E-Journal of Humanities, Arts and Social Sciences (EHASS)
ISSN – Online 2720-7722 | Print 2821-8949
Volume 6 Issue 4 SASE Special Issue March 2025 pp 71 - 87
Available online at: https://noyam.org/journals/ehass/
DOI: https://doi.org/10.38159/ehass.2025646

Post-graduate Teachers' STEM Education Experiences and the Development of their 21st Century Skills: A Case Study of Two Higher Education Institutions in South Africa and Mauritius

Ronicka Mudaly [1], Bongani P. Ndlovu [1], Tamirirofa Chirikure [2], Doras Sibanda [1], Merventharan Perumal Moodley[1], Fawzia Bibi Narod [3] & Vickren Narrainsawmy [3]

[1] University of KwaZulu-Natal, Durban, South Africa.
[2] University of Botswana, Gaborone, Botswana.
[3] Mauritius Institute of Education, Reduit, Mauritius.

ABSTRACT

Developing strong 21st century skills is crucial for teachers, and exploring how Science, Technology, Engineering, and Mathematics (STEM) education experiences can contribute to this development in teacher education holds significant value. The purpose of this research was to explore how STEM education experiences foster the development of 21st century skills in post-graduate teachers within the context of the Global South. Methodologically, it followed an exploratory case study with a sample of 53 postgraduate students who were purposively selected from one university in South Africa and one higher education institution in Mauritius. The first set of data was generated using a semi-structured questionnaire. To corroborate the questionnaire data, a sample of 5 postgraduate teachers was interviewed, forming the second data set. Findings from this study revealed that the "ways of thinking" were the 21st century skills that were most enhanced by the STEM experience. This is compared with other 21st century skills sets like living in the world, ways of working, and tools for working, which were developed to a lesser extent. Data from the interviews confirmed that postgraduate teachers find the ways of thinking, due to their experiences with STEM, to be the most enhanced 21st century skill. The findings in this paper have implications for teacher development, especially in STEM education. It recommends that teacher education programs in the Global South leverage the potential of STEM education experiences to equip teachers with the necessary 21st century skills for effectively preparing future generations for the challenges and opportunities they will encounter.

Correspondence
Ronicka Mudaly
Email:
Mudalyr@ukzn.ac.za

Publication History
Received:
26th October, 2024.
Accepted:
3rd April, 2025.
Published:
23rd May, 2025.

Keywords: *Communication and Collaboration, Metacognitive Awareness, STEM Education, Twenty-First Century Skills*

INTRODUCTION

Globally, success in Science, Technology, Engineering and Mathematics (STEM) education is viewed as crucial in fostering creativity and innovation, thus preparing the current generation for future working and learning opportunities. Given this global priority, it is disquieting to read about the diminishing

appetite for STEM-related studies and careers.[1] There are several factors mentioned in the literature that contribute to this trend, and some of these are linked to historical, socio-economic and political characteristics, which differ in Global North and Global South settings. The Brandt line delineates the Global South and the Global North zones. This division is based primarily on political and socioeconomic development.[2] Extractivism of minerals and other forms of exploitation of natural resources by foreign nations, colonial histories and the legacy of coloniality, characterise most Global South settings. Developing countries in Africa, Eastern Europe, Latin America and Asia comprise the Global South zone. Free market economies with higher gross domestic product, as well as technological superiority, are the privilege of people in the Global North countries. North America, Europe and Australia, countries which have great technological and industrial advancement, are classified as being in the Global North zone.

Other reasons for a decreased interest in STEM fields include the shortage of human resource capacity to teach STEM subjects,[3] the quality of STEM education in under-resourced schools,[4] and equitable access to STEM education.[5] Within the context of the Global South, 21st century skills are difficult to realise because of several factors such as poverty, limited educational resources, traditional curricula, and cultural differences. Socio-economic disadvantage, access to quality STEM education mainly by a minority of elite students, and the persistence of under-qualified teachers in STEM-linked subjects are some challenges in STEM fields. In addition, a scarcity of STEM learning models which privilege project-based learning, problem solving, and coding, collude to prohibit full participation in STEM fields in South Africa.[6] These challenges hinder the development of essential skills like critical thinking, problem-solving, and digital literacy. By addressing human capacities, and resource disparities, and promoting equity, all students can be empowered, especially those in the Global South, to reach their full potential in STEM fields.

Within South African secondary schools, four STEM-linked subjects are offered in public schools, namely, Life Sciences, Mathematics, Mathematical Literacy, and Physical Sciences. A scientometric analysis of the education sector in South Africa included details of the performance of Grade 12 learners in STEM-related subjects from 2008 to 2019.[7] This revealed an increase in the number of Grade 12 students who passed Mathematics and Physical Sciences and who were eligible to pursue STEM-related bachelor degrees. The total enrolment in STEM fields at universities increased by 36% during the 2007 to 2017 decade, but one-third of this number comprised African students who were from other African countries. Upon graduation in STEM fields, a majority of African students who are foreign nationals return to their native countries. South Africa acts as a conduit for the "brain circulation" of mid-level professionals within the African continent, as noted by Kahn and Oghenetega in their research.[8] This

[1] Nguyen Thi To Khuyen et al., "Measuring Teachers' Perceptions to Sustain STEM Education Development," *Sustainability* 12, no. 4 (2020): 1531; Emma Hillermann, Miloš Savić, and Rama Kothapalli, "The Effect of STEM Research Experiences on Fields of Interest and Career Paths," *International Journal of Science and Mathematics Education* 22, no. 5 (June 2, 2024): 1107–26, https://doi.org/10.1007/s10763-023-10409-3.

