EUROPEAN JOURNAL OF STEM EDUCATION

European Journal of STEM Education,
2024, 9(1), 15
ISSN: 2468-4368

lectito

Bridging Gaps in STEM Education: The Case for Dedicated Learning Centres in South African Townships and Rural Areas

Samuel Ntsanwisi [1*]

[1] *Durban University of Technology*, SOUTH AFRICA

*Corresponding Author: samsrecp@gmail.com

Citation: Ntsanwisi, S. (2024). Bridging Gaps in STEM Education: The Case for Dedicated Learning Centres in South African Townships and Rural Areas. *European Journal of STEM Education*, 9(1), 15. https://doi.org/10.20897/ejsteme/15481

Published: October 16, 2024

ABSTRACT

This article explores the critical need for improved Mathematics, Science, Engineering and Technology (STEM) education in South African townships and rural areas, where persistent challenges in teaching methods and resource accessibility have hindered the development of these crucial subjects. The perception of Mathematics and Science as complex subjects, coupled with societal pressures to prioritise less 'challenging' subjects, has resulted in a quantity-over-quality approach to education. This article argues for establishing dedicated Mathematics, Science, Engineering, and technology centres in these underserved regions, drawing upon global research findings that underscore the importance of continuous improvement in STEM subjects for individual and national advancement. The proposed centres aim to address educational disparities by providing innovative teaching methods, resource access, and mentorship programs. These proposed centres intend to rectify educational disparities by offering innovative teaching methods, improved resource access, and mentorship programs. Through examining successful case studies and potential challenges, this article calls for a comprehensive approach to reshape the STEM education landscape in South African townships and rural areas, contributing to a more equitable and robust educational system.

Keywords: empowerment, STEM education, underserved communities, learning centres, South Africa

INTRODUCTION

South African Mathematics and Science education is recognised globally as among the worst (Mabena and Mokgosi, 2021), hindering learners' access to higher education and essential work skills. Maarman and Lamont-Mbawuli highlight the persistent issues of high dropout rates and suboptimal pass rates in Grades 7–12, with identified improvement methods facing implementation challenges (Maarman and Lamont-Mbawuli, 2017). Weybright *et al.* (2017) emphasise the global link between education and health, particularly addressing the alarming dropout crisis in South Africa and predicting factors such as gender, living arrangements, smoking, and motivation. The preceding underscores the urgency for comprehensive prevention programs and a transformative shift in the perception of teaching as a profession to address the deep-rooted challenges in the South African education landscape.

In pursuing sustainable economic growth, prioritising Mathematics and Science education cannot be overstated (Weng, 2017). While South Africa faces numerous challenges in its education system (Sutherland, 2020), particularly in mathematics and Science (Jojo, 2020), advocating for a shift in perception is crucial. While addressing these challenges is imperative, it is essential to recognise the broader spectrum of Science, Technology, Engineering and Mathematics (STEM) subjects and their pivotal role in sustainable economic growth (Van Gend, 2023).

This essay contends that fostering a genuine belief that anyone can excel in these subjects given proper teaching and accessible resources (Ríordáin *et al.*, 2016) is critical to unlocking individual potential and national economic prosperity.

South Africa's economic landscape is evolving, demanding a workforce with advanced skills and knowledge (Reddy *et al.*, 2016). Mathematics and Science, often relegated to the periphery in education discourse (Schaeffer *et al.*, 2021), are the linchpin of technological innovation, research, and development – essential for a competitive and thriving economy (Weng, 2017). By underscoring the significance of these subjects, this study paves the Way for a future workforce that can contribute significantly to the country's economic growth. By instilling confidence in every learner's ability to excel in these subjects and addressing systemic challenges, this study paves the Way for a more robust, equitable, and prosperous future.

Dispelling the myth that Mathematics and Science are exclusive domains reserved for a select few is paramount (Chestnut *et al.*, 2018). Accessible and quality education in these subjects can dismantle preconceived notions about inherent talent, emphasising that anyone, irrespective of background or initial proficiency, can grasp these concepts when provided with effective teaching (McKinney and Frazier, 2008). Such a mindset shift is instrumental in maximising the untapped intellectual potential across diverse communities in South Africa.

Investing in the comprehensive development of STEM subjects is a strategic solution to bridge existing socio-economic gaps (Walker *et al.*, 2019). By ensuring that all students have access to well-trained educators, modern teaching methodologies, and adequate resources (Chisom, Unachukwu and Osawaru, 2024), an environment where learning is inclusive and equitable can be created. This inclusivity addresses immediate educational challenges and lays the foundation for a more balanced and dynamic workforce.

While urban areas may boast established science centres (South African Agency for Technological Advancement, 2024), the imperative for STEM centres in townships and rural areas lies in fostering inclusivity and addressing educational disparities, ensuring that children across diverse socio-economic backgrounds have equitable access to transformative Science, technology, engineering, and mathematics (STEM) education. In sync with this article, the Department of Science and Innovation, in collaboration with the Departments of Basic Education in the Eastern Cape, has diligently worked to establish a science centre in rural Cofimvaba, Eastern Cape, South Africa, which reflects a solid commitment to advancing science education in rural regions and fostering grassroots innovation (Campbellscience, 2024). Furthermore, the South African Department of Education (2017) references the Nelson Mandela Foundation's report, Emerging Voices (2005), highlighting the crucial need to provide rural schools with quality education to protect children's well-being and promote social and political engagement within these communities. It also mentions the advocacy for a revised definition of 'rural' and a customised classification of rural schools by the Rural Education Research Team, aiming to accurately capture the unique characteristics of South Africa's rural educational landscape. The recommended flexible definition considers the dynamic nature of rural lifestyles, including factors like distance and the distinctive challenges rural schools face.

Through collective efforts and strategic investments in education, South Africa can position itself as a hub for innovation, thereby driving sustained economic growth. In addition, to ensure broader accessibility and address educational disparities, this study explores the establishment of STEM Centres in townships and rural areas of South Africa. These centres can serve as focal points for enhancing teaching resources, providing additional support to learners, and fostering a conducive learning environment, thus advancing mathematics and science education nationwide.

METHODOLOGY

This article deploys the literature review methodology, which involves a comprehensive analysis of scholarly works and research findings to illuminate the challenges in Mathematics and Science education within South African Townships and rural areas. Boumezrag (2022) highlights the critical nature of literature reviews in critically evaluating existing knowledge, theories, methodologies, and research findings, enabling researchers to build innovative ideas.

By synthesising existing literature, the study delves into the perception issues surrounding Mathematics and Science, including the impact of teaching methods and marketing. Global research is employed to benchmark the current state against international standards, underlining the urgency for continuous improvement. The literature review informs the Proposal for dedicated learning centres, supported by successful case studies. This approach ensures the recommendations are grounded in a well-established knowledge base, reinforcing the need for transformative changes in mathematics and science education in these underserved regions.

LITERATURE REVIEW

The Perception of Maths and Science as Complex Subjects

Examining perceptions of mathematics and science difficulty reveals pervasive challenges impacting students and prospective teachers, emphasising gender-specific beliefs (Jenifer *et al.*, 2024) and age as a determinant of primary children's attitudes (Murphy and Beggs, 2003). Dahiya (2014) addresses the common perception of mathematics as a dry, routine, complex, and seemingly irrelevant subject in schools, often needing more discovery and imagination. Chala, Kedir and Wami (2020) state that physics is recognised as one of the most challenging and influential subjects within the natural sciences, often posing difficulties for students. The author further indicates a direct link between a disadvantaged school environment and students' attitudes toward physics, with cultural beliefs playing a significant role in shaping students' misconceptions and influencing their understanding of natural phenomena in the physics classroom (ibid). Mazana, Montero and Casimir (2018) highlight a significant but weak correlation between attitudes and academic performance in mathematics, while Kunwar (2020) addresses Maths phobia, attributing it to various factors, attributing the issue to factors such as curriculum structure, school facilities, instructional techniques, teachers' performance, technology use, and evaluation systems, stressing the need for collaborative efforts. Outside of South Africa, Ali (2008) investigates students' attitudes and challenges in learning mathematics in Pakistan, emphasising the importance of curriculum design aligned with working memory limitations for meaningful learning. Ozdemir and Onder-Ozdemir (2017) focus on vocational high school students in Turkey, stressing the role of Mathematics as a gateway to societal progress and the need to address factors shaping students' beliefs in success or failure. Thus, a global concern surrounds the perception of Mathematics as a challenging subject. The above studies underscore a widespread phobia across age, gender, and technological awareness, emphasising the urgency of targeted interventions and collaborative measures to foster positive attitudes and prevent declining interest in these subjects.

