

The Role of Information and Communication Technologies (ICTS) In Promoting Stem Education in South Africa: Implication for Teacher Education and Development

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Abstract

Despite the aspirations of the broad populace and the commitments of the leaders of the country, South Africa is struggling to overcome the effects of apartheid and colonialism. This paper explores the role of ICTs in promoting STEM education. This is a desktop review paper that discusses an overview of STEM education, the intersection of ICTs and STEM education, the transdisciplinary role of technology in STEM, the fundamental roles of ICTs in promoting STEM education in South Africa and the implication of ICT in STEM for teacher education and development. The paper concludes that the role of Information and Communication Technologies (ICTs) in promoting STEM (Science, Technology, Engineering, and Mathematics) education in South Africa is critical to offer transformative potential in enhancing STEM education by improving access, engagement, and instructional effectiveness, and their integration into teacher education and development. It must progressively address shortcomings in its education systems to realise an urgently improved economy and to overcome historical injustices.

Keywords: *Information and Communication Technologies (ICTs), STEM Education, Teacher Education and Development, South Africa.*

Introduction

In recent years, the United Nations member states have demonstrated an increasing dedication to utilising information and communication technologies (ICTs) to achieve universal education goals. This interest is particularly reflected in Sustainable Development Goal 4 (SDG 4), which acknowledges the potential of ICTs to help modernise education delivery and help educational systems adapt to new challenges. Utilising digital technologies to enhance learning outcomes, quality, and accessibility is specifically encouraged by the 2015 Incheon Declaration of Education 2030. Despite this agreement, it is nonetheless true that policymakers have paid very little attention to the prospects presented by new educational technology models to improve STEM teaching and learning, particularly in Africa and South Africa, the study's focus.

The growing demand for information and communication technology (ICT) abilities and the rising demand for STEM (science, technology, engineering, and mathematics) skills are two issues facing the South African educational system. Computer literacy is encouraged by the current educational policy in South Africa. ICT is utilised for teaching and learning in STEM fields as well as outside of them, according to studies (Mumcu, Atman-Uslu, & Yildiz, 2022). However, the scarcity of computers and other ICT tools, as well as the professional competence that instructors in these learning areas require, limits the potential of ICT to improve STEM education in South Africa. In light of this, this article makes the case for ICT-infused STEM education to develop the knowledge and abilities necessary to meet the expectations of South African society in the twenty-first century. Science, Technology, Engineering, and Mathematics (STEM) education in South Africa is discussed in the study, along with the potential and limited integration of ICTs.

In the context of STEM education—which emphasises Science, Technology, Engineering, and Mathematics—information and communication technologies (ICTs) are digital tools and resources used to store, process, communicate, and create information. ICTs are a broad category of technical resources and tools that improve research, teaching, and learning. Students and teachers may interact, communicate, obtain information, and solve problems via digital platforms, thanks to ICTs in STEM education. Computers, software, multimedia platforms, digital simulations, data-gathering instruments, internet

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resources, and interactive learning environments are some examples of these technologies. ICTs support experiential, inquiry-based learning, which is critical for understanding STEM concepts. ICT tools, including educational software and simulations, make abstract STEM subjects more relatable by enabling students to visualise difficult ideas, such as physics phenomena or molecule structures in chemistry. Students may explore, design, and test models without the need for actual resources, thanks to engineering design software, programming tools, and virtual laboratories. ICT enables real-time data collection, modelling, and analysis in fields like engineering and mathematics, which enhances students' comprehension of real-world applications (Barakabitze et al., 2019).

STEM courses are now more accessible because of Learning Management System (LMS) platforms like Moodle or Blackboard, which streamline content delivery, evaluation, and student-teacher interaction. Students may code, simulate, and solve STEM-related problems with the help of programs like Scratch, Python, and MATLAB, which improve computational thinking. With the use of these immersive tools, students can investigate STEM subjects in a three-dimensional setting, such as analysing virtual organisms in biology or modelling a physics experiment in space (Hrynevych et al., 2021). Students and teachers may work together on projects, share data, and communicate in real-time thanks to collaborative tools like Google Workspace, Microsoft Teams, and cloud-based platforms.

