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PERCEPTION OF TECHNOLOGICAL INTEGRATIONS AS A CATALYST FOR STEAM TEACHER EDUCATION

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Abstract. STEAM Education connotes the addition of Arts to STEM education. The fourth industrial revolution as a buildup from the first three revolutions is rapidly changing the education landscape. This study examined students' perception of technology integration for enhancing STEAM teacher training programmes in VUCA times while investigating influencing factors and impending challenges for a holistic assessment. The descriptive survey research design was adopted for this study. The population for the study was students for tertiary institutions while the target population was university teacher trainees offering STEAM-related subjects. The data was collected using a researcher designed and validated questionnaire with an overall Cronbach alpha reliability index of 0.81. The collected data was analysed descriptively (using frequency, percentages, percentile ranking) and inferentially (using a multi-level Factorial ANOVA) tested at 0.05 level of significance. The findings from this study revealed that students had a positive perception of technology integration for enhancing STEAM teacher training programmes. However, the highest-ranking influencing factor for technology integration was the availability of adequate infrastructure while the inadequate access to technology infrastructure was observed as the highest-ranked impediment. The findings of this study informed the conclusion drawn which shows how important technological integration is in pedagogy. As such, teacher training institutions must have the latest resources and use them to advance student growth, including soft skills while upholding STEAM education's emphasis on creativity and innovation as hallmarks of discoveries.

Keywords*:* technological integration and pedagogical, 4IR, STEAM Education, learning, teacher training.

1. INTRODUCTION

The Fourth Industrial Revolution (4IR) is a term used to describe the current period of rapid technological change, which is characterised by the integration of digital, physical and biological systems. 4IR is transforming the way we live and work, and is creating new opportunities for innovation, economic growth and social development. Africa is not exempt from this trend and must quickly adapt in order to keep pace with the rest of the world. Science, Technology, Engineering, Arts and Mathematics (STEAM) education is key to equipping the African workforce with the necessary skills to participate productively and innovatively in 4IR. Worthy of note is that the pandemic also highlighted the importance of flexibility and adaptability in education. Schools and universities had to adjust their teaching methods and curriculum to meet the changing needs of students and respond to the challenges of the pandemic. This flexibility has allowed educators to experiment with new teaching models and approaches, such as emergency remote teaching and learning (Chirinda et al, 2020) project-based learning (Malan et al. 2014), blended learning (Daramola, 2024), flipped classrooms (Daskan & Yildiz, 2020; Rao, 2019), problem-based learning (Oladele et al., 2024) and competency-based education

(Açıkgöz & Babadoğan, 2023) which are basic requirements for STEAM education. These learning styles are fast gaining relevance as the new normal (Gurajena et al., 2021). It is important for the education systems in Africa to fully integrate 4IR tools as the world drifts towards the Fifth Industrial Revolution-5IR also known as 5ires (Mathur et al., 2022).

1.1. Statement of the problem

The COVID-19 pandemic had a significant impact on the education sector worldwide. It forced schools, colleges, and universities to rapidly adapt to new ways of teaching and learning, including remote and hybrid learning models as the "new normal" that prioritizes flexibility, technology, and innovation. One of the most significant changes brought about by the pandemic is the widespread adoption of 4IR technologies in education to ensure that students could continue with their education remotely at the peak of the pandemic (Ayanwale & Oladele, 2021). This shift towards technology accelerated the development of new tools and resources that could be appropriated to enhance the STEAM education for societal relevance and transformation (Mhlanga & Moloi, 2020; Timotheous et al., 2023). Examples included interactive simulations, virtual and augmented reality environments, and AI-powered and inspired personalized learning systems. Therefore, COVID-19 came and accelerated 4IR adoption in education as emergency remote teaching and learning (ERTL). Simultaneously, it laid bare, the digital divide/inequalities (between rich and poor schools). More privileged schools (and HEIs) transitioned almost seamlessly from face-to-face (F2F) to ERTL. For students, learning now requires smart devices, where available. Platform functionalities evolved in tandem with increased adoption (e.g. platforms diversified to include more participants, breakaway/parallel chat rooms in Zoom, MS Teams, BB Collaborate Ultra, Moodle, etc.). Invigilation or proctoring apps (e.g., Invigilator) surfaced to protect the integrity of examinations and assessments. Also, combining online and offline peer support groups in community (Strand et al., 2020). The foregoing shows the progress made with integrating these new technologies in STEAM education.

While existing research provides valuable insights (Rahmawati et al., 2019; Tytler, 2020), there is a need for more empirical evidence to guide technology integration strategies in improving STEAM teacher education specifically in the Nigerian context. Also, there is a need to explore related challenges and barriers faced by educators and institutions in integrating technology into teacher training curricula. Understanding these challenges is essential for developing targeted interventions and support mechanisms to facilitate successful technology integration and ensure that teacher training programs adequately prepare educators for the digital age.

The purpose of this study is to examine students' perception of technology integration for enhancing STEAM teacher training programmes in volatile, uncertain, complex and ambiguous (VUCA) times while investigating influencing factors and impending challenges for a holistic assessment.

The specific objectives of this study are to: (1) examine students' perception of technology integration in STEAM teacher training programmes; (2) investigate the factors influencing technology-enhanced STEAM teacher training programmes; and (3) identify the challenges in integrating technology into STEAM teacher training programme.