Teachers are frequently implicated in contributing to the phobia of Mathematics and Science through their influence on teaching methods and perceptions. Hurley, Butler and McLoughlin (2024) analyse immersive learning programs for STEM teachers, revealing variations in motivation and structures that impact personal and professional development. Thi To Khuyen *et al.* (2020) surveyed Vietnamese teachers, finding positive views on STEM education, particularly among science and higher-educated teachers, providing insights for effective professional development. Additionally, Louie (2017) exposes exclusionary practices in math classes, Stols *et al.* (2015) address the underutilisation of online resources by South African Maths teachers, and Leavy, Hannigan and Fitzmaurice (2013) examine tensions in prospective secondary Maths teachers' attitudes. Kite and Park (2024) underscore the importance of integrating computational thinking (C.T.) into education, advocating for frameworks, professional development, and exemplars to guide successful incorporation into core STEM curricula. The study highlights the promise of an unplugged and process-based approach to C.T./science integration, emphasising the need to support teachers in their efforts, particularly in algorithm creation. Hait and Mishra (2018) explore students' fear of Maths, concluding that alternative teaching methods may alleviate anxiety, emphasising the need for comprehensive pedagogical reforms. These studies collectively contribute insights into the challenges, perceptions, and potential solutions in mathematics and science education, from early childhood to secondary teacher preparation.

The Importance of Maths and Science

Mathematics, Science, and technology play crucial roles in our daily lives, influencing various aspects of modern living and shaping our understanding of the world. Jayanthi (2019) underscores mathematics' pivotal role in societal progress, noting its historical significance in advancing Science and technology. The multifaceted importance of mathematics, from commerce to cognitive benefits like reasoning and analytical thinking, is highlighted. Sami Khan and Salman (2020) emphasise mathematics' indispensability in personal growth, problem-solving, and effective communication, urging increased interest in mathematics across various fields. Hafni *et al.* (2020) recognise STEM education as a comprehensive approach to enhancing skills and addressing Industry 4.0 demands in Indonesia. Oliveros Ruiz *et al.* (2014) stress early science education's critical role in cultivating future scientists for research and innovation in emerging economies—Tayur (2023) advocates for diverse practical applications of mathematical research, promoting innovation and fairness. Weng (2017) underscores the foundational role of derivative functions in enhancing visual thinking and practical skills. Hassi and Laursen (2015) introduce personal empowerment through mathematical learning. Bolstad (2023) explores global encounters with mathematical literacy, while Jackson *et al.* (2019) focus on social mechanisms influencing interest in science careers. Collectively, these studies advocate for inclusive, ethically guided, and practically impactful mathematics and science education.

The significance of STEM education and its impact extends to national progress and career opportunities. Yamada (2023) highlights the impact of technological advances on society and the importance of STEM proficiency in a knowledge-based economy. Venter and Rodrigues Van Niekerk (2018) address the shortage of technicians and engineers in South Africa, presenting a STEM-based approach to attract students. Markus and Mhlolo (2018) focus on the skills crisis in South Africa, emphasising the need for improvements in mathematics and sciences at the high school level. Adams *et al.* (2008) stress the pivotal role of STEM in the economy, national security, and global leadership, emphasising the need for an inclusive learning environment. Moore and Smith (2014) discuss the growth of engineering education research (EER) and the significance of STEM integration. Illustrating this as a continental phenomenon, Umar (2019) examines STEM education in Nigeria, addressing challenges and recommending strategies for effective implementation. Expanding the scope globally, Sellami *et al.* (2023) analyse high school students' STEM interests in Qatar. Encompassing a comprehensive perspective on STEM career choices, Ketenci, Leroux and Renken (2020) explore factors influencing high school students' STEM career choices, highlighting the persistence of gender gaps. In alignment, White and Smith (2022) investigate gender disparities in STEM graduates' employment destinations. Building on the evolving landscape of workforce education, Malyn-Smith *et al.* (2010) delve into program changes and the cultivation of 'technological thinking' among youth. In a contemporary context, Lin *et al.* (2023) investigate the integration of 3D printing in technology and engineering education, showcasing the ongoing advancements in educational approaches. Thus, STEM is promoted as a dynamic force in the broader education and career development

Navigating the Paradox: Matric Pass Rates, Quality of Education, and the STEM Dilemma in South Africa

While various authors present differing views on Grade 12 Mathematics and Science results in South Africa, a common thread emerges – the imperative to continually enhance these subjects. Studies by Sabelo Velenkosini (2022) and Ngobese (2013) advocate raising the minimum matric pass mark to 50% to align with quality education goals, ensuring better opportunities for learners. The Minister of Education, Angie Motshekga, lauds the 2023 NSC results, emphasising collaborative efforts and increased admissions to Bachelor studies. Noteworthy improvements in Mathematics and Science are highlighted (South African Department of Basic Education, 2023). Le Cordeur (2024) critiques the emphasis on quantity over quality in pass rates, pointing out that the pass rate, when considering dropouts, is much lower, around 55%. Laurence (2024) notes scepticism by Professor Kakoma Luneta, who raises concerns about conceptual understanding in Maths and Science education, questioning the government's 2030 goal for eligible learners. Bhagwonparsadh and Pule (2023) stress the importance of addressing the crisis in education, emphasising high standards and effective management. Collectively, studies by Mohaladi (2004), Malatji (2019), Kahn (2006), Shepherd and Van Der Berg (2020), Spaull (2015), Lam, Ardington and Leibbrandt (2011), Taylor (2010), Spaull and Kotze (2015) and Lubisi and Nekhwevha (2024) emphasise the need for comprehensive interventions and equitable resource distribution to enhance the overall quality of education in South Africa.

Examining the quality of a matric pass rate is crucial, as it significantly influences learners' future opportunities by facilitating access to higher education and the labour market. Ndlebe's (2022) study emphasises the advantage of possessing a Matric for employment, particularly post-matric education, showcasing the persistent bias towards educated individuals in the South African labour market. Kaleva *et al.*'s (2019) study in Finland underlines the influence of mathematics choices on university admissions, especially in STEM fields, urging efforts to address gender-based educational differences. Stephen's (2024) investigation into introducing technical Science in TVET colleges reveals a significant increase in pass rates for Physical Science, prompting a further examination of technical Science's effects on learners' readiness for vocational careers. Nong's (2016) research on career guidance in secondary schools highlights its neglect, recommending the elevation of Career Guidance to a whole subject. Maila and Ross (2018) identify linguistic constraints and a lack of career guidance as barriers to tertiary education in disadvantaged rural communities, stressing the need for improved linguistic skills and enhanced career guidance. Finally, Sahin, Gulacar and Stuessy's (2015) study emphasises the role of Science Olympiads in shaping students' career aspirations, reinforcing plans for STEM majors and enhancing twenty-first-century skills, with a call to address gender disparities in engineering careers. These studies underscore the importance of informed educational choices and comprehensive support systems for learners' successful transitions into higher education and future careers.