Some advantages of ICT in STEM education include increased student engagement, which is made possible by interactive, visual, and hands-on learning—all of which are made possible by ICT technologies. ICTs make it possible for adaptive learning technology to accommodate each student's particular demands and learning style. The same STEM education curriculum is available to students from different backgrounds, and they may engage in global learning communities and access top-notch resources. Students who are exposed to ICTs in STEM classes are better able to develop important 21st-century skills, including digital collaboration, data literacy, coding, and critical thinking (Barakabitze et al., 2019).

Some places have limited access to reliable internet and ICT equipment, which can exacerbate the digital divide in STEM education. This is one of the issues associated with ICT in STEM education. Teachers need to be adept at using ICT technologies, which frequently call for continuous assistance and training. It can be difficult to successfully include ICT in the STEM curriculum; thorough preparation and alignment with learning objectives are necessary (Barakabitze et al., 2019).

STEM Education in South Africa: An Overview

To address South Africa's socioeconomic issues, including income disparity, joblessness, and technological advancement, STEM education is a crucial area of concentration. It seeks to develop a workforce that can solve national problems, advance innovation, and enhance infrastructure. The importance of STEM education as a major force behind economic development and progress has been acknowledged by the South African government. As a result, enhancing STEM instruction in schools and colleges has been a top priority for the Department of Basic Education (DBE) and the Department of Science and Innovation (DSI). Encouraging more students to enrol in and succeed in STEM topics is the goal of the 2019 National Development Plan (NDP) and Action Plan. The National Youth Policy also aims to develop young South Africans' STEM-related skills (Mumcu et al., 2022). Notwithstanding the widespread acknowledgement of the potential benefits of STEM education and the initiatives taken by the South African government and relevant educational institutions, the country still has difficulties developing STEM education.

The infrastructure differences in South Africa's public education system, particularly between urban and rural schools, are a defining feature. Lack of skilled STEM teachers restricted learning resources, and poor access to labs and technology are some of the issues that many rural schools confront. The STEM curricula in South Africa's public schools are in line with the Curriculum Assessment Policy Statements (CAPS), which place a strong focus on critical thinking, problem-solving, and scientific investigation. Nonetheless, there are continuous attempts to update this curriculum to better reflect the technological developments of the twenty-first century. Better-resourced schools typically do better in STEM disciplines, particularly private and certain urban public schools. They frequently have access to stronger infrastructure, more skilled STEM professors, and more sophisticated technologies (Mumcu et al., 2022). The lack of qualified

STEM teachers is one of the issues affecting STEM education in South Africa. Because they have not had enough training in pedagogy and content expertise, many teachers are ill-equipped to teach STEM subjects. With an emphasis on developing skills in ICT, maths, and science instruction, initiatives like the TeachSA initiative and collaborations with academic institutions and non-governmental organisations strive to enhance teacher education. To enhance STEM teaching strategies, especially when integrating information and communication technologies (ICTs) into the classroom, teachers must engage in ongoing professional development (Barakabitze et al., 2019).

A key element of the government's plan to enhance STEM education is the incorporation of ICT into the classroom. Students can access digital learning resources, simulations, and live experiments using ICTs, but this requires dependable infrastructure, including devices, electricity, and internet connectivity. By giving resources to disadvantaged schools, initiatives like the ICT in Education Policy seek to close the gap. There are still issues, nevertheless, particularly in rural areas with inadequate infrastructure, which results in differences in the quality of schooling. Initiatives from the private sector, such as tech firms and non-governmental organisations, are also contributing to the introduction of resources and technology in schools (Hrynevych et al., 2021).

Innovative approaches to STEM education, including robotics workshops, coding boot camps, and the encouragement of girls in STEM through various mentorship programs, have been developed as a result of collaboration between the government, corporate sector, and non-governmental organisations (Mumcu et al., 2022). To boost interest and proficiency in these areas, the government and a few private organisations have also set up STEM-focused educational institutions, such as technical high schools and science academies. Schools that collaborate with the South African Mathematics and Science Foundation and programs from the Square Kilometre Array (SKA) project, which provides astronomy and astrophysics training, are two examples. The University of Cape Town (UCT), Stellenbosch University, and the University of the Witwatersrand (Wits) are a few of South Africa's top universities in STEM subjects. These universities are renowned for their work in fields like biotechnology, astronomy, data science, and engineering (Hrynevych et al., 2021).