The above objectives guided the study research questions while research question one was further translated into hypothesis as stated below:

H_0: Students' perceptions of technology integration in STEAM teacher training programmes do not significantly differ based on gender, discipline, level and age.

2. LITERATURE REVIEW

STEM is an acronym that stands for Science, Technology, Engineering, and Mathematics. In recent years, there has been a growing trend towards expanding this acronym to include the Arts, resulting in the acronym STEAM. The addition of the Arts is seen as a way to incorporate creativity and innovation into STEM fields and to promote a more well-rounded approach to education and problem-solving. The idea of incorporating the Arts into STEM education has been around for several years, but it gained momentum with the millennium. In 2006, the Rhode Island School of Design (RISD) introduced a STEAM initiative that aimed to promote the integration of art and design into STEM education later adopted by other institutions and organizations (Allina, 2018; Marwala, 2018; Peelor, 2016).

STEAM is a multi-, inter- and transdisciplinary approach that aims to develop critical thinking, problem-solving, and creativity skills among students (Madden et al., 2013). These subjects help students to think critically, solve complex problems, and develop creative solutions. STEAM education provides students with practical skills that will enable them to solve real-world problems, and it has become increasingly important in the 21st century due to the demand for a highly skilled workforce (Montés et al., 2023). Proponents of STEAM education argue that including the Arts in STEM education can lead to more innovative and effective problem-solving, as well as a more holistic approach to learning (Woodford, 2022). They also point to the fact that many of the most successful and groundbreaking innovations in history have come from individuals who combined technical expertise with artistic creativity (Cohendet, 2017; Vygotsky, 2020). In STEAM education, the focus is not only on learning these subjects individually but also on integrating them to provide a holistic education experience. This approach is gaining popularity as it prepares students for the challenges of the 21st century workforce. It equips them with the soft skills needed to succeed in a rapidly changing world where technological advancements are transforming the way we live and work, being a major characteristic of 4IR (Marr, 2020).

4IR is somewhat of a mute question by now, but thanks to 4IR tools like Google, databases and other electronic search engines, answers are at our fingertips. We just need to crosscheck the facts for consistency as critical consumers of ubiquitous information and knowledge around us (Hussin, 2018). The first industrial revolution (1IR - Industry 1.0 refers to the Coal age), the second industrial revolution (2IR - Industry 2.0 refers to the Electricity age), and the third industrial revolution (3IR- Industry 3.0 refers to the computer age) are predecessors to the 4^{th} which, at the time of conceptualization, was unlike anything humankind had experienced before (Schwab, 2016). 1IR occurred from the late 18th century to the mid-19th century brought about industry from the agro-based economies with products from mechanized processes. This was largely driven by the discovery of coal and its mass extraction, as well as the development of the steam engine and metal forging which completely changed the way goods were produced and exchanged. Inventions such as spinning machines and looms to make fabric were making their appearance. Canal transportation began replacing wagons and mules for moving around goods and services (UpKeep, 2023). As such, this period witnessed a transition from hand production methods to machine-based manufacturing, which had a profound impact on society, economy, and culture and set the stage for subsequent industrial revolutions. In Al Khwarizmi's time (circa 850 AD), the mathematics curriculum consisted of the arithmetic and algebra of inheritance of camels, horses and cows, and the geometry of land areas as erstwhile measures of wealth (Nabirahni et al., 2019). Trigonometric problems of the time were about ships (like the Titanic) OR of the type: Cecil John Rhodes bought 300 shares of coal mine stock for R20,550 when the price of the stock went up, he sold it for R216.00 a share. What was his total profit on the stock? Therefore, Industry 1.0 thus directly influenced the content of the school mathematics curriculum (i.e. Industry 1.0 => Education 1.0 => STEAM Education 1.0 => STEM Education 1.0 => Mathematics Education 1.0).

2IR, also known as the technological revolution, took place from the late 19th century to the early 20th century, revolved around the discovery of electricity, gas and oil and led to the invention of the internal combustion engines (Richmond Vale Academy, 2022). The steam engine, which had powered the first industrial revolution, was replaced by electricity and the internal combustion engine. This led to the development of new industries such as automobile manufacturing, electrical power generation, and telecommunications. This development permeated the world markets with steel and chemical products galvanizing communication technology with the analogue telegraph and subsequent upgrades to digital which brought about the digital telephone. Transportation also got a quantum leap boost with the invention of the internal combustion cars and aerodynamic planes while mechanical production grew in speed and volume through mass production. The development of new sources of energy, communication technology, and manufacturing processes that characterized the 2IR led to significant improvements in people's lives (Richmond Vale Academy, 2022). With education 2.0, Mathematics curricula and texts changed (from horse-drawn and ox-drawn wagons, water-powered sawmills and wind-powered ships to steam-engine locomotives and steam-engine ships to motor cars and aeroplanes) and told stories and contexts that reflected this epoch. STEAM Ed 2.0: Trigonometric problems, changed from navigation with ships to aeroplanes taking off from Airport A, flying in the direction of X1 degrees at a speed of Y1 km/h against wind speed of Y2 km/h in the direction of X2 degrees. Students were then teased to find the actual speed of the plane. Alternatively, problems around municipal bills emerged: The January electricity bill was R450.00, which was twice as much as the December bill. The February electricity bill was R40.00 higher than the December bill. What was the total cost of electricity for the three months?