[2] Marcin Wojciech Solarz, "'Third World': The 60th Anniversary of a Concept That Changed History," *Third World Quarterly* 33, no. 9 (October 12, 2012): 1561–73, https://doi.org/10.1080/01436597.2012.720828; Géza Barta, " Solarz, MW: The Global North-South Atlas. Mapping Global Change," *Hungarian Geographical Bulletin* 69, no. 1 (2020): 76–78; Nicholas Lees, "The Brandt Line after Forty Years: The More North–South Relations Change, the More They Stay the Same?," *Review of International Studies* 47, no. 1 (January 16, 2021): 85–106, https://doi.org/10.1017/S026021052000039X.

[3] Sarfraz Aslam et al., "Challenges in Implementing STEM Education: Insights from Novice STEM Teachers in Developing Countries," *Sustainability* 15, no. 19 (2023): 14455.

[4] Pallavi Amitava Banerjee, "A Systematic Review of Factors Linked to Poor Academic Performance of Disadvantaged Students in Science and Maths in Schools," *Cogent Education* 3, no. 1 (December 31, 2016): 1178441, https://doi.org/10.1080/2331186X.2016.1178441.

[5] Laura Avendano et al., "Bringing Equity to Underserved Communities through STEM Education: Implications for Leadership Development," *Journal of Educational Administration and History* 51, no. 1 (January 2, 2019): 66–82, https://doi.org/10.1080/00220620.2018.1532397.

[6] Michael Kahn, "Science, Technology, Engineering and Mathematics Education" (Paper presentation]. 4th HRDC summit: Skills required for the 21st century …, 2021).

[7] Michael Kahn and Joshua Oghenetega, "Origins and Destinations Known: A Tracer Study of International African Doctoral Graduates from South Africa's Universities," *Industry and Higher Education* 35, no. 5 (October 27, 2021): 559–69, https://doi.org/10.1177/0950422221989645.

[8] Kahn and Oghenetega, "Origins and Destinations Known: A Tracer Study of International African Doctoral Graduates from South Africa's Universities."

contextual background in South Africa is relevant to teachers, many of whom had pursued pure STEM fields or studied education programmes that included STEM subjects.

This study is of the view that teachers' experiences of STEM education, their capacity to teach, and the international trends which reveal that many students do not choose to pursue careers in STEM-related fields,[9] particularly those in the Global South as compared to the Global North, are intricately linked.[10] This lack of focus on developing essential 21st century skills, coupled with the documented global decline in students pursuing STEM careers, particularly in the Global South, necessitates a deeper understanding of how teachers' perceptions of STEM subjects influence their teaching practices. Therefore, a crucial research area lies in understanding the connection between teachers' perceptions of STEM subjects and their ability to deliver engaging and effective STEM education. This paper examines how teachers' experiences of STEM education contributed to the development of their 21st century skills. The following key question underlies the study: "*What 21st century skills do teachers who are engaged in postgraduate studies develop as a result of their experiences of STEM education*?"

This paper reports a part of a larger collaborative study between a higher education institution (HEI) in Mauritius and one in South Africa about STEM education and teacher training for 21st century citizenship. It begins by providing insight into the research team and the research focus. Next, it explores the place of 21st century skills in education in general and STEM education in particular. A discussion of the exploratory case study design follows, and the data generated from questionnaires and interviews is presented. The data is analysed by borrowing the constructs from Binkley et al. which are ways of thinking, working, and living in the world, and tools for working, and finally, the findings are discussed.[11]

This study is conducted by a group of seven science and technology teacher educators from higher education institutions in South Africa and Mauritius. The researchers view their contexts as postcolonial societies, with economies that depend on success in STEM-related fields. This derives from the African Union's Science, Technology and Innovation Strategy for Africa (STISA-2024) which emphasizes the need for building critical STEM skills and promoting innovation across the continent for economic development.[12] This has provided the impetus for a collaborative research project which focuses on STEM education in the Global North and Global South. This paper is based on one aspect of the larger project and privileges the opinions and voices of post-graduate teachers in the field who share their experiences of STEM education, especially as it relates to the development of their 21st century skills. Further details of this project are presented in the methodology section.