The Need for Improvement

Global research emphasises continuous improvement in mathematics and science education. Costa, Obara and Broietti (2020) conducted a systematic literature review, emphasising the need for more publications focused on critical thinking in Science and Mathematics Education. Anderson *et al.* (2020) examine STEM education in

Australasia, exploring challenges faced by teachers and advocating for further exploration of curriculum reforms and effective professional learning. Adams *et al.* (2018) discuss the transformative impact of science education on global challenges, calling for a more inclusive vision. Camanho *et al.* (2023) evaluate the performance evolution of European countries in education, noting both improvements and disparities. Finally, Pakarinen *et al.* (2024) compare teaching practices in Grade 1 classrooms in Finland and Japan, revealing the influence of cultural values. Tailoring educational approaches to align with cultural values could enhance the effectiveness and relevance of STEM education in rural and Township areas. This collective research underscores mathematics and science education's global dynamic and evolving landscape.

Noting the above, several studies delve into South Africa's performance on the global stage in terms of international assessments. Mullis and Martin (2019) present the outcomes of TIMSS 2019, showcasing global trends in mathematics and Science among fourth and eighth-grade students. East Asian countries, notably Singapore, lead in average mathematics scores. Reddy *et al.* (2019) focus on South Africa's participation in TIMSS 2019, revealing its comparatively low performance. Saal and Graham (2023) explore the use of educational technology in South African and German primary school mathematics, noting challenges and policy implications based on TIMSS 2019 data. Offering a different perspective, Jerrim (2023) explores the worldwide interest in International Large-Scale Assessments (ILSAs), revealing a decline in attention to assessments like TIMSS and PIRLS compared to PISA. While global interest has diminished, cross-country variations persist, with factors beyond assessment scores influencing attention. While Jerrim's work does not directly address improving mathematics and science marks in South Africa, it underscores the importance of considering factors beyond assessment scores and the need for a comprehensive understanding of global educational evaluations. In the broader context of the discussion, the core message remains imperative for South Africa to enhance its performance in mathematics and Science indirectly through the global assessment landscape, as highlighted by various authors, including Jerrim.

In rural and Township South Africa, collaborative research highlights the urgent necessity for ongoing enhancements in STEM (Science, Technology, Engineering, and Mathematics) education. Nemadziva, Sexton and Cole (2023) focus on addressing low throughput in science education in South Africa, identifying factors such as policy changes, resource limitations, and insufficient engagement strategies. Molaudzi (2021) delves into the misperceptions surrounding STEM in underprivileged African communities, emphasising the challenges schools face and the necessity for proper utilisation, study materials, and trained teachers to overcome negative perceptions. Tikly *et al.* (2018) comprehensively address challenges in STEM secondary education across Sub-Saharan Africa, proposing strategic options to enhance the quality, accessibility, and attractiveness of STEM education. Tlhabane (2023) aligns with the National Development Plan's (NDP) goals for South Africa, focusing on improving literacy, numeracy, mathematics, and Science outcomes through the Integrated National Strategy for Mathematics, Science, and Technology (MST) Education. Nyamunda (2021) highlights the lack of technological adaptation in South African education, revealing fault lines in international comparative results and urging for a transformation in Education 4.0. Mtotywa *et al.* (2024) emphasise the education system's restructuring to align with Industry 4.0, identifying 12 critical success factors essential for preparedness and competitiveness in developing countries, including South Africa. The overarching conclusion is the necessity for continuous enhancements in STEM education to meet the demands of the evolving global landscape.

Proposal for the Establishment of Maths and Science Centres

Studies advocate for establishing dedicated mathematics and science centres, emphasising their pivotal role in enhancing STEM education. Martins *et al.* (2024) showcase the effectiveness of a group mentoring program in enhancing fifth-grade students' self-regulation and school engagement. Murcia and Pepper (2018) evaluate SciTech STEM Centre's professional learning strategy, highlighting its positive impact on teachers and students in STEM, fostering increased confidence and deeper curriculum understanding. Nzekwe-Excel (2010) addresses student withdrawal in higher education, highlighting the positive influence of Mathematics Learning Development Centres on confidence levels and grades. Bhaird, Morgan and O'Shea (2009) explore the Mathematics Support Centre's positive impact on first-year students' grades, particularly benefitting those with weaker mathematical backgrounds. Hafni *et al.* (2020) underscore the importance of a STEM approach in education to equip students with skills for Industry 4.0, especially in the Indonesian context. Achiam (2023) and Gursoy (2020) advocate for out-of-school science education, discussing its role in addressing complex global challenges and providing practical learning experiences. Both studies suggest that having dedicated centres for learning outside the traditional classroom setting is crucial for a holistic and enriched educational experience. SAASTEC (2012) provides an overview of science centres, emphasising their role in interactive, inquiry-based learning and worldwide growth. Costanzo (2022) highlights the crucial role of science centres and museums in promoting science and technology literacy, fostering community engagement, and addressing Sustainable Development Goals (SDGs). Shana and Abulibdeh (2020) recommend providing secondary school students with practical lessons by ensuring well-equipped laboratories. The overarching theme is a collective call for establishing and supporting dedicated centres to advance mathematics and science education, emphasising their multifaceted benefits in enhancing learning outcomes and fostering broader societal development.

The potential benefits of improved teaching methods, enhanced resource access, and effective mentorship programs are central to proposing dedicated centres. Efe and Topsakal (2022) demonstrate the positive impact of science centres on secondary school students' perceptions of the nature of science, indicating increased scientific knowledge levels. Rákosi and Pongrácz (2023) explore the role of science centres in promoting Sustainable Development, emphasising the need for further research and alignment with the United Nations' Sustainable development goals. Persson (2014) presents a pragmatic perspective on the global growth of science centres, highlighting their diverse impact and the importance of contextual learning. Osika *et al.* (2022) underscores the importance of Contextual Learning, advocating for incorporating real-world contexts to enhance student engagement, motivation, and meaningful connections. The article offers practical strategies, such as exploring real-world applications, incorporating workplace problems into assessments, and promoting industry engagement, asserting that contextualised learning contributes to a seamless transition from academia to the professional world (ibid). Falk *et al.* (2014) provide empirical evidence supporting the correlation between science centre visits and enhanced science and technology literacy outcomes for youth and adults. Lastly, the European Trade Union Committee for Education Eurydice Report (2022) investigates the role of education systems and teaching practices in improving students' knowledge and skills in mathematics and Science, highlighting the importance of learning support and socio-scientific questions. Noted in the report is the importance of learning support and socio-scientific questions in improving students' knowledge and skills in mathematics and Science, which aligns with the goals of dedicated science centres, as they are designed to provide interactive and engaging learning experiences, offering additional support beyond traditional classroom settings (South African Agency for Technological advancement, 2024). These studies underscore the multifaceted advantages of establishing dedicated mathematics and science centres, highlighting their crucial role in shaping effective education strategies and fostering broader societal development.

Successful Case Studies

In a comprehensive review of successful mathematics and science programs in similar socio-economic contexts, a meta-analysis by Nelson *et al.* (2024) underscores the efficacy of caregiver-implemented math interventions in informal learning environments, particularly benefiting children with weaker mathematical backgrounds while also emphasising the need for enhanced reporting quality and effective interventions. ArcelorMittal South Africa (2024) sponsors three Science Centres, fully funding their operations and employing 49 staff members to provide tuition in maths, Science, life sciences, and English for over 20,000 children and 500 teachers annually, aiming to address the national skills crisis by enhancing performance in scientific, engineering, and technological fields. Similarly, the Sci-Bono Discovery Centre's Core Function team achieved noteworthy milestones in 2022–2023, showcasing a 162% increase in Science Education Centre visitors (Sci-Bono Discovery Centre, 2023). Complementing this, Cigrik and Ozkan's (2015) study on the Bursa Science and Technology Center illustrates the positive impact of science centre visits on students' scientific skills, echoing the broader global trend of integrating Science, technology, society, and environment in contemporary education. In alignment with these findings, Faure (1999) details the establishment of Futropolis, a science and technology centre in Cape Town, aiming to promote techno-literacy through interactive exhibits, while Perkins (2014) highlights the evolving role of science centres, advocating for their engagement in global development challenges. Moreover, the accreditation of the Science and Technology Education Centre at UKZN (University of KwaZulu-Natal) (University of Venda Department of Marketing, 2021) and the inauguration of the Science Education Centre (Sci-Ed) at the University of the Free State (News24, 2022) signal significant strides in promoting STEM education and societal impact through innovative teaching and learning initiatives, underscoring the crucial role of science centres in nurturing scientific curiosity and skill development among learners in diverse communities.