The impact of the 2IR on STEAM education was particularly significant because it led to the development of new approaches to teaching and learning. One of the most important changes was the emergence of vocational education, which focused on providing practical training in areas such as mechanics, electricians, and other skilled trades (Okoye & Udoudo, 2015). This type of education was designed to prepare students for the demands of the new industrial economy, and it emphasized hands-on learning and real-world experience. Another important development in STEAM education during the 2IR was the growth of specialized schools and colleges. These institutions focused on providing more advanced training in specific areas of STEAM, such as engineering, artisanry or architecture designed to prepare students for professional careers in these fields and emphasized theoretical and technical knowledge (Sloan, 2020). The 2IR also had a significant impact on the arts, particularly in the area of design. Significant impact on the development of STEAM-related research was also experienced as new technologies emerged. In this regard, scientists and engineers were able to conduct more advanced experiments and develop new theories about the natural world. This led to the establishment of new research institutions, such as the Massachusetts Institute of Technology (MIT) in the United States, which became a center for advanced scientific research and innovation (Tikkanen, 2023).

The 2IR brought about changes that helped to prepare society for the demands of the new industrial economy and paved the way for future innovation which progressed through a decade till the 3IR also known as the digital/computer revolution. 3IR started in the late 20th century with the discovery of nuclear energy and invention of electronics to usher in the computer age (Clark & Cooke, 2010). 3IR saw the rapid development of digital technologies such as the personal computer, the internet, and mobile phones. These technologies enabled people to access information and communicate with one another on a global scale, breaking down barriers of time and distance thus revolutionizing the way different sectors of the economy operate interdependently and how individuals live their lives (Herburger, 2020). 3IR has transformed the world into a global village, allowing people to connect and communicate in ways that were unimaginable just a few decades ago. It is especially important to note that the expansion of internet connectivity has contributed to the democratisation of information and knowledge. This has made it possible for anyone with a device that is linked to the internet to gain access to a vast amount of information on any subject. With reference to the education sector, the 3IR has empowered individuals to learn new skills and participate in educative online communities while embracing lifelong learning (Organisation for Economic Co-operation and Development- OECD, 2018). As a result, there have been significant impacts on the field of education, particularly in the areas of science, technology, engineering, arts, and mathematics (STEAM). The third industrial revolution led to a significant increase in the demand for skilled workers in the areas of STEAM. With the rise of automation, traditional manufacturing jobs were replaced by jobs that require softer technical skills, such as programming, data analytics, and design. Also, with the rise of technology, traditional methods of teaching became less effective, and educators had to adapt their teaching methods to keep up with the changing times (Mehta, 2023). In the digital era, teachers have had to learn new digital literacies and develop pedagogies to engage students and make learning more interactive with a significant shift towards project-based learning, problem-based learning, blended or hybrid learning, flipped classrooms, and ERTL. This approach to learning emphasizes hands-on activities, experimentation, and problem-solving, allowing students to apply their knowledge and skills to real-world problems (Mpungose, 2020). By engaging in these new pedagogies, students develop critical thinking skills, learn how to collaborate effectively with others, and gain practical experience in their chosen field.

While the attention was earlier on STEM education with arts and humanities often seen as separate from the sciences, having little overlap between the two fields. However, as technology became more pervasive, there has been a growing recognition that creativity and innovation are essential components of STEAM education (Mahmudovna et al., 2022). By integrating art and design into STEM education, students are encouraged to think creatively and develop innovative solutions to complex problems (Vygotsky, 2020). Another impact of the 3IR on STEAM education has been the rise of online learning. With the advent of the internet, students can now access a wealth of educational resources from anywhere in the world which is germane to use (GoGuardian Team (2023). Online learning platforms, such as Khan Academy and Coursera, offer a wide range of courses and tutorials in STEAM subjects, making it easier for students to learn at their own pace and on their own schedule (Ulum, 2023).

The 4th is built on the shoulders of the 3rd which is still co-evolving with the 4th (Moll, 2022). Schwab's (2016) refers to 'new technologies' such as artificial intelligence, robotics, the Internet of Things (IoT), blockchain, and 3D printing, among others (Ayanwale et al., 2022). These new technologies are deployed through mobile devices (iPad, iPhone, Samsung, Huawei), Internet of Things (smartphones, smartboards, smart TV, smart fridges, smart watches, etc.), artificial intelligence applied in location detection (GPS, Google Maps, big data bases), smart classrooms, Advanced Human-machine interface authentication and fraud detection (examination proctoring, automated item generation, online assessment platforms, etc.), (Blockchain) 3D printing (of furniture, industrial components, houses), Smart Sensors (CCTV) and Nanotechnologies, Big Data Analytics (Voice detection, Facial recognition, econometrics, Google Translate, Facebook, etc.), Multi-level customer (user/student) interaction and profiling, Virtual and augmented reality for learning (DGSs, Virtual labs, Simulations, YouTube videos) and Artificial Intelligence/Cloud computing/Cloud pedagogy (e.g. Heutagogy) (Oladele et al., 2021). As a result, there has been a growing need for students to be trained in these areas, particularly in coding, robotics, and artificial intelligence (Karalekas et al., 2023).