Increasing the number of women in STEM disciplines is a major priority in South Africa. The goal of programs like TechWomen, Women in STEM South Africa (WISSA), and African Women in Science and Engineering (AWSE) is to empower women and promote their participation in STEM fields that have historically been dominated by men. To improve gender parity in the scientific and technology fields, schools, colleges, and businesses frequently provide workshops, mentorship programs, and scholarships to encourage girls and women to pursue STEM fields. Although delivering high-quality, egalitarian STEM education in South Africa is fraught with difficulties, there have been encouraging advancements. Public-private collaborations, ICT integration, and government policy are important forces behind bettering STEM education results. Continued investment in STEM infrastructure, teacher training, and diversity will be essential in determining the future of the country if South Africa is to close its educational gaps and promote innovation (Mumcu et al., 2022).

The Intersection of ICTs and STEM Education in South Africa

For pupils in South Africa to be ready for the challenges of the twenty-first century, ICT and STEM education must be combined. ICT resources have revolutionised conventional teaching methods and are especially pertinent to improving STEM education in the nation. ICT integration is essential for enhancing STEM education results, resolving access issues, and promoting economic growth as South Africa works to close skills, innovation, and infrastructure gaps (Mumcu et al., 2022).

A vast array of digital learning resources, such as interactive simulations, coding platforms, virtual laboratories, and e-textbooks, are made available through ICT. Because they enable students to interact with complex concepts through interactive and visual representations, these technologies are extremely important in STEM education. For instance, students can perform virtual experiments in physics, chemistry, and biology classes using simulations, which enhances their comprehension of scientific concepts without requiring costly lab equipment. Even in elementary school, students are being taught

coding and computational thinking abilities, which are crucial in today's STEM professions, through the use of coding platforms like Scratch, Python, and Blockly (Hrynevych et al., 2021).

STEM resources and conventional scientific labs are limited in many underfunded schools, especially in rural locations. ICT can act as a link, offering virtual resources in place of tangible ones. Initiatives like Vodacom's e-school program provide free online learning resources for science and math courses that are available on PCs and mobile devices. Through public-private collaborations, ICT laboratories with computers, internet connectivity, and educational software are being implemented in several schools, guaranteeing that students in underprivileged areas are also exposed to digital resources that are essential for STEM education. Particularly in places with little infrastructure, tablet-based learning and mobile learning platforms are becoming adaptable options. For example, schools nationwide now have thousands of tablets loaded with STEM education materials because of government and non-profit initiatives (Terzieva, 2020). The lack of certified educators with current knowledge of STEM subjects and digital technologies is a major obstacle in South Africa's STEM education system. Online teacher training programs are one way that ICT can close this gap: Teachers can incorporate ICT into their teaching methods by taking advantage of online courses and certifications offered by platforms such as Google for Education and Microsoft Education (Mumcu et al., 2022).

To assist them in creating and delivering more captivating STEM lessons, educators are provided with a vast assortment of digital resources. Open-source resources for STEM disciplines are available on platforms like Siyavula, which help teachers better explain complex ideas. ICT Professional Development Organisations such as SchoolNet South Africa often host workshops and training programs on the use of digital tools for teaching STEM subjects, which enhances teachers' digital literacy and their capacity to effectively engage students (Mumcu et al., 2022). In STEM education, inquiry-based learning is crucial since it motivates students to investigate, enquire, and try new things. ICT facilitates this by giving students access to platforms that let them conduct independent research. For example, students can undertake independent research on STEM-related issues thanks to internet research tools, which give them access to a wealth of data, academic articles, and research papers. This encourages creativity, critical thinking, and problem-solving. ICT tools allow students to gather and analyse data in real-time in disciplines like engineering, physics, and mathematics. By connecting theoretical information with real-world applications, this makes learning more applicable and meaningful (Terzieva et al., 2020).

ICTs give South African students the chance to work together with classmates both domestically and abroad. Platforms such as Google Classroom, Microsoft Teams, and Zoom support collaborative projects involving robotics, engineering design, and coding (Hrynevych et al., 2021). Programs like the SKA (Square Kilometre Array) Youth Programs and the African School on Internet Governance introduce students to cutting-edge STEM subjects like astronomy and provide chances for them to work with international organisations and teams. This enables South African students to engage in global innovation and establish connections with STEM groups throughout the world (Mumcu et al., 2022).