LITERATURE REVIEW

The Place of 21st Century Skills in Education

As globalization becomes the new normal, education must prioritize 21st century skills to prepare students for a world characterized by intense international interaction, interconnectedness for a sustainable future, and a focus on integrating knowledge across disciplines.[13] Some argue, as evidenced in the foreword to "*Assessment and Teaching of 21st Century Skills*" by Care, et.al., that a significant gap exists between modern, technologically advanced social and economic systems and education systems, which are perceived to be lagging in preparing students for the demands of the current and the future world.[14] This view was also expounded in an article titled "How to bring our schools out of the 20th century" in Times Magazine.[15] They critique the parochial boundaries of school subjects, the inadequate leveraging of technology in teaching, assessment and learning, and the expectation for learners to engage with pre-formulated instead of relevant, complex problems. In a similar vein, Binkley et al. assert that:

[9] Thi To Khuyen et al., "Measuring Teachers' Perceptions to Sustain STEM Education Development."
[10] Dr Kehdinga George Fomunyam, "Towards Enhancing Science, Technology, Engineering, and Mathematics (STEM) Education: A Case for Higher Education in Africa.," 2021.
[11] Marilyn Binkley et al., "Defining Twenty-First Century Skills," *Assessment and Teaching of 21st Century Skills*, 2012, 17–66.
[12] African Union, "Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024)," *Science & Technology African Union Commission, Ed*, 2014.
[13] Carol Reade et al., "Educating Global Citizens for the 21st Century: The SJSU Salzburg Program," *Journal of Corporate Citizenship*, no. 49 (2013): 100–116.
[14] Esther Care, Patrick Griffin, and Barry McGaw, *Assessment and Teaching of 21st Century Skills* (Springer, 2012).
[15] Claudia Wallis and Sonja Steptoe, "How to Bring Our Schools Out of the 20th Century," *Time Magazine*, 2006.

> *"…success (in work) lies in being able to communicate, share, and use information to solve complex problems, in being able to adapt and innovate in response to new demands and changing circumstances, in being able to marshal and expand the power of technology to create new knowledge, and in expanding human capacity and productivity*."[16]

Various scholars have proposed different frameworks for understanding 21st century skills. Terms such as life skills, transversal skills, critical skills, and digital skills have been frequently used to describe these competencies.[17] Voogt and Roblin distinguish between basic knowledge and skills (within specific disciplines such as science and mathematics) and applied skills (which include critical thinking, teamwork, self-regulation, creativity, and problem-solving).[18] The work of the National Academy of Science showed that 21st century skills can be categorized into three main areas: cognitive, interpersonal, and intrapersonal. Cognitive skills encompass problem-solving, critical thinking, and systems thinking. Interpersonal skills include communication, teamwork, cultural sensitivity, and social abilities. Intrapersonal skills include self-management, self-development, and self-regulation.[19]

Recently, Carlgren challenged the traditional split between propositional knowledge (facts and theories) and "knowing how" (skills). By introducing "knowns" and "knowings," Carlgren argues that powerful knowledge encompasses both the factual content (knowns) and the processes of acquiring and using that knowledge (knowings).[20] This blurs the line by emphasizing that powerful knowledge isn't just inert information, but a dynamic interplay between knowledge and its application. The concept of powerful knowledge aligns well with the emphasis on 21st century skills. Just as Carlgren argues that powerful knowledge is not just inert information but a dynamic interplay between factual content (knowns) and the processes of using that knowledge (knowings), 21st century skills encompass a broad set of abilities that apply knowledge and values to diverse situations. Science education exemplifies this connection. Science isn't simply a collection of facts (content knowledge) but also involves developing scientific process skills, like argumentation.[21] This aligns with the 21st century skill of discourse, which is crucial for collaborative problem-solving.[22]

Creativity is a thinking skill which involves generating new ideas in general, while innovation has been linked to economics, where new ideas lead to new products.[23] Creating a classroom environment where learners can feel secure can encourage learners to take risks can foster creativity.[24] Critical thinking and problem-solving involve understanding strategies for engaging in addressing unfamiliar challenges. Analysing, interpreting, synthesising, explaining, and evaluating evidence, as well as the capacity for self-reflexivity are associated with critical thinking skills. Problem solving, which shares critical thinking skills, is often planned using project work.

Binkley et.al., call for a transformation in the education system by leveraging technology to teach 21st century skills.[25] They refer to four categories of 21st century skills, namely, ways of thinking, ways of working, tools for working, and living in the world. Figure 1 pictorially shows how the primary skills and the secondary skills of the 21st century are classified.