4IR will unambiguously require a new set of skills from STEAM teachers in training. As automation and artificial intelligence become more prevalent, many routine jobs will become automated, and students will need to be equipped with advanced technological skills to thrive in the new economy (Sakar, 2023). The focus of STEAM education will shift towards developing critical thinking, problem-solving, creativity, and collaboration skills, as these are the skills that will be highly valued in the 4IR (Oladele et al., 2023). Similar to the 3IR, the 4IR will change the way STEAM subjects are taught. Traditionally, these subjects have been taught in a theoretical and abstract manner. However, the 4IR requires a more hands-on approach, with a focus on real-world applications. Furthermore, the 4IR is also encouraging a more interdisciplinary approach to STEAM education. The integration of science, technology, engineering, arts, and mathematics is becoming more important, as many of the complex challenges of the future resulting to "wicked problems" will require transdisciplinary approaches which is rated superior to multi-disciplinarity (Denard, 2021). The emergence of trans-disciplinarity is necessary to address a critique of traditional knowledge as compartmentalized while ensuring ethical standards (Oladele, 2022). For example, the development of smart cities (characterized by smart technologies and powered by renewable or green energy sources) will require collaboration between engineers, architects, urban planners, and artists and a joint commitment to implementing solutions for sustainability (Mills et al., 2021). The need for sustainability is strengthened with the focus of 5ire on stakeholder value rather than shareholder value as a key driver with the goal of reinforcing the industry's role in meeting societal needs (Mattila et al., 2022). The authors envisage an Industry 5.0 that would be an improvement on the 4IR in terms of strike a balance between machine and human engagement, collaboration is between people and robots and a combination of cognitive computers and human intelligence.

However, there is no dichotomous separation between the 3rd and 4th, nor even the between 1st, 2nd and 3rd, and so these are better construed as a continuum. However, the 4IR has left the world partly confused and mesmerized powered by cyber systems, and the loud talk about 5IR already underway (Mattila et al., 2022). It encompasses technologies which have revolutionized the way we live and work, and they are expected to have a significant impact on education, especially STEAM education. Worthy of note is the fact that the 4IR is also placing a greater emphasis on creativity in STEAM education. Creativity is becoming more important, as many of the jobs of the future will require individuals to think creatively and to come up with innovative solutions to complex problems while ensuring sustainability (Mattila et al., 2022).

The forgoing accounts of the first to the fourth industrial revolution show that technological advancement is progressively improving and closely linked to STEAM education. It is therefore imperative to examine how trainee teachers in STEAM fields perceive technology in the light of their training. Perception means "*a power to see what is not evident to the average mind*" perception implies quick and often sympathetic discernment (as of shades of feeling) (Merriam-Webster, 2024). This definition shows that perception is ingrained in the mind and drives action and being the essence of moral judgment (Gray et al., 2012). Accuracy in measuring respondents' perceptions was identified as one of the biggest challenges for survey researchers. However, this method helps respondents precisely clarify their judgments for each alternative (Sato, 2009). The measurement of perception can be carried out using Likert scales which systematically position respondents positively or negatively in a subtle manner (Moura, 2020). Similarly, Taylor (2021) stressed that measuring perception helps to emphasis on those who rate an issue positively and negative. This approach is useful for solving the problem of response set also common with questionnaires (Applequist, 2017).

3. METHODOLOGY

The study adopts a descriptive survey research design. The study population would be teacher trainees in higher learning institutions while the target population would be university preservice teacher studying STEAM-related subjects. A university was selected using the convenience sampling technique while pre-service teachers from the selected university were sampled using cluster sampling technique to include those in STEAM-related subjects. A self-developed questionnaire titled "Technological Integrations for Steam Teacher Education" was used for data collection. The instrument was developed on a four-point Likert response scale of Strongly Agree, Agree, Disagree and Strongly Disagree to examining students' perception on technological integration for STEAM teachers' Education with 3 sub-scales. Each of the scales were originally designed ten items each. The instrument was face and content validated by experts in educational technology and teacher training. This resulted to some items being merged and others deleted leaving the sub-scale on perception on technological integration in STEAM teachers Education with seven items, while the sub-scale assessing factors influencing technological integrations and challenges were left with 5 items each. The instrument obtained a Cronbach alpha reliability index of 0.8 which was deemed appropriate for rating scales. The questionnaire was administered using online Google forms Data. The collated data were analysed using descriptive statistics consisting of frequency, percentages and percentile ranking to answer the non-testable research questions and inferential statistics of the multi-level Factorial Analysis of Variance (ANOVA) to answer the testable research questions at 0.05 level of significance. The analysis was conducted using SPSS, Version 27.

Study Ethics: The authors ensured that participants were fully informed of the purpose and action-based approach of the research. Also, the data collection process was explained fully to the study participants. The researchers obtained informed consent from all parties involved in the research prior to implementing the research project and voluntary participation in the conducted surveys was ensured. The findings of this study are none-identity specific for while also ensuring institutional non-disclosure.

4. RESULTS

The demographic information of respondents was analysed using frequency and percentages as shown in Table 1.