Current Classroom Dynamics: Unveiling Challenges and Innovations

Numerous studies shed light on the intricate challenges of the classroom environment when implementing practical mathematics and science education in South Africa. Daniyan (2015) reveals hurdles intermediate-phase mathematics teachers face, including inadequate training, language barriers, overcrowded classes, and a lack of resources. Jojo (2020) delves into pervasive challenges in mathematics education, emphasising post-apartheid curriculum reforms and the distribution of mathematical knowledge. Badasie and Schulze (2018) demonstrate how action research can aid teacher professional development and underscore South Africa's shortage of qualified teachers in critical subjects. Mabena and Mokgosi (2021) identify factors influencing learners' confidence and performance, such as ill-discipline and inadequate pedagogical content knowledge. Grayson (2009) highlights the critical challenges facing science and mathematics education, calling it a national crisis. Tsanwani *et al.* (2014) investigate under-performance in mathematics, emphasising factors like motivation and self-concept. Graham (2023) addresses overcrowded classrooms as contributing to low mathematics achievement, indicating a pressing need for targeted interventions. Science centres could serve as transformative solutions, addressing these challenges by providing dedicated spaces for hands-on, inquiry-based learning, alleviating the strain on teachers, and fostering a more conducive environment for STEM education. The studies collectively emphasise the urgent need to overcome these intricate barriers through innovative educational approaches, making a compelling case for establishing and supporting mathematics and science centres in South Africa to enhance the overall quality of education in these crucial subjects.

Several studies suggest tangible solutions within the envisioned STEM centres. Waititu (2024) investigates strategies for integrating Information and Communication Technology (ICT) into mathematics lessons, emphasising the need for more ICT resources to enhance student engagement. Maarman and Lamont-Mbawuli (2017) discuss challenges in the South African education system and underscore the importance of diverse stakeholders, including teachers, learners, parents, and government, in improving educational outcomes. Mainali (2020) highlights the significance of diverse representation modes in mathematics teaching and calls for increased research in this area. Kukul (2024) explores pre-service mathematics teachers' positive attitudes towards digital storytelling, indicating potential integration into future teaching practices. Evans *et al.* (2024) study instructional strategies and find that teachers reducing cognitive load contribute to increased student motivation and achievement.

Another study (unspecified author) proposes using differentiated instruction to enhance teaching and learning, addressing challenges such as overcrowded classrooms and limited resources. Finally, Ziyadullaevna and Iskandarovna (2023) explore the positive impact of Information and Communication Technology (ICT) on students' performance expectancy and motivation in mathematics education, recommending its integration into teaching practices. Collectively, these studies offer practical insights for improving mathematics and science education.

The Transformative Impact of Science Centres on Quality, Quantity, and Preparedness on Higher Education

Several studies explore the link between improved foundational education in maths and Science and its positive influence on admissions and success rates in higher education. Brock (2010) emphasises the need for significant reforms in remedial education, student support services, and financial aid to enhance completion rates in nonselective community colleges. Bettinger, Boatman and Long (2013) address low college completion rates, advocating for redesigning developmental courses and effective remediation programs. Freeman *et al.* (2014) conducted a meta-analysis supporting active learning as a more effective teaching practice in STEM education than traditional lecturing. Johannes and Lombard (2018) focus on factors influencing successful transitions from high school to higher education, emphasising pre-arrival programs and interventions targeting prospective students. Fu and Gao (2024) explore the role of higher education in promoting economic growth, highlighting the importance of scale, structure, and quality criteria, thus aligning STEM subjects with economic growth. Wilson-Clark and Saha (2019) guide the United Nations International Children's Emergency Fund (UNICEF) to enhance skills and work outcomes for adolescents transitioning from school to decent work, addressing barriers and evidence-based strategies. Thus, their guidance to UNICEF could align with the overarching goals of promoting education, skill development, and economic empowerment in underserved communities. Collectively, these studies underscore the critical role of foundational education in shaping successful pathways to higher education and beyond.

Leveraging the Latest Innovative Technology in Science Centres

Various initiatives stand out globally in exploring the intersection of technology and science education. Sci-Enza, affiliated with the University of Pretoria, employs interactive displays and modern technologies, making Science accessible and practical for diverse audiences (Department of Education Innovation Unit for Community Engagement, no date). The Cape Town Science Centre innovatively introduces the AstroTrek Virtual Reality Exhibition, providing a transformative cosmic journey (Cape Town Science Centre, 2021). In Delhi, plans to enhance science education involve equipping centres with advanced technology, including virtual reality and astronomical models (The Times of India, 2024). Meanwhile, Floyd (2023) sheds light on the growing role of artificial intelligence (A.I.) in Africa, urging comprehensive policy frameworks for sustainable development. Berens *et al.* (2023) advocate for collaboration between AI experts and scientists to address complex challenges through AI applications. Elsayed (2021) emphasises the crucial role of science centres, like the Planetarium Science Center, in fostering a lifelong learning process and a scientific-oriented mindset, especially in developing countries. Finally, How and Hung (2019) focus on integrating A.I. analytics in STEAM education, showcasing its potential to enhance students' thinking skills through practical applications in predicting material behaviour. Collectively, these efforts underscore the transformative impact of technology on science education, emphasising inclusivity, accessibility, and the need for collaborative approaches to address emerging challenges.

CONCLUSION

In conclusion, the literature review illuminates the complex landscape of mathematics and science education in South African townships and rural areas, emphasising pervasive challenges and proposing viable solutions. Collectively, the studies underscore the urgent need for targeted interventions to enhance STEM education, especially in underserved communities.

The persistent perception of mathematics and Science as complex subjects influenced by gender, age, and cultural beliefs requires immediate attention. Teachers play a crucial role in shaping these perceptions, and efforts should focus on effective professional development to improve teaching methods and motivation.

The significance of mathematics and Science in societal progress, personal growth, and career opportunities cannot be overstated. The global consensus on the importance of STEM proficiency reflects the interconnectedness of education with economic development and innovation. South Africa, facing a skills crisis and challenges in matric pass rates, must navigate the paradox of quantity versus quality in education.

The proposed establishment of dedicated mathematics and science centres emerges as a transformative solution. Successful case studies and global research demonstrate the positive impact of such centres on student engagement, teacher development, and community involvement. By addressing challenges in the existing classroom dynamics, these centres offer a promising avenue for hands-on, inquiry-based learning, alleviating resource constraints and overcrowded classrooms.

Furthermore, leveraging the latest innovative technology in science centres aligns with the evolving global education landscape. Initiatives incorporating virtual reality, artificial intelligence, and interactive displays showcase the potential to make Science more accessible, engaging, and aligned with the demands of the 21st century.

The transformative impact of enhanced STEM education reaches beyond immediate academic success. Studies consistently highlight the correlation between foundational solid education, higher education admissions, and success rates. This connection underscores the importance of investing in STEM education as a strategic pathway to economic growth and workforce development.

The urgency and importance of investing in mathematics and science education in South African townships and rural areas are evident throughout the literature. The proposed establishment of mathematics and science centres is a beacon of hope, offering a holistic solution to address challenges, foster positive attitudes, and prepare the next generation for success in a rapidly advancing world. The call to action is clear: collaborative efforts, innovative strategies, and sustained investments are essential to chart a course towards a brighter future for STEM education in South Africa.