---

[16] Binkley et al., "Defining Twenty-First Century Skills."
[17] Chris Joynes, Serena Rossignoli, and Esi Fenyiwa Amonoo-Kuofi, "21st Century Skills: Evidence of Issues in Definition, Demand and Delivery for Development Contexts," 2019; H. Belchior-Rocha et al., "21st Century Skills and Digital Skills, Are One and the Same Thing?," *Edulearn20 Proceedings, IATED*, 2020, 2752-2758.
[18] Joke Voogt and Natalie Pareja Roblin, "A Comparative Analysis of International Frameworks for 21 St Century Competences: Implications for National Curriculum Policies," *Journal of Curriculum Studies* 44, no. 3 (June 2012): 299–321, https://doi.org/10.1080/00220272.2012.668938.
[19] National Research Council, *Assessing 21st Century Skills: Summary of a Workshop* (Washington, DC: National Academies Press, 2011).
[20] Ingrid Carlgren, "Powerful Knowns and Powerful Knowings," *Journal of Curriculum Studies* 52, no. 3 (May 3, 2020): 323–36, https://doi.org/10.1080/00220272.2020.1717634.
[21] Carlgren, "Powerful Knowns and Powerful Knowings."
[22] Audrey Msimanga and Anthony Lelliott, "Talking Science in Multilingual Contexts in South Africa: Possibilities and Challenges for Engagement in Learners Home Languages in High School Classrooms," *International Journal of Science Education* 36, no. 7 (May 3, 2014): 1159–83, https://doi.org/10.1080/09500693.2013.851427.
[23] Reade et al., "Educating Global Citizens for the 21st Century: The SJSU Salzburg Program."
[24] Avril Loveless, "Creativity, Technology and Learning–a Review of Recent Literature," 2007.
[25] Binkley et al., "Defining Twenty-First Century Skills."

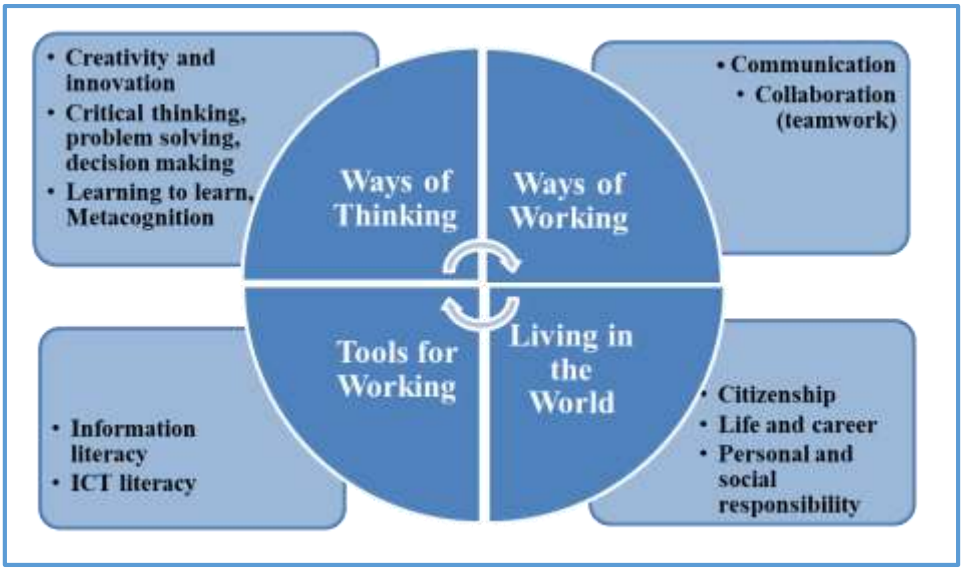

Figure 1: Primary and Secondary 21st Century Skills

Ways of thinking include creativity and innovation, critical thinking, problem-solving, and decision-making. Ways of thinking also encompass learning to learn, and metacognition. Ways of working refer to skills of communication and collaboration (teamwork). Information literacy and ICT literacy are key skills associated with tools for working. The last category, living in the world, refers to citizenship at local and global levels, life, and career, as well as personal and social responsibility – including cultural awareness and competence.

Twenty-first Century Skills and STEM Education

The engagement in STEM education contributes to the enhancement of these 21st century skills, especially critical thinking skills, creative thinking skills, and the capacity for innovation and logical reasoning. Problem-solving skills, developed through STEM education, enable students to apply knowledge to real-life situations, and this renders knowledge more relevant and meaningful in the modern world.[26] A study conducted by Wan Husin et al. measured the development of students' 21st century skills after they had participated in a STEM education programme.[27] Results revealed that 21st century skills, especially "digital age literacy, inventive thinking, effective communication, and high productivity" were enhanced after the STEM education programme.[28]

Evidence from the study conducted by Wan Husin et al. revealed that students' digital age literacy skills had improved, as reflected by their ability to generate and use new technology effectively.[29] Their inventive thinking, which includes cognitive skills and life skills, also improved. Their cognitive ability to think creatively and critically, and apply problem solving skills when designing innovative activities was enhanced. Improved life skills were demonstrated by students' willingness to take risks to pursue new ideas and manage complex issues. Students' capacity for effective communication increased because they demonstrated effective interpersonal skills and interacted and communicated effectively while working collaboratively within teams. Evidence of students' high productivity was revealed when they generated original, high-quality end products which were relevant to the lives of people. Their high productivity was made possible by their ability to prioritise and delegate tasks effectively.

[26] Ronal Rifandi and Yosi Laila Rahmi, "STEM Education to Fulfil the 21st Century Demand: A Literature Review," in *Journal of Physics: Conference Series*, vol. 1317 (IOP Publishing, 2019), 012208.
[27] Wan Nor Fadzilah Wan Husin et al., "Fostering Students' 21st Century Skills through Project Oriented Problem Based Learning (POPBL) in Integrated STEM Education Program.," in *Asia-Pacific Forum on Science Learning & Teaching*, vol. 17, 2016.
[28] Wan Husin et al., "Fostering Students' 21st Century Skills through Project Oriented Problem Based Learning (POPBL) in Integrated STEM Education Program."
[29] Wan Husin et al., "Fostering Students' 21st Century Skills through Project Oriented Problem Based Learning (POPBL) in Integrated STEM Education Program."

