level and D&T student performance

The D&T students were asked to rate the demonstration of the teacher's level of digital technology skills and asked to indicate the last D&T test score that they attained the previous month. To establish an association between the teacher's digital technology skills level and D&T student performance variables, chi-square tests were conducted. Table 4 illustrates the results of the test.

Table 4:

*Impact of teacher's digital technology skills level on D&T student performance*

	Value	df	Significance (2-sided)
Pearson Chi-Square	9.800 <sup>a</sup>	8	.279
Likelihood Ratio	10.542	8	.229
Linear-by-Linear Association	.464	1	.496
N of Valid Cases	273		

Table 4 shows that the result of the 'Pearson Chi-Square' is  $\chi^2(8) = 9.800, p = .279$ . This means that there is no statistically significant association between the effective use of available resources and D&T student performance. There is insufficient evidence for an association between the variables. In other words, the data does not provide vital support or strong support, meaning evidence is not enough to conclude that there is a significant effect or difference.

Table 5 provides a summary of the underlying data for the test in Table 4. Students who rated their teachers' digital technology skills level as fair achieved the highest D&T mean score

(59%), followed by those who perceived their teachers' skills as good, with a mean score of 58%.

Table 5:

*Impact of teacher's digital technology skills level D&T student performance*

		Test score
		Mean (%)
Effective facilitation of D&T teachers using digital technology resources	Unsatisfactory	55
	Fair	59
	Good	58
	Very Good	55
	Excellent	52
	Total	57

Students who perceived their teachers' digital technology skills level to be excellent had achieved a low D&T mean score (52%).

## THE INTEGRATION OF DIGITAL TECHNOLOGY IN DESIGN AND TECHNOLOGY CURRICULUM AND ITS IMPACT ON STUDENTS' ACQUISITION OF 21<sup>ST</sup> CENTURY SKILLS

### Research question 2

*How does the integration of digital technology in Botswana's senior secondary design and technology curriculum impact students' acquisition of 21<sup>st</sup> century skills?*

To answer this research question, the students were asked to rate the demonstration of the teacher's digital technology skill level and to rate the level of skill of the teacher to demonstrate the specified 21<sup>st</sup> century skills. Critical thinking, creativity, collaboration and communication skills were computed using SPSS. The following were the findings:

### Facilitation of available digital technology to assist in attaining 21<sup>st</sup> century skills

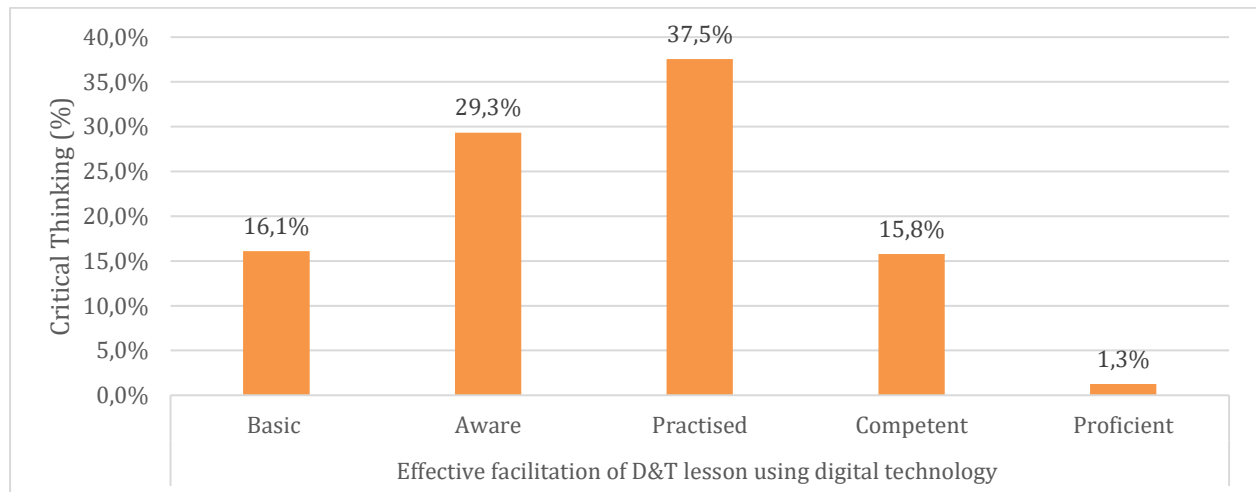
The integration of digital technology in D&T education can provide students with rich learning experiences that promote the development of 21<sup>st</sup> century skills. This section provides insights into how the teacher's effective facilitation of D&T lessons with available digital technology is associated with assisting students in attaining 21<sup>st</sup> century skills.