Tab. 1

Demographic information of study respondents

Demographic Data		Frequency	Percentage (%)
Gender	Male	99	49.0
	Female	103	51.0
	Total	**202**	**100**
Discipline	Science	35	17.3
	Basic Technology	31	15.3
	Technology Engineering	40	19.8
	Arts	61	30.2
	Mathematics	35	17.3
	Total	**202**	**100**
Study Level	100	38	18.8
	200	56	27.7
	300	31	15.3
	400	77	38.1
	Total	**202**	**100**
Age Range	18-25	146	72.3
	26-32	55	27.2
	33-40	1	0.5
	Total	**202**	**100**

Source: Field Survey, 2024

As shown in Table 1, 99(49.0%) of the respondents were males, while 103(51.0%) were females. This information shows that more females participated in the study than males. Also, the statistics on discipline showed that 35(17.3%) of the study participants were in the sciences, 31(15.3%) were studying basic technology, 40(19.8%) were studying technology engineering, 61(30.2%) were studying arts while 35(17.3%) were studying mathematics. This information shows that most of the study participants were students studying arts-oriented courses. On study level, 38(18.8%) were in one hundred level, 56(27.7%) were in two hundred level, 31(15.2%) were in three hundred level, while 77(38.1%) were in four hundred level. This information revealed that most of the respondents were in their final years of study. With respect to the study participant's age range, 4146(72.3%) were aged between 18-25 years, 55(27.2%) were aged between 26-32 years while 1(0.5%) were aged between 33-40 years. This information on age categories revealed that most study participants ranged between 18 to 25 years of age.

4.1. Answering the research questions

Research Question One: What are the perceptions of students on technology integration in STEAM teacher training programmes? The perception of students on technology integration in STEAM teacher training programmes was analysed using frequency, percentages and percentile ranking.

Tab. 2

Frequency and percentages of students' perception on technology integration in STEAM teacher training programmes

No	Item- Technology integration:	SD	D	A	SA	Rm.	Rk.
		F (%)	F (%)	F (%)	F (%)		
1	improves students' retention	8(4.0)	23(11.4)	81(40.1)	90 (44.6)	P	3rd
2	promotes student collaboration.	5(2.5)	29(14.4)	94(46.5)	74 (36.6)	P	4th
3	promotes the development of communication skills	3(1.5)	13(6.4)	88(43.6)	98(48.5)	P	2nd
4	helps accommodate students' personal learning styles.	7(3.5)	- (0.0)	73(36.1)	122 (60.4)	P	1st
5	motivates students to get more involved in learning act.	32(15.8)	7(3.5)	104(51.5)	59(29.2)	P	6th
6	promotes the development of students' interpersonal skills.	54(26.7)	35(17.3)	61(30.2)	52 (25.7)	P	7th
7	improves student learning of critical concepts and ideas.	32(15.8)	5(2.5)	97(48.0)	68(33.7)	P	5th

Note. SD: Strongly Disagree; A: Agree; D: Disagree; SA: Strongly Agree; F: Frequency; Rm: Remark; P: Positive; Rk: Rank

As shown in Table 2, the perceptions of students on technology integration in STEAM teacher training programmes were positive regarding improving students' retention (40.1+44.6=)84.7% ranking third), promoting student collaboration (83.1 per cent ranking fourth), promoting the development of communication skills (92.1 per cent ranking second), helping to accommodate students' personal learning styles (96.5 per cent ranking first), motivating students to get more involved in learning act (80.7 per cent ranking sixth), promoting the development of students' interpersonal skills (55.9 per cent ranking seventh) and improving student learning of critical concepts and ideas (81.7 per cent ranking fifth). This result connotes that the students perceived technological technology integration in STEAM teacher training programmes positively with technological integration helps accommodate students' personal learning styles ranking first and promoting the development of students' interpersonal skills ranking last.

Research Question Two: What are the factors influencing technology-enhanced STEAM teacher training programmes? Factors influencing technology-enhanced STEAM teacher training programmes was analysed using frequency, percentages and percentile ranking.

Tab. 3

Frequency and percentages of factors influencing technology-enhanced STEAM teacher training programmes

No	Factors	SD	D	A	SA	Rm.	Rk.
		F (%)	F (%)	F (%)	F (%)		
1	Lack of awareness about the potential benefits of technology in education influences its adoption for teacher training	1(0.5)	- (0.0)	66(32.7)	135(66.8)	IF	1st
2	Availability of adequate infrastructure, such as reliable internet connectivity and modern	1(0.5)	- (0.0)	67(33.2)	134(66.3)	IF	1st

	teaching facilities						
3	Availability of technological support staff	3(1.5)	5(2.5)	105(52.0)	89(44.1)	IF	5th
4	Flexibility in teacher training programmes	3(1.5)	2(1.0)	103(51.0)	94(46.5)	IF	3rd
5	Attitudes towards technology and innovation	3(1.5)	4(2.0)	100(49.5)	95(47.0)	IF	4th

Note. SD: Strongly Disagree; A: Agree; D: Disagree; SA: Strongly Agree; F: Frequency; Rm. Remark, IF: Influencing factor; Rk: Rank

As shown in Table 3, the factors influencing technology-enhanced STEAM teacher training programmes were lack of awareness about the potential benefits of technology in education influences its adoption for teacher training and availability of adequate infrastructure, such as reliable internet connectivity and modern teaching facilities (99.5 per cent both ranking first), Availability of technological support staff (92.1 per cent ranking fifth), Flexibility in teacher training programmes (97.5 per cent ranking third), and students' attitudes towards technology and innovation. (95.5 per cent ranking fourth). This result connotes that all the issues raised were influencing factors with integrating technology in STEAM teacher training programmes with the availability of adequate infrastructure, such as reliable internet connectivity and modern teaching facilities ranking first and the availability of technological support staff ranking last.