Because gender imbalance in STEM is a serious problem everywhere, including in South Africa, ICT can be used as a tool to overcome it. Through specialised programs, mentorship, and inclusive learning environments, ICT provides creative approaches to involving girls in STEM education. By providing virtual mentorships, coding workshops, and exposure to female role models in STEM fields, programs such as the TechnoGirls initiative employ ICTs to encourage young girls to pursue STEM careers. The gender gap in STEM participation can be closed by allowing girls who might encounter social or cultural obstacles to participate in STEM programs in person to learn online. The digital gap continues to be a major obstacle despite initiatives to include ICT in education. Access to essential technology, such as computers, the internet, and dependable electricity, is frequently restricted in rural and underprivileged schools. This prevents ICT-enabled STEM education from being distributed fairly (Hrynevych et al., 2021). To close the digital gap, infrastructural development—such as broadband internet and electricity—is just as important as providing ICT hardware, especially in developing nations. For some schools, the expenses of buying digital gadgets, maintaining ICT infrastructure, and training teachers can be unaffordable. To guarantee the long-term integration of ICT into South African education, sustainable funding models are required, notwithstanding efforts by the public and private sectors to reduce these costs (Terzieva et al., 2020).

The Transdisciplinary Role of Technology in STEM

By serving as a link between and integrating the domains of science, technology, engineering, and mathematics, technology plays a crucial transdisciplinary role in STEM education. Technology makes it possible to approach problem-solving, learning, and creativity collaboratively and holistically, in contrast to traditional discipline boundaries. In this sense, technology is not only a STEM subject but also an essential facilitator that cuts across disciplines, enabling the smooth application of engineering principles, mathematical reasoning, and scientific notions. Through the provision of instruments and platforms that promote interdisciplinary cooperation, technology unifies science, engineering, and mathematics. In STEM education, professionals and students can investigate complicated issues that call for expertise from several professions by using technological tools like data analytics platforms, digital simulations, and computational software. Developing solutions for real-world issues, such as healthcare innovation and climate change, requires this integration (Hidroğlu & Karakaş, 2022).

Technology in science makes it possible for researchers and students to perform experiments and visualise scientific phenomena that would not otherwise be possible in advanced simulations, virtual labs, and real-time data processing. For instance, modelling molecular structures and biological processes using computational biology and bioinformatics goes beyond conventional biological research techniques. With the use of programs like MATLAB, Python, or GeoGebra, students may solve complicated equations, build models, and view data in real-time, improving mathematical modelling and statistical analysis in mathematics. In disciplines like engineering, economics, and physics, these technologies make it possible to put mathematical theories into practice (Hidroğlu & Karakaş, 2022). From CAD software for design to 3D printing for quick prototyping, technological breakthroughs are revolutionising engineering sectors. A more effective engineering process is produced by these technologies, which enable engineers to test ideas, visualise structures, and refine designs before real implementation.

Some research collaborations between educational institutions and other stakeholders have been informed by the growing need for advancement in STEM education. These partnerships allow students to learn about and experience cloud computing firsthand (Bull et al., 2019). By enabling experts and students to simulate, experiment, and model different scenarios, technology in STEM education promotes creativity, critical thinking, and problem-solving skills. This means that in a transdisciplinary setting, technology aids students in making connections between ideas from several STEM disciplines (Aslan-Tutak, 2020). These technologies are commonly used to assess complicated datasets, make predictions, and optimise systems in a variety of STEM fields. Machine learning, for instance, combines aspects of science, technology, and mathematics to evaluate climate data and forecast future environmental changes in environmental science. Robotics exemplifies the transdisciplinary function of technology by fusing engineering, technology, and mathematics. Coding, mathematics methods, and engineering principles are frequently used in robotics projects, combining different fields into a cohesive educational process (Aslan-Tutak, 2020).

Numerous STEM fields make extensive use of these technologies to examine intricate data, make predictions, and enhance systems. For instance, in environmental science, machine learning integrates aspects of science, technology, and mathematics to assess climate data and forecast future environmental changes. Engineering, technology, and mathematics are all combined in robotics, illustrating the transdisciplinary nature of technology. Typically, robotics projects use engineering principles, mathematics methods, and coding, combining various fields into a cohesive educational process (Aslan-Tutak, 2020).

Technology serves as a common ground where STEM disciplines intersect, and it is frequently necessary to take a transdisciplinary approach when using it to solve real-world problems and challenges. For instance, engineering, physics, and math skills are needed to design and build renewable energy systems (such as wind or solar) in addition to technical tools for modelling, design, and implementation (Ring-Whalen et al., 2018). Technology is essential to the development of medical devices and diagnostic instruments that incorporate engineering, physics, and biological knowledge. Technologies that combine science and engineering to give healthcare solutions include telemedicine, genome sequencing, and bioprinting (Cansu & Çakıroğlu, 2020).