#### (a) Critical thinking skills

This variable was computed from the following items: students can freely create solutions to problems their way, be given a chance to troubleshoot problems, promote the generation of innovative solutions, entertain possibilities other students may miss and prompt interest and curiosity. Students were asked to rate the teachers' level of skill on these items based on these options: basic, aware, practised, competent and proficient. The researcher computed the items to form variable: critical thinking skills. To determine the use of digital technology on D&T pedagogy to support the attainment of critical thinking skills, the use of Custom Tables in SPSS was applied. The students perceived that 37.5% of the D&T teachers with practised level of skill on digital technology demonstrated critical thinking skills, as reflected in Figure 3. Furthermore, the students perceived that 15.8% of D&T teachers who possessed competent

digital technology skills demonstrated critical thinking skills. The results imply that most of the students (54.6%) perceived that the level of the teachers' digital technology skill influences demonstration of critical thinking skills.

*Figure 2:  
Using digital technology to attain critical thinking*

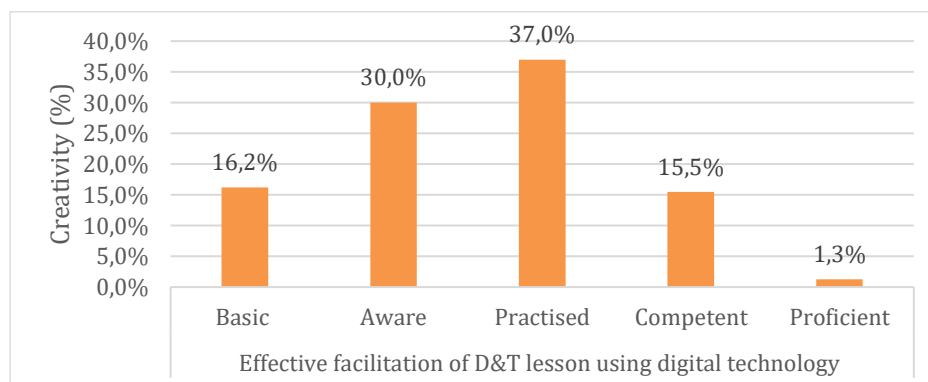


**(b) Creativity skills**

Creativity skills involved students' ratings of the following items: using and applying various ideas and methods in the learning process so that classroom learning is not monotonous, stimulating student motivation in learning, and demonstrating practical skills by connecting things to the realities of daily life.

To determine the use of digital technology on D&T pedagogy to support the attainment of creativity skills, the use of Custom Tables in SPSS was applied. Figure 4 shows that 37% of students perceived those teachers who possessed practised digital technology skills demonstrated creativity skills. It can also be noted that 30.0% of the students perceived their teachers to possess awareness level of skill on digital technology demonstrated creative skills. The results show that most of the students (53.8%) perceived that teachers' digital technology skill level influence creativity skills.