Research Question Three: What are the challenges faced in integrating technology into STEAM teacher training programme?

Challenges faced in integrating technology into STEAM teacher training programme was analysed using frequency, percentages and percentile ranking.

Tab. 4

Frequency and percentages of challenges faced in integrating technology into STEAM teacher training programme

No	Challenges	SD	D	A	SA	Rm	Rk.
		F (%)	F (%)	F (%)	F (%)		
1	Inadequate access to technology infrastructure	6(3.0)	1(0.5)	87(43.1)	108(53.5)	Ch.	1st
2	Inadequate digital training and support	15(7.4)	- (0.0)	112(55.4)	75(37.1)	Ch.	2nd
3	Limited resources to invest in technology infrastructure	33(15.8)	7(3.5)	78(38.6)	85(42.1)	Ch.	5th
4	Inadequate research and evidence of technology integration effectiveness	20(9.9)	1(0.5)	89(44.1)	92(45.5)	Ch.	4th
5	Resistance from institutional leadership	14(6.9)	5(2.5)	98(48.5)	85(42.1)	Ch.	3rd

Note. SD: Strongly Disagree; A: Agree; D: Disagree; SA: Strongly Agree; F: Frequency; Rm. Remark, Ch.: A Challenge; Rk: Rank

As shown in Table 3, the challenges faced in integrating technology into STEAM teacher training programme were inadequate access to technology infrastructure (96.6 per cent both ranking first), inadequate digital training and support (92.5 per cent ranking second), limited resources to invest in technology infrastructure (80.7 per cent ranking fifth), inadequate research and evidence of technology integration effectiveness (89.6 per cent ranking fourth) and resistance from institutional leadership (90.6 per cent ranking third). This result connotes that all the issues raised posed as challenges to integrating technology into STEAM teacher training programme with inadequate access to technology infrastructure ranking first and limited resources to invest in technology infrastructure ranking last.

4.2. Hypothesis Testing

H0: Students' perception of technology integration in STEAM teacher training programmes do not significantly differ based on gender, discipline, level and age.

Tab. 5

Tests of Between-Subjects Effects of Students' perception of technology integration in STEAM teacher training programmes

Source	Type III Sum of Squares	df	Mean Square	F	P-value	Partial Eta Squared
Corrected Model	788.926[a]	64	12.327	1.232	.156	.365
Intercept	17026.020	1	17026.020	1701.754	.000	.925
GENDER	21.528	1	21.528	2.152	.145	.015
AGE	54.600	2	27.300	2.729	.069	.038
LEVEL	60.329	3	20.110	2.010	.115	.042
DISCIPLINE	7.529	4	1.882	.188	.944	.005
GENDER * AGE	25.454	1	25.454	2.544	.113	.018
GENDER * LEVEL	37.556	3	12.519	1.251	.294	.027
GENDER * DISCIPLINE	181.945	4	45.486	4.546	.002	.117
AGE * LEVEL	54.726	3	18.242	1.823	.146	.038
AGE * DISCIPLINE	13.715	4	3.429	.343	.849	.010
LEVEL * DISCIPLINE	79.685	12	6.640	.664	.784	.055
GENDER * AGE * LEVEL	11.314	3	3.771	.377	.770	.008
GENDER * AGE * DISCIPLINE	26.968	4	6.742	.674	.611	.019
GENDER * LEVEL * DISCIPLINE	74.822	11	6.802	.680	.756	.052
AGE * LEVEL * DISCIPLINE	55.468	7	7.924	.792	.595	.039
GENDER * AGE * LEVEL * DISCIPLINE	5.394	1	5.394	.539	.464	.004
Error	1370.683	137	10.005			
Total	98481.000	202				
Corrected Total	2159.609	201				
R Squared = .365 (Adjusted R Squared = .069); Dependent Variable: Perception; Sig Value: 0.05						

According to Table 5, F-values and corresponding p-values of students' perception of technology integration in STEAM teacher training programmes were not significantly different based on gender (F=2.152; p=0.15), Age (F= 2.2729; p= 0.07), Level (F=2.100; p= 0.11) and Discipline (F= 0.188; p= 0.94). Considering this result from the hypothesis testing, the hypothesis stating that students' perception of technology integration in STEAM teacher training programmes do not significantly differ based on gender, discipline, level and age is therefore accepted. This result connotes that students did not differ in their perception of technological integrations for STEAM teacher education irrespective of their gender, age, levels of study and discipline across the STEAM subjects. Further leveraging the power of the multi-level Factorial ANOVA used, all the possible interactions between pairs of the test variables was also assessed. The result (also see Table 5) revealed no significant interaction between the tested pairs with the p-values greater than 0.05 except for the Gender-Discipline pair that has a p-value of 0.00. This result show that while the variables assessed individually did not show significant differences in students' perception of the outcome variable, putting together gender and disciplines showed a significance in their perception. In view of the significance recorded based on the interaction between gender and discipline, a post hoc test was conducted through a multiple comparison as shown on Table 6.