The capacity of technology to unify several disciplines under a single platform is demonstrated by platforms like GitHub, which enable collaborative development in fields like software engineering, where engineers, mathematicians, and programmers work together on projects. Technology such as virtual reality (VR) and augmented reality (AR) enable students to interact with engineering models and scientific ideas in immersive settings. For instance, AR enables students to better comprehend the spatial linkages in their projects by superimposing engineering plans onto actual environments. As a result, the educational process becomes more dynamic and comprehensive (Bull et al., 2019).

Learning to code is a fundamental component of STEM education and is required for programming and computational thinking. Because programming tools like Scratch, Python, and C++ need applied knowledge (engineering), logical thinking (mathematics), and practical problem-solving (science), they are inherently transdisciplinary. (Bull and others, 2019). Scientists and engineers may analyse and present complex datasets in visually relevant ways with the help of software like Tableau, R, or Excel. These resources facilitate the accessibility of statistical and mathematical data, promoting scientific and engineering research and assisting students in making connections between various STEM fields. By enabling objects to gather and share data on their own, the Internet of Things (IoT) combines engineering and technology. This can be used to solve real-world problems across multiple fields, such as using IoT in agriculture (science), industrial automation (engineering), and data analytics (mathematics) (Cansu & Çakıroğlu, 2020).

Civil engineering, data science, and computer programming expertise are necessary for creating smart infrastructure, which is made possible by technologies like artificial intelligence (AI), the Internet of Things (IoT), and big data analytics. Sustainable development, intelligent urban design, and resource efficiency are made possible by this transdisciplinary approach (Sivaraj et al., 2019). Students are exposed to a range of career options and skills pertinent to the current workforce through the integration of technology throughout STEM disciplines. Because STEM technology is transdisciplinary, students are prepared to work in fields including data science, biomedical engineering, and environmental technology—all of which require a variety of abilities (Dare et al., 2019).

The need for people who know how to use technology to tackle challenging technical and scientific problems is increasing as companies shift towards automation and artificial intelligence. Students who are prepared with transdisciplinary technology abilities are more likely to be able to adjust to changing positions that call for proficiency in systems engineering, data analysis, and coding. Technology gives students the means to design, prototype, and commercialise products, allowing them to investigate entrepreneurial endeavours in STEM subjects. For instance, students can more easily experiment with building working prototypes of their ideas thanks to 3D printing and inexpensive computing platforms like Arduino and Raspberry Pi (Helvacı et al., 2021).

Key Roles of ICTs in Promoting STEM Education in South Africa

ICTs give teachers and students access to a multitude of digital tools, including simulations, virtual labs, online courses, and interactive content that can help simplify difficult STEM subjects. There are few high-quality textbooks and lab equipment available in many South African schools that are underfunded and located in rural areas. By making e-books, digital libraries, and virtual STEM activities accessible, ICTs can close this gap (Barak, 2018; Mumcu et al., 2022).

Students participate in more active learning experiences thanks to ICT resources like interactive software and virtual simulations. These tools facilitate cooperation, problem-solving, and real-time experimentation—all of which are essential in disciplines like physics and mathematics. Additionally, ICT can support inquiry-based learning, a pedagogical strategy that works especially well in STEM education. For instance, students can experiment with variables in ways that aren't feasible in a conventional lab setting by utilising software like PhET to simulate chemical processes or physics experiments (Mumcu et al., 2022). ICTs facilitate online education and distance learning, which is crucial for students in underserved or remote parts of South Africa, where it may be difficult to find qualified STEM teachers. Students can access STEM education from any location by using digital platforms, which helps close the nation's socioeconomic and

geographic gaps. High-speed internet connections are made available to schools by online education platforms like the South African National Research Network (SANReN), which facilitates remote learning.

Personalised learning through data-driven education is made possible by ICTs. Learning management systems (LMS) and assessment tools allow teachers to monitor students' progress in real-time and modify their lessons to suit each student's needs. All children should have the chance to thrive in STEM courses, and data analytics can assist in identifying underperforming pupils and offering prompt intervention. For instance, Google Classroom's personalised feedback feature and Smartick's adaptive learning platform enable teachers to offer focused interventions depending on each student's performance.