METHODOLOGY

This qualitative study was conducted at two higher education institutions (HEIs) for teacher education across two countries in the Global South, namely, South Africa and Mauritius. Each institution served students from diverse socio-economic settings. This study reported on part of a larger study (Ethical clearance Protocol Reference: HSSREC/0000/3880/2022) that involved an undergraduate sample, which comprised 27 South Africans and 4 Mauritians, and a postgraduate sample, which comprised 35 South African and 18 Mauritian participants. This paper reports on results from the postgraduate group only, because this group had more similarities in terms of academic qualifications. This group served as a case for this study.

Research Design

This study adopted an exploratory case study approach. According to Cohen, Manion, and Morrison, case studies are suitable because they provide insight into the background of the problem.[30] Yin indicates that asking "how" and "what" questions can be examined using exploratory case studies.[31]

An in-depth explanation of a particular phenomenon can be obtained using an exploratory case study design.[32] The selection of the exploratory case study allowed for the excavation of experiences of learning and teaching in STEM disciplines, and how these experiences contributed to the development of 21st century skills.[33]

Sample

The postgraduate group comprised 53 participants, who were purposively selected. The criteria for the selection of participants were that they were enrolled in postgraduate programmes in education at either one of the HEIs and that they expressed a willingness to engage in this study. Participants were enrolled in one of the following programmes: Postgraduate Certificate in Education, Honours in Science and Mathematics Education, or Honours in Bachelor of Education. Each participant had studied at least two STEM sub-fields from the following list: Life Sciences, Biology, Natural Sciences, Physical Sciences, Technology, Design and Technology, and Computer Education. The 53 participants completed semi-structured questionnaires. Participants who provided detailed, rich insights into their experiences of STEM education were invited to engage in interviews. Ten participants accepted this invitation to participate in individual, semi-structured interviews. This paper undertakes an in-depth exploration into the views of five of the 10 interviewees, to study the phenomenon more deeply. A brief description of these interviewees follows in Table 1.

Table 1: Description of the Interviewees

Pseudonym	Qualification	Specialization	Research area	Gender	Nationality
Phillipa	BSc (Physical Sciences); PGCE	Physical Sciences	Atmosphere of exoplanets	Female	Mauritian
Bill	BSc (Biological Sciences)	Biology	Pollination, with biotechnology	Male	South African
Hunter	BSc	Human anatomy; Human physiology	DNA identification	Male	South African
Chilisa	BSc (Chemistry), PGCE	Chemistry	Inorganic chemistry	Female	Mauritian

[30] L. Cohen, L. Manion, and K. Morrison, *Research Methods in Education* (Routledge, 2018).
[31] R. K. Yin, *Case Study Research and Applications: Designs and Methods* , 6th ed. (London: SAGE, 2018).
[32] Yin, *Case Study Research and Applications: Designs and Methods* .
[33] Wan Husin et al., "Fostering Students' 21st Century Skills through Project Oriented Problem Based Learning (POPBL) in Integrated STEM Education Program."

Zama	M Ed Mathematics education	Mathematics	Learning mathematics using visualisation	Female	South African

Data Collection and Analysis

To comprehensively understand the context in which participants developed 21st century skills within STEM subfields, a qualitative approach was employed. Data was collected through open-ended surveys and in-depth interviews, the latter of which were held using Zoom. The surveys provided a foundation for identifying categories and associated 21st century skills by analysing raw data. Interviews offered a deeper exploration of participants' STEM learning experiences, allowing them to choose their preferred interview setting. This combined methodology aimed to generate rich, contextual data for thorough analysis. Through the voices of participants, space and time were reconfigured in their quest to make sense of their learning in STEM and share their understanding with us. Insights from multiple sources of data enhanced the credibility of the findings in this study.[34]

PRESENTATION OF FINDINGS AND ANALYSIS

Deductive qualitative analysis was employed, involving two independent raters who coded questionnaire responses. To enhance inter-rater reliability, both raters initially coded five preliminary responses using the 21st century skills framework proposed Figure 1, as an analytical lens. The framework outlined four skill categories: ways of thinking, ways of working, tools for working and living in the world. Subsequent qualitative responses were coded according to these categories. It is essential to note that the presented data quantifies the frequency of skill mentions by participants. Importantly, some participants exhibited multiple skill development through their STEM experiences. Figure 2 shows the frequency with which these skills were mentioned by the participants.