REFERENCES

Achiam, M. (2023). Science education for a sustainable future: The role of out-of-school experiences. *AIP Conference Proceedings*, 2569(1), 060013. https://doi.org/10.1063/5.0112901

Adams, C., Chamberlin, S., Gavin, M. K., Schultz, C., Sheffield, L. and Subotnik, R. (2008). The STEM Promise: Recognising and Developing Talent and Expanding Opportunities for Promising Students of Science, Technology, Engineering and Mathematics, *Oregon Department of Education*. Available at: http://www.ode.state.or.us/wma/stem/stem-white-paper.

Adams, J., Avraamidou, L., Bayram Jacobs, D., Boujaoude, S. B., Bryan, L., Christodoulou, A., Couso, D., Danielsson, A. T., Dillon, J., Evagorou, M., Goedhart, M., Kang, N.-H., Kaya, E., Kayumova, S., Larsson, J., Martin, S. N., Martinez-Chico, M., Marzàbal, A., Savelsbergh, E. R., ... and Zembal-Saul, C. (2018). The Role of Science Education in a Changing World, *Lorentz Center Leiden*. Available at: www.tue.nl/taverne.

Ali, A. A. (2008). *Perceptions, difficulties and working memory capacity related to mathematics performance* [MSc. thesis, University of Glasgow].

Anderson, J., English, L., Fitzallen, N. and Symons, D. (2020). The contribution of mathematics education researchers to the current STEM education agenda, in J. Way, C. Attard, J. Anderson, J. Bobis, H. McMaster and K. Cartwright (eds), *Research in Mathematics Education in Australasia 2016–2019* (pp. 27–57). Singapore: Springer. https://doi.org/10.1007/978-981-15-4269-5_3

ArcelorMittal South Africa. (2024). South Africa Science Centres are Inspiring Young Minds, *ArcelorMittal*. Available at: https://corporate.arcelormittal.com/media/cases-studies/south-africa-science-centres-inspiring-young-minds.

Badasie, R. G. and Schulze, S. (2018). The professional development of mathematics and science teachers: Insights gained from an action research project. *Journal for New Generation Sciences*, 16(2), 30–46.

Berens, P., Cranmer, K., Lawrence, N. D., von Luxburg, U. and Montgomery, J. (2023). AI for science: An emerging agenda. *arXiv*. https://doi.org/10.48550/arXiv.2303.04217

Bettinger, E. P., Boatman, A. and Long, B. T. (2013). Student supports: Developmental education and other academic programs. *The Future of Children*, 23(1), 93–115. https://doi.org/10.1353/foc.2013.0003

Bhagwonparsadh, Y. and Pule, K. G. (2023). Learning support strategies to overcome the effects of promoting condoned senior phase mathematics learners to the FET phase. *Research in Social Sciences and Technology*, 8(1), 16–30. https://doi.org/10.46303/ressat.2023.2

Bolstad, O. H. (2023). Lower secondary students' encounters with mathematical literacy. *Mathematics Education Research Journal*, 35(1), 237–253. https://doi.org/10.1007/s13394-021-00386-7

Boumezrag, M. B. (2022). Importance of literature review in research: An overview and guidelines. *El-Ryssala for Studies and Research in Humanities*, 7(5), 402–410.

Brock, T. (2010). Young adults and higher education: Barriers and breakthroughs to success. *The Future of Children*, 20(1), 109–132. https://doi.org/10.1353/foc.0.0040

Camanho, A. S., Stumbriene, D., Barbosa, F. and Jakaitiene, A. (2023). The assessment of performance trends and convergence in education and training systems of European countries. *European Journal of Operational Research*, 305(1), pp. 356–372. https://doi.org/10.1016/j.ejor.2022.05.048

Campbellscience. (2024). South Africa: Launch of an Innovative Science Facility with Sustainable Technology, *Campbell Science*. Available at: https://www.campbellsci.co.za/south-africa-innovative-science-facility.

Cape Town Science Centre. (2021). AstroTrek Virtual Reality Exhibition, *Cape Town Science Centre*. Available at: https://www.ctsc.org.za/new-astrotrek-virtual-reality-exhibition/.

Chala, A. A., Kedir, I. and Wami, S. (2020). Secondary school students' beliefs towards learning physics and its influencing factors. *Research on Humanities and Social Sciences*, 10(7), 37–49. https://doi.org/10.7176/RHSS/10-7-05

Chestnut, E. K., Lei, R. F., Leslie, S.-J. and Cimpian, A. (2018). The myth that only brilliant people are good at math and its implications for diversity. *Education Sciences*, 8(2), 65. https://doi.org/10.3390/educsci8020065

Chisom, O. N., Unachukwu, C. C. and Osawaru, B. (2024). STEM education advancements in African contexts: A comprehensive review. *World Journal of Advanced Research and Reviews*, 21(1), 145–160. https://doi.org/10.30574/wjarr.2024.21.1.2719

Cigrik, E. and Ozkan, M. (2015). The investigation of the effect of visiting science center on scientific process skills. *Procedia - Social and Behavioral Sciences*, 197, 1312–1316. https://doi.org/10.1016/j.sbspro.2015.07.405

Costa, S. L. R., Obara, C. E. and Broietti, F. C. D. (2020). Critical thinking in science education and mathematics education: Research trends of 2010–2019. *Research, Society and Development*, 9(9), e115996706. https://doi.org/10.33448/rsd-v9i9.6706

Costanzo, G. D. (2022). The Value of Science Centres – Especially in Low- and Middle-Income Countries, *InterAcademy Partnership*. Available at: https://www.interacademies.org/publication/value-science-centres-especially-low-and-middle-income-countries.

Dahiya, V. (2014). Why study mathematics? Applications of mathematics in our daily life. *International Journal of Innovative Science, Engineering and Technology*, 1(10), 151–177. https://doi.org/10.1142/9789814313353_0009

Daniyan, O. O. (2015). *Challenges in teaching learners experiencing barriers in mathematics at the intermediate phase: Tshwane South District* [PhD dissertation, University of South Africa].

Department of Education Innovation Unit for Community Engagement. (n.d.). *Sci-Enza: On Campus Community Partnerships*. Pretoria (South Africa): University of Pretoria.

Efe, H. and Topsakal, Ü. U. (2022). The effect of science centres on perceptions of secondary school students towards the nature of science. *South African Journal of Education*, 42(2), 1–13. https://doi.org/10.15700/saje.v42n2a2017

Elsayed, A. (2021). Science centers as an essential tool for AI pre-college education in developing countries, in *Proceedings of the 2021 IEEE Global Conference on Artificial Intelligence and Internet of Things* (pp. 94–99). IEEE. https://doi.org/10.1109/GCAIoT53516.2021.9692949

Eurydice Report. (2022). *Increasing Achievement and Motivation in Mathematics and Science Learning in Schools*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2797/11306

Evans, P., Vansteenkiste, M., Parker, P., Kingsford-Smith, A. and Zhou, S. (2024). Cognitive load theory and its relationships with motivation: A self-determination theory perspective. *Educational Psychology Review*, 36, 7. https://doi.org/10.1007/s10648-023-09841-2

Falk, J. H., Needham, M. D., Dierking, L. D. and Prendergast, L. (2014). *International Science Centre Impact Study Final Report*. Corvallis (OR): John H. Falk Research.

Faure, C. R. (1999). *The Cape Town Science Centre: A Comprehensive Business Plan*. Cape Coast (South Africa): Potchefstroom University for Christian Higher Education.