Implications of ICT into STEM for Teacher Education and Development

Teachers' proficiency with these tools is essential to the successful integration of ICTs into STEM education. In South Africa, where many teachers still lack the knowledge or self-assurance to integrate ICT into their lesson plans, this has important ramifications for teacher development and education (Mumcu et al., 2022). ICT competency must be given top priority in teacher education programs to promote successful STEM education. To efficiently and creatively teach STEM subjects, teachers need to be taught in the use of digital tools, platforms, and resources. Knowing how to use ICT in lesson preparation, instruction, and assessment is part of this (Barak, 2018).

Digital literacy, the pedagogical use of technology, and familiarity with STEM-specific software or online platforms should be the main topics of teacher training programs. Considering how quickly technology is developing, it is essential to pursue ongoing professional growth. Teachers must receive continual training to stay current with new resources and approaches. STEM teachers should have regular access to online professional learning communities, mentorship, and ICT training workshops from the Department of Basic Education (DBE) and higher education institutions. With an emphasis on incorporating ICTs into every facet of teaching and learning, the DBE's e-education approach promotes professional development for educators (Mumcu et al., 2022).

Increased teacher cooperation and peer learning are also made possible by ICT tools. Teachers can exchange best practices, resources, and tactics for teaching STEM courses with technology through online professional communities or platforms like teacher forums and social media groups. Teachers can share knowledge about ICT use in the classroom and learn from one another globally through platforms like Microsoft Education Community. Blended learning strategies, which integrate traditional in-person instruction with digital resources, ought to be emphasised in teacher education programs. This creates a hybrid learning environment that can adjust to the demands of various students by assisting teachers in becoming more at ease with technology and preparing them to use comparable techniques in their classrooms (Barak, 2018). Teachers in rural and underdeveloped areas, where access to ICT infrastructure and training opportunities may be restricted, require special attention. This necessitates focused interventions to guarantee fairness in teacher education, including partnerships with digital companies, mobile training units, and government-led programs that give teachers and schools in these areas the gadgets and internet connection they need (Barak, 2018).

Although integrating ICT into STEM education in South Africa has many advantages, several issues must be resolved. This includes but is not limited to, infrastructure issues; many remote schools continue to lack internet connectivity, dependable electricity, and the hardware required for ICT integration. Partnerships between the public and private sectors are essential to addressing these infrastructural issues. Resistance from Teachers Due to perceived complexity, time constraints, or a lack of confidence, some educators may be reluctant to embrace ICT. To solve this issue, as well as the sustainability one, change management techniques and support networks are required. ICT projects must be long-lasting and not exclusively dependent on outside funds or temporary endeavours. Investment in local capacity-building and long-term planning are crucial (Mumcu et al., 2022).

Conclusion

ICTs are essential for advancing STEM education in South Africa because they increase student access, engagement, and the calibre of instruction. However, teachers must be well prepared through focused instruction and continual professional development to use ICTs effectively. South Africa can create a more effective and equitable STEM education system and better prepare its students to participate in a global economy driven by technology by giving educators the tools they need to fully use digital tools. To fully reap the benefits of ICTs in STEM education, issues with fairness, infrastructure, and teacher development must be resolved. By boosting learning opportunities, increasing resource accessibility, and giving students the tools they need for the future, ICTs revolutionise STEM education. But for implementation to be successful, infrastructure issues must be resolved, teacher preparedness must be guaranteed, and curricula must be created that make the most of ICT's potential for teaching and learning.

By serving as a unifying tool that makes it easier to integrate science, mathematics, engineering, and technology itself, technology plays a critical transdisciplinary role in STEM education. In addition to improving creativity and problem-solving skills, it also promotes teamwork and makes it possible to apply information practically in a variety of fields. To solve complicated global issues and prepare students for future employment in a world that is becoming more technologically advanced and interconnected, STEM disciplines and technology must come together. Information and communication technologies (ICTs) play a crucial role in advancing STEM (science, technology, engineering, and mathematics) education in South Africa, particularly when it comes to creating a workforce that can fulfil the demands of the economy in the twenty-first century. By increasing access, engagement, and instructional efficacy, ICTs have the potential to revolutionise STEM education. Their incorporation into teacher preparation programs has important ramifications for the nation's overall STEM teaching standards.

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