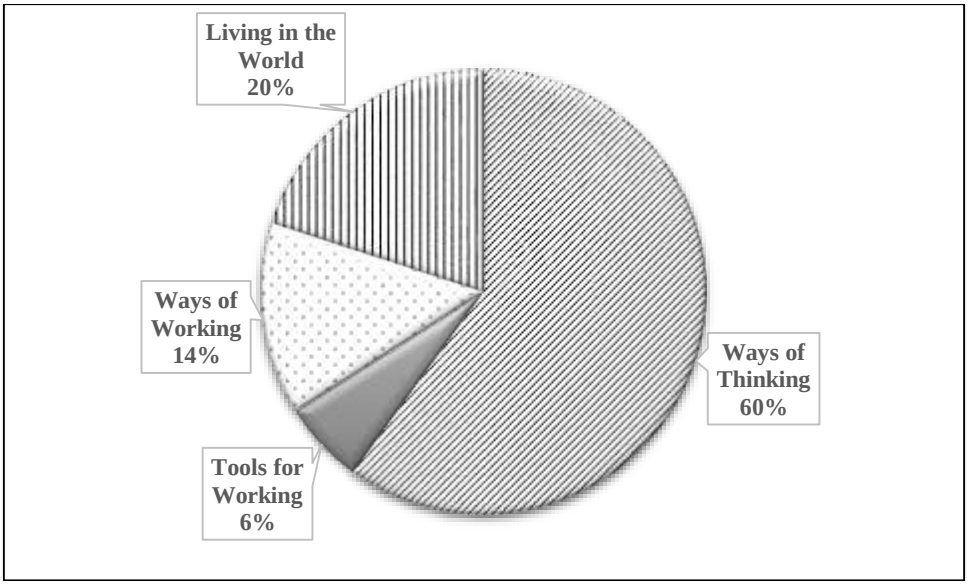

Figure 2: 21st Century Skills Enhanced by STEM Learning

This study found that STEM experiences had the greatest impact on participants' development of 21st century "ways of thinking" skills, according to a survey, with 60% of respondents agreeing. Within this skill set, critical thinking was mentioned 17 times while innovation had a frequency of 11. Adaptability and reflexive thinking were mentioned five times by the participants. The least mentioned skills within this set were creativity and research planning with a frequency of two and one respectively.

[34] Cohen, Manion, and Morrison, *Research Methods in Education*.

Data from interviews revealed that the participants attributed their ways of thinking and development of 21st century skills largely to participation in practical work and research projects in STEM. Although research was not mentioned directly in the questionnaire responses, it was referred to as the catalyst for developing 21st century skills in the interviews. The following excerpts provide evidence of their valuing of practical work in their experiences of STEM:

> *I remember doing a hands-on investigative activity for growing crystals. It was an inquiry-based activity that we had to do. We had to use the Epsom salts - magnesium sulphate. And we had to combine it with water to see how the crystals form…. that was one of the defining moments…I remember… like critical thinking in inquiry-based because we are interested in finding out how these crystals are formed from Epsom salts*. (Zama)

Critical thinking and deductive reasoning, by making connections between the growing crystals that she had observed and the processes which were responsible for this, were evident in Zara's account of learning science during her primary school years.

For Hunter, practical work:

> *… was fun … exciting and I found that through practical and lab work it actually helped to enhance my content knowledge.*

Bill explained:

> *I like the practical content* (at primary school) *a lot … I couldn't actually understand a lot of theory that we did in class but after doing a practical, I would actually relate to it and understand the theory… "oh, the leaves are green because of chlorophyll" and if I look outside, I look at the sun and I think, "Oh, now the leaves are taking light energy". So, the content was very interesting, because I was able to relate it, to what is happening in the actual environment.*

Chilisa concurred by asserting:

> *The combination of theory and practical work including hands-on, and demonstration helps to understand abstract scientific concepts* (in secondary school).

Deepening understanding by doing science through practical work as seen in Shana and Abulibdeh was reported by the participants in this study.[35] Bill used an explicit example to show how practical work can be extended to real-life experiences. Practical work provided "evidence" which fostered participants' understanding of what was taught theoretically.[36]

Each of the interviewees reflected on university-level research project work which was crucial in the development of 21st century skills. Chilisa referred to the use of knowledge from different STEM subjects to conduct research, as is evident in the following excerpt:

> *…research project on the determination of protein levels in food… I had to blend different subject areas such as chemistry - molecular structure of protein, biology - protein in food, mathematics - for plotting graphs, and (use) technology - during poster making.*

Another example of drawing from knowledge across STEM subjects was mentioned by Chilisa:

> *Mole concept in chemistry, I could see the connection with mathematics, … respiration in biology (linked to) pressure and volume in physics, I connected it with what I learned in chemistry classes.*

A transdisciplinary approach, drawing on knowledge and skills across several STEM disciplines, enhanced Chilisa's learning.[37]

[35] Zuhrieh Shana and Enas S Abulibdeh, "Science Practical Work and Its Impact on High Students' Academic Achievement," *JOTSE* 10, no. 2 (2020): 199–215.
[36] Binkley et al., "Defining Twenty-First Century Skills."
[37] L Darling-Hammond et al., "Preparing School Leaders for a Changing World: Lessons from Exemplary Leadership Development Programs" (Stanford, CA, 2007).