Floyd, R. (2023). *L'intelligence Artificielle au Service du Processus D'élaboration des Politiques* [*Artificial Intelligence in the Policy-Making Process*]. Accra (Ghana): African Center for Economic Transformation.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H. and Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Fu, H. and Gao, Y. (2024). What makes higher Education contribute to high-quality economic development-a-synergy effect analysis based on scale, structure and quality elements. *Applied Mathematics and Nonlinear Sciences*, 9(1), 1–16. https://doi.org/10.2478/amns.2023.2.01370

Graham, M. A. (2023). Overcrowded classrooms and their association with South African learners' mathematics achievement. *African Journal of Research in Mathematics, Science and Technology Education*, 27(2), 169–179. https://doi.org/10.1080/18117295.2023.2244217

Grayson, D. J. (2009). *Critical Issues in School Mathematics and Science: Pathways to Progress*. Pretoria (South Africa): Academy of Science of South Africa.

Gursoy, G. (2020). The significance of science centers in science education, in H. Gur (ed), *Academic Studies in Educational Sciences*. Lyon, France: Livre de Lyon.

Hafni, R. N., Herman, T., Nurlaelah, E. and Mustikasari, L. (2020). The importance of science, technology, engineering, and mathematics (STEM) education to enhance students' critical thinking skill in facing the Industry 4.0. *Journal of Physics: Conference Series*, 1521(4), 042040. https://doi.org/10.1088/1742-6596/1521/4/042040

Hait, M. A. and Mishra, A. (2018). A study of fear of mathematics among students. *International Journal for Innovative Research in Multidisciplinary Field*, 4(12), 70–75.

Hassi, M.-L. and Laursen, S. L. (2015). Transformative learning. *Journal of Transformative Education*, 13(4), 316–340. https://doi.org/10.1177/1541344615587111

How, M.-L. and Hung, W. L. D. (2019). Educing AI – Thinking in science, technology, engineering, arts, and mathematics (STEAM) education. *Education Sciences*, 9(3), 184. https://doi.org/10.3390/educsci9030184

Hurley, M., Butler, D. and McLoughlin, E. (2024). STEM teacher professional learning through immersive STEM learning placements in industry: A systematic literature review. *Journal for STEM Education Research*, 7(1), 122–152. https://doi.org/10.1007/s41979-023-00089-7

Jackson, M. C., Leal, C. C., Zambrano, J. and Thoman, D. B. (2019). Talking about science interests: The importance of social recognition when students talk about their interests in STEM. *Social Psychology of Education*, 22(1), 149–167. https://doi.org/10.1007/s11218-018-9469-3

Jayanthi, R. (2019). Mathematics in society development – A study. *Iconic Research and Engineering Journals*, 3(3), 59–64.

Jenifer, J. B., Jaxon, J., Levine, S. C. and Cimpian, A. (2024). "You need to be super smart to do well in math!" Young children's field-specific ability beliefs. *Developmental Science*, 27(1), e13429. https://doi.org/10.1111/desc.13429

Jerrim, J. (2023). Has peak PISA passed? An investigation of interest in international large-scale assessments across countries and over time. *European Educational Research Journal*, 23(3), 450–476. https://doi.org/10.1177/14749041231151793

Johannes, P. and Lombard, P. (2018). Factors that influence the transition from high school to higher education: A case of the JuniorTukkie programme. *African Journal of Career Development*, 2(1), a5.

Jojo, Z. (2020). Mathematics education system in South Africa, in G. Porto Jr. (ed), *Education Systems Around the World* (pp. 1–15). IntechOpen. https://doi.org/10.5772/intechopen.85325

Kahn, M. (2006). Disaggregated data illustrating inequalities: Matric matters', in V. Reddy (ed), *Matric Marking* (pp. 127–138). Cape Town (South Africa): Human Sciences Research Council Press.

Kaleva, S., Pursiainen, J., Hakola, M., Rusanen, J. and Muukkonen, H. (2019). Students' reasons for STEM choices and the relationship of mathematics choice to university admission. *International Journal of STEM Education*, 6, 43. https://doi.org/10.1186/s40594-019-0196-x

Ketenci, T., Leroux, A. and Renken, M. (2020). Beyond student factors: A study of the impact on STEM career attainment. *Journal for STEM Education Research*, 3(3), 368–386. https://doi.org/10.1007/s41979-020-00037-9

Kite, V. and Park, S. (2024). Context matters: Secondary science teachers' integration of process-based, unplugged computational thinking into science curriculum. *Journal of Research in Science Teaching*, 61(1), 203–227. https://doi.org/10.1002/tea.21883

Kukul, V. (2024). Should I use digital storytelling in my future classroom? Why or why not? Investigating pre-service math teachers' acceptance of digital storytelling. *E-Learning and Digital Media*, 21(1), 70–86. https://doi.org/10.1177/20427530231156173

Kunwar, R. (2020). Mathematics phobia: Causes. *International Journal of Creative Research Thoughts*, 8(8), 818–822.

Lam, D., Ardington, C. and Leibbrandt, M. (2011). Schooling as a lottery: Racial differences in school advancement in urban South Africa. *Journal of Development Economics*, 95(2), 121–136. https://doi.org/10.1016/j.jdeveco.2010.05.005

Laurence, S. (2024). Matric Results Improve, But Maths Needs Urgent Attention, *Tech Central*. Available at: https://techcentral.co.za/matric-results-improve-maths-attention/238240/.

Le Cordeur, M. (2024). Matric Results: South Africa's Record School Pass Rates Aren't What They Seem – What's Really Happening in the Education System, *The Conversation*. Available at: https://theconversation.com/matric-results-south-africas-record-school-pass-rates-arent-what-they-seem-whats-really-happening-in-the-education-system-221787.

Leavy, A. M., Hannigan, A. and Fitzmaurice, O. (2013). If you're doubting yourself then, what's the fun in that? An exploration of why prospective secondary mathematics teachers perceive statistics as difficult. *Journal of Statistics Education, 21*(3). https://doi.org/10.1080/10691898.2013.11889684

Lin, K.-Y., Lu, S.-C., Hsiao, H.-H., Kao, C.-P. and Williams, P. J. (2023). Developing student imagination and career interest through a STEM project using 3D printing with repetitive modelling. *Interactive Learning Environments*, 31(5), 2884–2898. https://doi.org/10.1080/10494820.2021.1913607

Louie, N. L. (2017). The culture of exclusion in mathematics education and its persistence in equity-oriented teaching. *Journal for Research in Mathematics Education*, 48(5), 488–519. https://doi.org/10.5951/jresematheduc.48.5.0488

Lubisi, A. and Nekhwevha, F. H. (2024). Effects of family background on poor academic performance of grade 12 learners. *International Journal of Social Science Research and Review*, 7(1), 270–277.

Maarman, G. J. and Lamont-Mbawuli, K. (2017). A review of challenges in South African education and possible ways to improve educational outcome as suggested by decades of research. *Africa Education Review*, 14(3–4), 263–289. https://doi.org/10.1080/18146627.2017.1321962

Mabena, N. and Mokgosi, P. N. (2021). Factors contributing to poor learner performance in mathematics: A case of selected schools in Mpumalanga Province, South Africa. *Problems of Education in the 21st Century*, 79(3), 451–465. https://doi.org/10.33225/pec/21.79.451

Maila, P. and Ross, E. (2018). Perceptions of disadvantaged rural matriculants regarding factors facilitating and constraining their transition to tertiary education. *South African Journal of Education*, 38(1), 1–12. https://doi.org/10.15700/saje.v38n1a1360

Mainali, B. (2020). Representation in teaching and learning mathematics. *International Journal of Education in Mathematics, Science and Technology*, 9(1), 1–21. https://doi.org/10.46328/ijemst.1111

Malatji, M. M. (2019). *Factors contributing to the low matric pass rate in Mopani District: A case study of secondary schools in Motupa Circuit* [Master's thesis, University of Limpopo].

Malyn-Smith, J., Bean, S., Coppola, R., Feller, R. and Gropen, J. (2010). Issues in STEM workforce education for information technology and STEM careers', in *Proceedings of the SITE 2010--Society for Information Technology & Teacher Education International Conference* (pp. 2996–3001). Association for the Advancement of Computing Education.