Tab. 6

Multiple Comparisons on Students' perception of technology integration in STEAM teacher training programmes across Disciplines

(I)DISCIPLINE	(J)DISCIPLINE	Mean Difference (I-J)	Std. Error	p-values	95% Confidence Interval	
					Lower Bound	Upper Bound
Science	Technology	.2516	.78013	.748	-1.2910	1.7943
	Engineering	.8750	.73211	.234	-.5727	2.3227
	Arts	2.2098*	.67073	.001	.8835	3.5361
	Mathematics	.4857	.75612	.522	-1.0095	1.9809
Technology	Science	-.2516	.78013	.748	-1.7943	1.2910
	Engineering	.6234	.75688	.412	-.8733	2.1201
	Arts	1.9582*	.69768	.006	.5786	3.3378
	Mathematics	.2341	.78013	.765	-1.3085	1.7767
Engineering	Science	-.8750	.73211	.234	-2.3227	.5727
	Technology	-.6234	.75688	.412	-2.1201	.8733
	Arts	1.3348*	.64354	.040	.0623	2.6074
	Mathematics	-.3893	.73211	.596	-1.8370	1.0584
Arts	Science	-2.2098*	.67073	.001	-3.5361	-.8835
	Technology	-1.9582*	.69768	.006	-3.3378	-.5786
	Engineering	-1.3348*	.64354	.040	-2.6074	-.0623
	Mathematics	-1.7241*	.67073	.011	-3.0504	-.3978
Mathematics	Science	-.4857	.75612	.522	-1.9809	1.0095
	Technology	-.2341	.78013	.765	-1.7767	1.3085
	Engineering	.3893	.73211	.596	-1.0584	1.8370
	Arts	1.7241*	.67073	.011	.3978	3.0504

Based on observed means.
The error term is Mean Square (Error) = 10.005.
**The mean difference is significant at the .05 level.*
Dependent Variable: Perception

As noted in Table 6, holding the disciplines of science, technology and engineering disciplines constant, Arts consistently accounted for the significance recorded with p-values of 0.00, 0.00 and 0.04 respectively. Holding the Arts discipline constant, all the four other disciplines (Science, Technology, Engineering and Mathematics) accounted for the significance Lastly, holding the discipline of Mathematics constant, the Arts discipline again accounted for the significant difference recorded. This result implies that there is a significant difference in students' perception of technological integrations when the gender-discipline intersection with the Arts discipline mostly accounting for the significance recorded.

5. DISCUSSION

The finding of this study suggests that students generally viewed the integration of technology in STEAM (Science, Technology, Engineering, Arts, and Mathematics) teacher training programs in a positive light. This finding indicates that students believe technological integration effectively supports personal learning styles. Furthermore, the fact that "technological integration helps accommodate students' personal learning styles" ranked first is a pointer to their appreciating how technology allows for a more personalized and adaptable approach to learning. implies that students. This could mean that technology enables differentiated instruction, where students can engage with content in a way that suits their unique needs, preferences, and learning paces. This finding is in line with that of (Oladele et al., 2023) which revealed that students had a positive experience with online teaching and learning and concluded that technology adoption for STEM education online teaching and learning is feasible in sub-Sahara Africa. The finding of this study also supports the finding that technology allows for flexibility such as that experienced during the emergency remote teaching and learning which is fast becoming the new normal (Gurajena et al.,2021). These approach to learning encourages project-based learning, blended learning, flipped classrooms, problem-based learning and competency-based education (Açıkgöz & Babadoğan, 2023; Chirinda et al, 2020; Daramola, 2024; Daskan & Yildiz, 2020; Malan et al. 2014; Oladele et al., 2024; Rao, 2019). Flexibility in the classroom is appropriate given that STEAM disciplines emphasise the integration of a multi-, inter-, and transdisciplinary approach with the goal of developing students' critical thinking, problem-solving, and creative skills. (Madden et al., 2013). Furthermore, as a key component of the 4IR relevant for the workforce of the twenty-first century, STEAM education focusses not only on teaching these subjects separately but also on integrating them to provide students with a holistic education experience while preparing them for success in a world that is changing quickly due to technological advancements that are changing the way people live and work. (Marr, 2020). The ranking emphasises a potential area for development in STEAM programs while ensuring that interpersonal skills are not overlooked while personal learning is supported by technology. It may be necessary for educators to devise methods for incorporating technology that also fosters social interaction and collaboration (Budnyk et al., 2021). This outcome underscores the significance of integration of technology into pedagogy practices. Not only is it important for universities to possess the most recent tools, but they must be utilised in a manner that optimises all aspects of student development, including soft skills.