Then she added:

> *The BSc research project at the university level… inorganic chemistry module on the application of the Kjeldahl method in food industries…through collaboration with various stakeholders and students, I developed higher-order thinking skills such as critical thinking skills, problem-solving skills, as well as creativity, communication skills, etcetera.*

The Kjeldahl method was used to quantify milk protein. Processes of digestion, distillation and titration were used by Chilisa. Chilisa alluded to the development of higher order thinking skills during this research project. Binkley et al. indicate that low order thinking skills, such as recall or inferring, are subordinate to 21st century ways of thinking, which include problem solving and critical thinking, as was alluded to by Chilisa.

Hunter also valued research projects as opportunities which provided the impetus for developing 21st century skills. He explained:

> *After my undergrad, I did develop critical thinking and problem solving skills, because, after my first year of general science, we were exposed to a lot of data, a lot of scientific analysis, and especially, for example, with genetics, we would look at how would we be able to use bacteria to create certain things, to study certain genes, to see the effects of that…Doing those kinds of projects, especially like in my final year, we had a project for DNA identification where we were able to work with no restrictions and were able to actually analyse certain sequences within a genome using computer programmes, and we were also able to synthesize information, that kind of really helped me with my critical thinking and problem solving skills.*

Project work, in Hunter's experience, created opportunities for learning problem solving skills, analytic thinking, and critical thinking skills. Critical thinking, highlighted by Hunter, is a fundamental 21st century skill and involves "accessing, analyzing and synthesizing information."[38]

Hunter and Zama focussed on creativity as a 21st century skill which was developed through research project work.

Hunter explained:

> *In terms of creativity…especially in genetics. When you are trying to create a new genome, or you are trying to create a conjugated genome, you need creativity to know how you are going to be able to link that small piece of DNA into another organism's genome.* (Hunter)

Zama shared this view, as is evident in the following excerpt:

> *… creativity… collaboration and communication like we, you read a lot of research papers. You communicate with others. You discuss what's happening… especially in the field, that you researching… Because of our load shedding problems that we're having at the moment. They (learners) are interested in working with ways that we can use alternative sources of power like solar power, so they make their own. But they form ways to make solar panels, and how to make their own solar panels, and they (work together to) build a prototype using a shoe box, so it'll be a house that's only using solar (power).* (Zama)

In South Africa, energy shortages have led to intermittent electricity supply, referred to as "load shedding." Zama had planned her instructional practices around a scenario, namely load shedding, and this was referred to as problem-based instruction by Binkley et al.[39] These authors assert that the skill associated with working creatively is to develop, implement and communicate new ideas to others effectively, and this was like Zama's experience of learning 21st century skills.

[38] Joynes, Rossignoli, and Amonoo-Kuofi, "21st Century Skills: Evidence of Issues in Definition, Demand and Delivery for Development Contexts."
[39] Binkley et al., "Defining Twenty-First Century Skills."

The interviewees also displayed the ability to reflect deeply on their learning. This "learning to learn" is associated with ways of thinking. Interviewees were conscious of their weaknesses in their knowledge and skill set, as is evident in the following excerpts from interview transcripts:

> *(It was) very difficult to implement STEM because I was not familiar with certain technology… (I lacked) advanced ICT skills especially in terms of coding.* (Phillipa)

> *My weakness (was) analysing both data and scientific text because… I wasn't really prepared for that when I came to university, so that is something I did struggle with.* (Hunter)

The interviewees also reflected on their strengths which they believed advanced their understanding of STEM.

> *My strengths for the STEM subjects were being able to understand abstract concepts and systems that govern the natural world.* (Hunter)
> *I'm more of a person who is very good at retaining information through listening.* (Bill)

Hunter also had an awareness of learning strategies which led to positive outcomes. He explained:

> *… in terms of studying at university, I kind of developed better learning tactics to make sure that I understood the content well. These included taking the notes that I had been given and trying to break them down and use them to create mind maps or any sort of graphical representation that would help me to kind of picture things very clearly … I would learn to read through the notes, obviously first, and then try and use those notes to create a sort of graphical representation, like a mind map …of "brain impulse" or cloud chart and then use Internet resources, to kind of fill in the gaps of my misunderstandings.*

Zama provided the following metacognitive insight:

> *I usually enjoy(ed) working with lots of examples as a learner. So, the more examples I did the better I became at that topic in maths … visuals like Sketchpad, help me to learn much better.*

Other 21st century skills that the participants displayed were perseverance and self-management, which are central to learning to learn and metacognition.

> *Doing IT course - to explain the use of software to write the code.... I contacted another person by mail from the Laboratories des meteorologie dynamiques. He was working with the software - he introduced this software - he has explained to me how to use it.... (he) was not always available - in the meantime – (I) try to search (to understand how to use information technology) by myself.* (Phillipa)

> *Whenever I face difficulties, I never give up - try to seek help … I try to learn – even if I cannot do something, I make an attempt to do it.* (Phillipa)

Phillipa enjoyed the benefits of the intrapersonal skill of self-management and control over her learning, which led to successful outcomes. She had developed the "soft skill" of taking an active responsibility for her own learning.[40]

The interviewees spoke about experiences of self-examination and self-correction, which provide evidence of metacognitive abilities.