*Figure 3:  
Using digital technology resources to attain creativity skill*

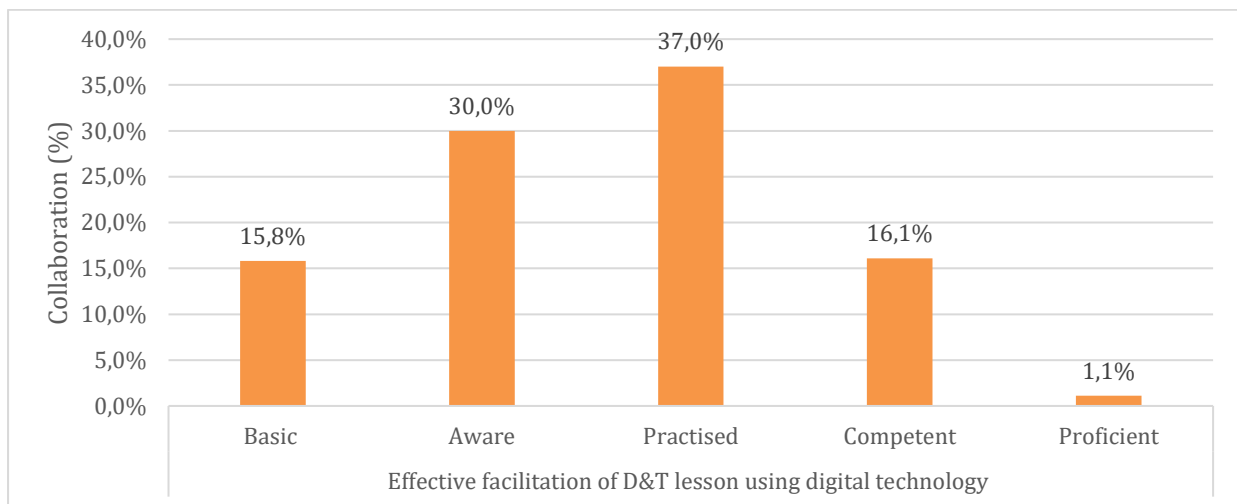


### (c) Collaboration skills

Students rated their teachers on the following items: occasionally engaging students in society projects, allowing students to form groups in some activities and submit their work as groups, and asking students to do assignments in groups so that they can discuss the content amongst themselves. These items were computed to form collaboration skills. To determine the association between teachers' digital technology skill level and demonstration of collaboration skills, Customs Tables were applied. Some students (37.0%) perceived those teachers whose level of digital technology skills as practised, demonstrated collaboration skills, as reflected in Figure 5. It can also be noted that 16.1% of the students perceived teachers with competent digital technology skills to demonstrate collaborative skills. Only 1.1% of the students perceived teachers' digital technology skill proficient to demonstrate collaboration skills.

Figure 4:

*Using digital technology resources to attain collaboration skill*

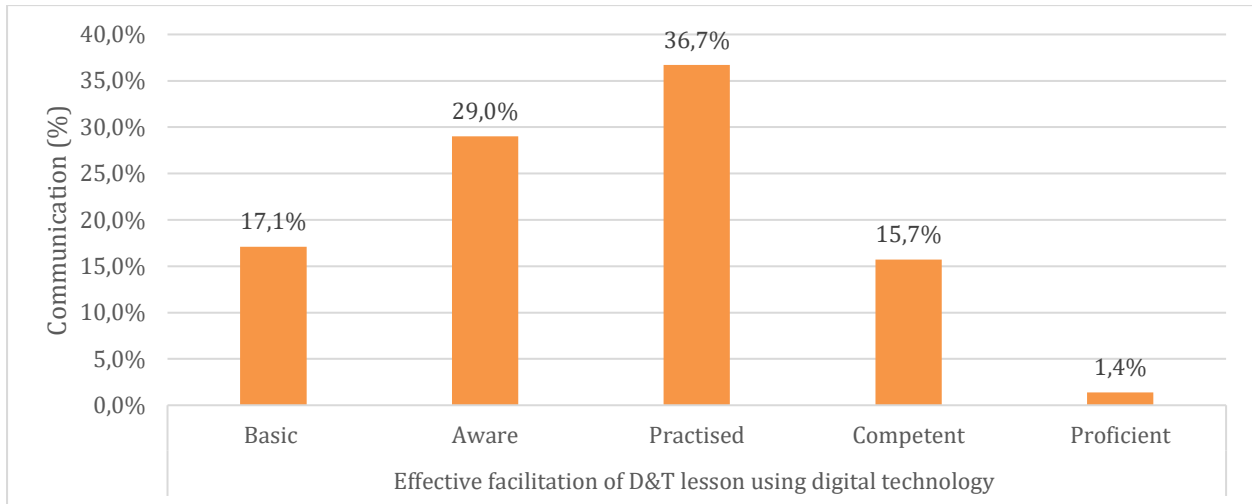


### (d) Communication skills

Students were asked to rate their teachers on these items: the ability to teach from simple to abstract activities, process and interpret both verbal and non-verbal information from others, negotiate positive outcomes with others through negotiation and instructing, convey information in the classroom to be easily understood by students and use relevant instructions. This was then computed into communication skills variable. To determine the association between teachers' digital technology skill level and demonstration of communication skills, Customs Tables were applied. Figure 6 reflects that those students (36.7%) who perceived teachers' digital technology skills level as practised, demonstrated communication skills.

Figure 5:

*Using digital technology resources to attain communication skill*



Additionally, 15.7% of students perceived those teachers with competent digital technology skills demonstrated communication skills. The results imply that most students (54.8%) found teachers with digital skills level to demonstrate communication skills.

## DISCUSSION

The results of this study highlight the significant potential of integrating digital technology into Design & Technology pedagogy to support the attainment of 21<sup>st</sup> century skills among senior secondary students in Botswana. By employing the TPACK framework, this research provides a structured lens through which to analyse the interplay between technology, pedagogy, and content knowledge in fostering skills such as critical thinking, collaboration, creativity, and digital literacy. The results indicate that D&T teachers with strong TK are more likely to integrate computers and laptops into their teaching practices. This aligns with the TPACK framework, which emphasises that effective technology integration depends on a teacher's ability to combine technological tools with pedagogical strategies and subject content. Additionally, the study reveals that students who perceived their teacher's digital technology skill level as practised demonstrated enhanced critical thinking skills during learning and instruction. This finding underscores the importance of TPK, the ability to strategically use digital tools to support cognitive development and engagement in learning activities. These results are aligned with a study conducted by Meija and Sargent (2023), who found that critical thinking skills can be fostered and strengthened through the strategic use of digital technology tools. Within the TPACK framework, this suggests that teachers who effectively integrate TPACK create learning environments that enhance students' analytical and problem-solving abilities.

This study revealed that the student perceptions that teachers with practised digital technology skills demonstrate greater creativity are well-supported by the TPACK framework. When teachers effectively integrate technology, pedagogy, and content, they create engaging, adaptive, and interactive learning environments that stimulate creative thinking. Participants perceived the teacher's digital technology skill level to influence creativity, highlighting enabled individualisation and flexibilization of education and making knowledge acquisition more accessible (Comi et al., 2017; Meroni et al., 2015). However, the study also found that some teachers lacked the necessary TPACK to fully leverage digital tools, often using

technology in superficial ways that did not enhance learning outcomes. This underscores the need for targeted professional development programmes to build teachers' TPACK competencies.

The study reveals that the use of digital tools, such as computer-aided design (CAD) software and online collaboration platforms, significantly enhances students' ability to engage in problem-solving and creative thinking. These tools align with the demands of the 21<sup>st</sup> century workforce, where technological proficiency and innovation are paramount. The results resonate with previous studies that emphasise the role of digital tools in fostering higher order thinking skills (Voogt et al., 2013). However, the study also highlights challenges, such as limited access to technology and insufficient teacher training, which hinder the full realisation of these benefits. These barriers are consistent with the broader literature on technology integration in sub-Saharan Africa (Hennessy et al., 2010).

The study results align with those of 2023 and Adegoke (2024), which emphasise the need for improved teacher training in collaborative methodologies and ICT-mediated tools. According to Haleem et al. (2022) digital technologies are a powerful instrument that can help improve education in various ways, such as making it easier for instructors to generate instructional materials and providing new methods for people to learn and collaborate. Lai et al. (2015) posit that ICT allows greater interactivity in learning, greater possibilities for cooperation, and improved communication between teachers and students.