Markus, E. D. and Mhlolo, M. K. (2018). Improving performance in mathematics and science: A case study of high schools in local municipalities of South Africa. *Advanced Science Letters*, 24(11), 8540–8544. https://doi.org/10.1166/asl.2018.12608

Martins, J., Rosario, P., Cunha, J., Nunez, J. C., Vallejo, G. and Moreira, T. (2024). How to help students in their transition to middle school? Effectiveness of a school-based group mentoring program promoting students' engagement, self-regulation, and goal setting. *Contemporary Educational Psychology*, 76, 102230. https://doi.org/10.1016/j.cedpsych.2023.102230

Mazana, M. Y., Montero, C. S. and Casmir, R. O. (2018). Investigating students' attitude towards learning mathematics. *International Electronic Journal of Mathematics Education*, 14(1), 207–231. https://doi.org/10.29333/iejme/3997

McKinney, S. and Frazier, W. (2008). Embracing the principles and standards for school mathematics: An inquiry into the pedagogical and instructional practices of mathematics teachers in high-poverty middle schools. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 81(5), 201–210. https://doi.org/10.3200/TCHS.81.5.201-210

Mohaladi, M. S. (2004). *The relationship between matriculation pass rates and the existence of total quality management (TQM) principles as a guiding management practice in Harrismith District schools* [Master's thesis, Concordia University].

Molaudzi, A. M. (2021). The role of resources in promoting teaching and learning in South Africa. *Innovare Journal of Education*, 12(2), 529–548. https://doi.org/10.1007/978-3-030-44217-0_35

Moore, T. J. and Smith, K. A. (2014). Advancing the state of the art of STEM integration. *Journal of STEM Education*, 15(1), 5–10. https://doi.org/10.2144/000113758

Mtotywa, M. M., Seabi, M. A., Manqele, T. J., Ngwenya, S. P. and Moetsi, M. (2024). Critical factors for restructuring the education system during the era of the fourth industrial revolution in South Africa. *Development Southern Africa*, 41(1), 16–37. https://doi.org/10.1080/0376835X.2023.2234399

Mullis, I. V. and Martin, M. (2019). *PIRLS 2021 Assessment Frameworks*. Philadelphia (PA): TIMMS and PIRLS International Study Centre, Lynch School of Education, Boston College and International Association for Evaluation of Educational Achievement.

Murcia, K. and Pepper, C. (2018). Evaluating the social impact of a science centre's stem professional learning strategies for teachers. *Issues in Educational Research*, 28(2), 438–452.

Murphy, C. and Beggs, J. (2003). Children's perceptions of school science. *School Science Review*, 84(308), 109–116.

Ndlebe, A. (2022). *The relationship between attaining Matric and labour market outcomes in South Africa* [MSc. thesis, University of the Western Cape].

Nelson, G., Carter, H., Boedeker, P., Knowles, E., Buckmiller, C. and Eames, J. (2024). A meta-analysis and quality review of mathematics interventions conducted in informal learning environments with caregivers and children. *Review of Educational Research*, 94(1), 112–152. https://doi.org/10.3102/00346543231156182

Nemadziva, B., Sexton, S. and Cole, C. (2023). Science communication: The link to enable enquiry-based learning in under-resourced schools. *South African Journal of Science*, 119(1/2), 1–9. https://doi.org/10.17159/sajs.2023/12819

News24. (2022). First Science Centre Opens in Bloem Game On!, *News24*. Available at: https://www.news24.com/news24/community-newspaper/vista/first-science-centre-opens-in-bloem-20221209-3.

Ngobese, C. N. (2013). *Improving the quality of Matric learner performance in mathematics and science in Gauteng* [Master's thesis, University of Witwatersrand].

Nong, T. W. (2016). *The impact of career guidance (CG) for career choice (CC) in the secondary schools of Sepitsi circuit in Ilebowakgomo District, Limpopo Province* [Master's thesis, University of Limpopo].

Nyamunda, J. (2021). How well is the South African education system preparing students for the Fourth Industrial Revolution? *Journal of Management and Administration*, 73, 59–73. https://doi.org/10.5281/zenodo.7607712

Nzekwe-Excel, C. (2010). Role of mathematics learning development centres in HEIs. *International Journal for Mathematics Teaching and Learning*.

Oliveros Ruiz, M. A., Vargas Osuna, L., Valdez Salas, B., Schorr Wienner, M., Sevilla Garcia, J., Cabrera Cordova, E., Nedev, R. and Ibarra, R. (2014). The importance of teaching science and technology in early education levels in an emerging economy. *Bulletin of Science, Technology & Society*, 34(3–4), 87–93. https://doi.org/10.1177/0270467614559124

Osika, A., MacMahon, S., Lodge, J. M. and Carroll, A. (2022). Contextual Learning: Linking Learning to the Real World, *Times Higher Education*. Available at: https://www.timeshighereducation.com/campus/contextual-learning-linking-learning-real-world.

Ozdemir, H. and Onder-Ozdemir, N. (2017). Vocational high school students' perceptions of success in mathematics. *International Electronic Journal of Mathematics Education*, 12(3), 493–502. https://doi.org/10.29333/iejme/627

Pakarinen, E., Imai-Matsumura, K., Yada, A., Yada, T., Leppanen, A. and Lerkkanen, M.-K. (2024). Child-centered and teacher-directed practices in two different countries: A descriptive case study in Finnish and Japanese grade 1 classrooms. *Journal of Research in Childhood Education*, 38(1), 30–49. https://doi.org/10.1080/02568543.2023.2188059

Perkins, N. I. (2014). Science Centres Face a New Challenge in Global Inequality, *Sci-Dev Net*. Available at: https://www.scidev.net/global/editorials/science-centres-face-a-new-challenge-in-global-inequality/.

Persson, P. (2014). *Science Centres Enhance Learning, Local Prosperity and Community Development*. Brunei: Peredvinperssonconsulting.

Rákosi, S. and Pongrácz, A. (2023). Role of science centres in the field of sustainability. *Chemical Engineering Transactions*, 107, 109–114. https://doi.org/10.3303/CET23107019

Reddy, V., Bhorat, H., Powell, M., Visser, M. and Arends, A., (2016). *Skills Supply and Demand in South Africa*. Pretoria (South Africa): LMIP Publication, Human Sciences Research Council, Pretoria.

Reddy, V., Winnaar, L., Juan, A., Arends, F., Harvey, J., Hannan, S., Namome, C. and Zulu, N. (2019). *TIMSS 2019 Highlights of South African Grade 5 Results in Mathematics and Science: Achievement and Achievement Gaps*. Pretoria (South Africa): South African Department of Basics Education.

Ríordáin, M. N., Johnston, J. and Walshe, G. (2016). Making mathematics and science integration happen: Key aspects of practice. *International Journal of Mathematical Education in Science and Technology*, 47(2), 233–255. https://doi.org/10.1080/0020739X.2015.1078001

Saal, P. E. and Graham, M. A. (2023). Comparing the use of educational technology in mathematics education between South African and German schools. *Sustainability*, 15(6), 4798. https://doi.org/10.3390/su15064798

SAASTEC. (2012). SAASTEC and its role in promoting the development of science centres and related organisations in Southern Africa, in *Proceedings of the 6th Science Centre World Congress* (pp. 106–107). Southern African Association of Science and Technology Centres. https://doi.org/10.1515/9783034610940.106

Sabelo Velenkosini, M. (2022). Reflections on lament of 30% Matric pass mark in South African schools. *International Journal of Scientific Research and Management*, 10(07), 2444–2451. https://doi.org/10.18535/ijsrm/v10i7.el03

Sahin, A., Gulacar, O. and Stuessy, C. (2015). High school students' perceptions of the effects of International Science Olympiad on their STEM career aspirations and twenty-first century skill development. *Research in Science Education*, 45(6), 785–805. https://doi.org/10.1007/s11165-014-9439-5

Sami Khan, S. Bin and Salman, R. (2020). Influence of mathematics in our daily lives. *Arts & Humanities Open Access Journal*, 4(2), 50–52. https://doi.org/10.15406/ahoaj.2020.04.00152

Schaeffer, M. W., Rozek, C. S., Maloney, E. A., Berkowitz, T., Levine, S. C. and Beilock, S. L. (2021). Elementary school teachers' math anxiety and students' math learning: A large-scale replication. *Developmental Science*, 24(4), e13080. https://doi.org/10.1111/desc.13080

Sci-Bono Discovery Centre. (2023). Sci-Bono Discovery Centre Annual Report: Building a Competent Society in the World of Science and Technology, *Sci-Bono*. Available at: https://www.riotinto.com/en/invest/reports/annual-report.