The findings of this study also revealed that lack of awareness about the potential benefits of technology in education influences its adoption for teacher training, availability of adequate infrastructure, such as reliable internet connectivity and modern teaching facilities, availability of technological support staff, flexibility in teacher training programmes and attitudes towards technology and innovation were influencing factors with integrating technology in STEAM teacher training programmes with the availability of adequate infrastructure, such as reliable internet connectivity and modern teaching facilities and the availability of technological support staff. This finding is in congruence with (Timotheous et al., 2019) as impacting influencing teaching and learning and schools' digital capacity for transformation. Furthermore, the ranking of reliable internet connectivity and modern teaching facilities as first points to the importance of the reality of the fourth industrial revolution which rest heavily on internet-savvy technologies (Ayanwale et al., 2022; Moll, 2022). Reliable infrastructure, including high-speed internet and modern teaching facilities, is crucial for effectively integrating technology into education. Without these, even the most innovative tools and teaching methods may fail. As such, students need consistent access to digital resources, virtual learning environments, and online communication platforms to facilitate STEAM education. It is crucial for the African education system to completely integrate 4IR tools as a means of enlightening itself towards the Fifth Industrial Revolution which is surly close upon us (Mathur et al., 2022). The availability of technological support staff ranking last may be due to a plethora of online support systems available to students (Strand et al., 2020).

This result connotes that all the issues raised posed as challenges to integrating technology into STEAM teacher training programme with inadequate access to technology infrastructure ranking first. This finding connotes that while integration of technology into STEAM education is essential for modern teaching, this process is not without challenges. Similar to the findings of this study, the need for improvements in internet access and technical support was reported by (Oladele et al., 2023). Similarly, the outcome of this study aligns with that of (Gurajena et al., 2021) which also identified the challenges faced by tertiary institutions to include technological challenges, pedagogical challenges and social challenges. Inadequate access to technology infrastructure emphasised as the most significant one means that the necessary tools and resources (like computers, internet connectivity, software, and other digital tools) are either insufficient or unavailable. Furthermore, the lack of resources can severely limit the ability of students to effectively incorporate technology into their learning trajectories.

The result of this research also revealed no significant differences in students' perception of the outcome variable. This finding connotes that, based on the data collected and analysed, there isn't enough evidence to suggest that the groups or conditions being compared perceive the outcome variable differently. This could occur for various reasons, including the possibility that students perceive technological integrations in the same light. However, putting together gender and disciplines showed a significance in their perception. This result show how an interplay of factors affects research outcomes which is relevant for the a multi-, inter- and transdisciplinary approach necessary for teaching STEAM subjects (Madden et al., 2013). Worthy of note with this Arts discipline interplay mostly accounting for the significance recorded. This finding shows that incorporating the Arts into STEM education is fast gained momentum with the millennium as a way of incorporating creativity and innovation into STEM fields and to promote a more well-rounded approach to education and problem-solving (Marwala, 2018). This finding is further strengthened as a welcome development as studies shows that successful and groundbreaking innovations in history have come from individuals who combined technical expertise with artistic creativity (Cohendet, 2017; Vygotsky, 2020). This finding also strengthens the growing recognition that creativity and innovation are essential components of STEAM education (Mahmudovna et al., 2022).

6. CONCLUSIONS

This study concluded that students had a positive perception on the integration of technology into STEAM teacher education with no significant differences in the perception held. Some influencing factors on the integration of technology into STEAM teacher education are lack of awareness about the potential benefits of technology in education influences its adoption for teacher training, availability of adequate infrastructure, such as reliable internet connectivity and modern teaching facilities, availability of technological support staff, flexibility in teacher training programmes and attitudes towards technology and innovation. Furthermore, all the surveyed challenges were relevant with inadequate access to technology infrastructure chief.

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Джумоке І. Оладеле, Мдутшекельва Ндлову. Рецепція технологічної інтеґрації як каталізатор підготовки вчителів STEAM. *Журнал Прикарпатського університету імені Василя Стефаника*, **11** (3) (2024), 75-90.

STEAM-освіта пов’язана із додаванням мистецтва до STEM. Четверта індустріальна революція, що виникла на основі перших трьох, швидко змінює освітній ландшафт. Це дослідження презентує сприйняття студентами інтеґрації технологій для вдосконалення програм підготовки вчителів STEAM у часи VUCA, а також фактори впливу й майбутні виклики для цілісної оцінки окресленої проблеми. Авторами обрано метод описового опитування. Об’єктом дослідження є студенти закладів вищої освіти, а цільовою групою – викладачі університетів, які викладають дисципліни, дотичні до STEAM. Дані були зібрані за допомогою розробленої та валідованої анкети із загальним індексом надійності альфа Кронбаха 0,81. Зібрані дані проаналізовано описово (з використанням частоти, відсотків, перцентильного ранжування) та інференційно (з використанням багаторівневого факторного аналізу ANOVA) з рівнем значущості 0,05. Виявлено, що студенти позитивно сприймають інтеґрування технологій для вдосконалення програм підготовки вчителів STEAM. З’ясовано, що фактором, який найбільше впливає на упровадження технологій для вдосконалення програм підготовки вчителів STEAM, була наявність належної інфраструктури, тоді як недостатній доступ до технологічної інфраструктури був визнаний найбільшою проблемою. Результати цього дослідження лягли в основу висновку, який показує, наскільки важливою є технологічна інтеґрація в педагогіці. Таким чином, педагогічні навчальні заклади повинні мати новітні ресурси і використовувати їх для стимулювання розвитку студентів, включаючи м’які навички, одночасно підтримуючи акцент STEAM-освіти на креативність та інновації як ознаки винахідницьких відкриттів.

Ключові слова: технологічна інтеграція та педагогіка, 4IR, STEAM освіта, навчання, підготовка вчителів.