The study emphasises the role of teachers in adapting and implementing digital technology in classrooms and the need for appropriate training to use and manage various digital technologies effectively. Get into Teaching (2016) reveals that computing is becoming vital in the education of children from about five years of age. Thus, educators should be abreast with digital technology developments to ensure learners' needs are catered for from a tender age. The study's findings support the urgent need for digital technology education.

The study highlights the unique contextual challenges faced by Botswana's education system, including infrastructural limitations, such as unreliable internet connectivity and a shortage of digital devices. These challenges are exacerbated by the rural-urban divide, with schools in urban areas having better access to resources than their rural counterparts. Despite these barriers, the study identifies several opportunities for growth. For instance, the Botswana government's commitment to digital transformation, as outlined in the *Vision 2036* policy framework, provides a strong foundation for scaling up technology integration in education. Additionally, the study found that students exhibited high levels of motivation and curiosity when engaging with digital tools, suggesting that technology can catalyse student engagement in D&T.

The study results have several implications for policy and practice. First, there is a need for increased investment in digital infrastructure, particularly in rural areas, to ensure equitable access to technology. Second, teacher training programmes should prioritise the development of TPACK competencies, equipping educators with the skills to integrate technology in meaningful ways. This could be achieved through workshops, online courses, and mentorship programmes. Third, curriculum developers should consider revising the D&T curriculum to explicitly incorporate 21<sup>st</sup> century skills and digital literacy, ensuring that students are prepared for the demands of the modern workforce.

While this study provides valuable insights, it is not without limitations. The research was conducted in a limited number of schools, which may affect the generalisability of the results. Additionally, the study focused primarily on the perspectives of teachers and students, leaving out other stakeholders, such as parents and policymakers. Future research could explore the role of these stakeholders in supporting technology integration. Longitudinal studies could also be conducted to assess the long-term impact of digital technology on students' 21<sup>st</sup> century skills and career outcomes.

## CONCLUSION

This study has explored the integration of digital technology into D&T pedagogy to support the attainment of 21<sup>st</sup> century skills among senior secondary students in Botswana. By employing the TPACK framework, the research has provided valuable insights into how technology, pedagogy, and content knowledge can be effectively combined to foster skills such as critical thinking, creativity, collaboration, and digital literacy. The results underscore the transformative potential of digital tools, such as computer-aided design (CAD) software and online collaboration platforms, in enhancing student engagement and learning outcomes.

However, the study also highlights significant challenges, including limited access to digital infrastructure, insufficient teacher training, and disparities between urban and rural schools. These barriers must be addressed to fully realise the benefits of technology integration in D&T education. The TPACK framework has proven to be a valuable tool for understanding the complexities of technology integration, emphasising the need for teachers to develop a deep understanding of how digital tools intersect with pedagogical strategies and content knowledge.

The implications of this study are far-reaching. Policymakers and educators in Botswana must prioritise investments in digital infrastructure and teacher professional development to ensure equitable access to technology and build educators' capacity to integrate it effectively. Additionally, curriculum revisions should explicitly incorporate 21<sup>st</sup> century skills and digital literacy, aligning education with the demands of the modern workforce.

The integration of digital technology into D&T pedagogy holds immense promise for preparing Botswana's senior secondary students for the challenges and opportunities of the 21st century. By addressing the identified challenges and leveraging the opportunities presented by digital tools, Botswana can position itself as one of the leaders in innovative education practices. Future research should focus on longitudinal studies to assess the long-term impact of technology integration on students' skills and career outcomes, as well as the role of other stakeholders, such as parents and policymakers, in supporting this transformative process. Through sustained efforts, Botswana can harness the power of digital technology to equip its youth with the skills needed to thrive in an increasingly digital and interconnected world.

## RECOMMENDATIONS

The following are recommended based on the study's results:

- Increase access to digital technology resources in D&T classrooms.
- Embed digital technology into the curriculum and assessment.

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