Sellami, A., Santhosh, M., Bhadra, J. and Ahmad, Z. (2023). High school students' STEM interests and career aspirations in Qatar: An exploratory study. *Heliyon*, 9(3), e13898. https://doi.org/10.1016/j.heliyon.2023.e13898

Shana, Z. and Abulibdeh, E. S. (2020). Science practical work and its impact on students' science achievement. *Journal of Technology and Science Education*, 10(2), 199. https://doi.org/10.3926/jotse.888

Shepherd, L. D. and Van Der Berg, S. (2020). Analysing Matric Data to Identify 'Promising' Schools in Mathematics Performance, *Stellenbosch*. Available at: https://ideas.repec.org/p/sza/wpaper/wpapers351.html.

South African Agency for Technological Advancement. (2024). Science Centres, *SAASTA*. Available at: https://www.thecanadianencyclopedia.ca/en/article/science-centre.

South African Department of Basic Education. (2023). *2023 NSC Exam Results Technical Report*. Pretoria (South Africa): South African Department of Basic Education.

South African Department of Education. (2017). *Report of the Rural Education Research Team Towards a Rural Education Policy*. Pretoria (South Africa): South African Department of Basic Education.

Spaull, N. (2015). Schooling in South Africa: How low quality education becomes a poverty trap, in A. De Lannoy S. Swartz, L. Lake and C. Smith(eds), *2015 Children's Institute, University of Cape Town*. Cape Town (South Africa): University of Cape Town.

Spaull, N. and Kotze, J. (2015). Starting behind and staying behind in South Africa. *International Journal of Educational Development*, 41, 13–24. https://doi.org/10.1016/j.ijedudev.2015.01.002

Stephen, M. M. (2024). The effects of technical science on learner performance and possible technical vocational career choices. *International Journal of Instruction*, 17(1), 769–786. https://doi.org/10.29333/iji.2024.17140a

Stols, G., Ferreira, R., Pelser, A., Olivier, W. A., Van der Merwe, A., De Villiers, C. and Venter, S. (2015). Perceptions and needs of South African mathematics teachers concerning their use of technology for instruction. *South African Journal of Education*, 35(4), 1–13. https://doi.org/10.15700/saje.v35n4a1209

Sutherland, E. (2020). The Fourth Industrial Revolution – The case of South Africa. *Politikon*, 47(2), 233–252. https://doi.org/10.1080/02589346.2019.1696003

Taylor, S. (2010). *The performance of South African schools: Implications for economic development* [PhD thesis, University of Stellenbosch].

Tayur, S. (2023). Management mathematics: The audacity of BOPE. *IMA Journal of Management Mathematics*, 35(1), 9–20. https://doi.org/10.1093/imaman/dpad021

The Times of India. (2024). High-Tech Learning for Delhi Students Soon with VR, Astronomical Models at Science Centres, *The Times of India*. Available at: https://timesofindia.indiatimes.com/education/news/high-tech-learning-for-delhi-students-soon-with-vr-astronomical-models-at-science-centres/articleshow/106561336.cms.

Thi To Khuyen, N., Van Bien, N., Lin, P.-L., Lin, J. and Chang, C.-Y. (2020). Measuring teachers' perceptions to sustain STEM education development. *Sustainability*, 12(4), 1531. https://doi.org/10.3390/su12041531

Tikly, L., Joubert, M., Barrett, A. M., Bainton, D., Cameron, L. and Doyle, H. (2018). Supporting Secondary School STEM Education for Sustainable Development in Africa, *University of Bristol*. Available at: https://www.bristol.ac.uk/media-library/sites/education/documents/Supporting%20Secondary%20School%20STEM%20Education%20for%20Sustainabale%20Development%20in%20Africa.pdf.

Tlhabane, S. (2023). *ECDoE 2-DAY STEM INDABA. State of mathematics in the country – Strategic goals and paradigms*. Pretoria (South Africa): South African Department of Basic Education.

Tsanwani, A., Harding, A., Engelbrecht, J. and Maree, K. (2014). Perceptions of teachers and learners about factors that facilitate learners' performance in mathematics in South Africa. *African Journal of Research in Mathematics, Science and Technology Education*, 18(1), pp. 40–51. https://doi.org/10.1080/10288457.2014.884262

Umar, Y. (2019). STEM Education as a catalyst for national development: Problems and prospects in Nigeria. *Learning Science and Mathematics*, (14), 48–59.

University of Venda Department of Marketing. (2021). Vuwani Science Resource Centre Awarded Level 2 Accreditation in the South African Network for a Period of Five (5) Years, *University of Venda*. Available at: https://www.univen.ac.za/news/vuwani-science-resource-centre-awarded-leve2-accreditation-in-the-south-african-network-for-a-period-of-five-5-years/.

Van Gend, I. (2023). STEM Subjects are Key to Getting South Africa's Youth Employed, *Nelson Mandela University News*. Available at: https://news.mandela.ac.za/Mandela-University-in-the-NEWS/Mandela-University-in-the-NEWS-Archive/STEM-subjects-are-key-to-getting-South-Africa's-yo .

Venter, J. and Rodrigues Van Niekerk, D. (2018). A contact-based practical approach to STEM projects in South Africa 12. *The Independent Journal of Teaching and Learning*, 13(2), 113–127.

Waititu, M. M. (2024). An exploration of the integration of ict in mathematics lessons in secondary schools, garissa county, Kenya. *Journal of Education*, 4(1), 12–22.

Walker, J., Pearce, C., Boe, K. and Lawson, M. (2019). The power of education to fight inequality: How increasing educational equality and quality is crucial to fighting economic and gender inequality. *Oxfam International*. https://doi.org/10.21201/2019.4931

Weng, T.-S. (2017). The importance of mathematics and science education in the context of digital technology on industrial innovation. *Research Journal of Applied Sciences, Engineering and Technology*, 14(11), 418–426. https://doi.org/10.19026/rjaset.14.5142

Weybright, E. H., Caldwell, L. L., Xie, H., Wegner, L. and Smith, E. A. (2017). Predicting secondary school dropout among South African adolescents: A survival analysis approach. *South African Journal of Education*, 37(2), 1353. https://doi.org/10.15700/saje.v37n2a1353

White, P. and Smith, E. (2022). From subject choice to career path: Female STEM graduates in the UK labour market. *Oxford Review of Education*, 48(6), 693–709. https://doi.org/10.1080/03054985.2021.2011713

Wilson-Clark, G. and Saha, S. (2019). *Transitions from School to Work*. New York City (NY): United Nations Children's Fund, Education Section.

Yamada, A. (2023). STEM field demand and educational reform in Asia-Pacific countries', in K. Devesh, L. Kong, F. Lo and D. M. Malone (eds), *The Oxford Handbook of Higher Education in the Asia-Pacific Region* (pp. 189–209). Oxford (UK): Oxford University Press. https://doi.org/10.1093/oxfordhb/9780192845986.013.9

Ziyadullaevna, S. M. and Iskandarovna, D. S. (2023). The methodology of teaching mathematics through ICT. *Innovation in Technology and Science Education*, 2(7), 169–175.