> *(In future I will) not use lfdz to study earth's atmosphere - conduct hands-on activities to make measurements about air pressure, and temperature.* (Phillipa)

Phillipa had used the lfdz software, taking Mars as a reference, to model the climate of the exoplanet atmosphere. If she had to go back and change what she had done, she said that she would not have used this software for the project related to Mars.

[40] Joynes, Rossignoli, and Amonoo-Kuofi, "21st Century Skills: Evidence of Issues in Definition, Demand and Delivery for Development Contexts."

> *I didn't dedicate time to studying (and failed a module) I've learned from it because in my second year repeating maths (together with other) modules that I was doing, I did very well.* (Bill)

> *My project (on pollination among plants) was affected a lot because it was in an open environment, so it has taught me that a lot of things (could have been achieved had I used) a controlled environment, for example, you can manipulate things, such as using the techniques in biotechnology…(next time) I (will opt) to do it in a greenhouse so I wouldn't have the issues I had with the rain which affected my specimens a lot.* (Bill)

The participants' reflections on their weaknesses, strengths, ability to self-examine and self-correct, as well as their perseverance and self-management, demonstrate their learning to learn, or metacognition, which is an important 21st century skill. Their knowledge of preferred learning strategies, what strategies they need to change and why, and their ability to monitor and evaluate their learning consciously, was a demonstration of what Cengelci and Egmir refer to as "metacognitive awareness."[41] The participants who were engaged in postgraduate teacher education revealed that they were "continuously monitoring, evaluating, and developing" themselves.[38] Their ability to take charge of their learning resulted in a more positive self-concept, as is evident in the following excerpts:

> *(I am now) more self-confident, (initially I) was … afraid to approach different people (for assistance in understanding the work) … (I have) courage to learn new things, to try new things.* (Phillipa)

> *(Studying STEM has helped me become) more confident in my speaking because of the orals that we sometimes do when presenting our projects*. (Bill)

Metacognitive awareness could be influential in the formation of a positive teacher professional identity.[42] Metacognitive skills are important for success in the 21st century work environment which has transitioned from an industrial to a more technologically driven, knowledge-rich economy.

"Living in the world" was the category which comprised 20% of questionnaire responses about 21st century skills enhanced by the STEM experience. Within this skill set, personal and social responsibility was the most frequently mentioned questionnaire response. Skills related to global life and citizenship were mentioned less frequently, whereas embracing diversity was mentioned once by a single participant. In-depth interviews about STEM experiences revealed more insights. For example, Zama focused on food security and environmental consciousness by explaining:

> *(We plant a) vegetable garden… We teach about sustainable development, our food shortages, and how growing their own food (using) organic (methods and materials) and looking after the environment (are important).* (Zama)

Phillipa explained that her research was pertinent to daily life events, and served as a preparation for life, as is evident in the following excerpt:

> *Helped me to understand climate change - the study of weather. How we can read the maps shown by meteorological services on TV?*

Phillipa also alluded to the importance of planting more trees and stopping deforestation, to mitigate climate change. Hunter explained how his learning of STEM subjects improved his understanding of science which applies to society by stating:

> *(Study of genetics promotes) understanding of real-life applications helped me to especially understand forensics.*

[41] Sümeyye Cengelci and Eray Egmir, "The Effect of 21st Century Learner Skills and Metacognitive Awareness on Early Teacher Identity.," *Shanlax International Journal of Education* 10 (2022): 270–83.
[42] Betina Hsieh, "Professional Identity Formation as a Framework in Working with Preservice Secondary Teacher Candidates.," *Teacher Education Quarterly* 43, no. 2 (2016): 93–112.

The next set of skills, namely, collaboration and communication, are linked to the 21st century skills category "ways of working". Collaboration and communication during teamwork, while engaging in research projects, were viewed as valuable by the participants. Analysis of questionnaire data revealed that collaboration, communication, and teamwork were mentioned five times. Examples of excerpts from interview transcripts which supported this data are presented:

> *(Study of STEM) helped me to communicate a lot better for example with those that are teaching me, such as my lecturers and also the fellow students that do STEM subjects with me… thinking outside of the box involves a lot of things, and one of them is collaboration, if you think outside the box, then you will start asking questions, you will start collaborating with people around you, you will be asking for more information, doing research, which I think is more relevant to the 21st century, because a lot of things have been implemented due to people who were innovative.* (Bill)

> *I was able to collaborate with my fellow students because we did the research project in groups, I learnt the importance of group work and collaborative work.* (Hunter)

Collaborative work is linked to peer support and enhances student-centred pedagogy.[43] Hunter and Bill acknowledged the advantages of working together and this is important for 21st century workspaces, which will depend on "networked collaboration."[44]

The 21st century skills category, tools for working, was also alluded to by participants. Based on questionnaire data, skills in the "tools for working" category were the least enhanced 21st century skills. There were four mentions in the questionnaires about the use of ICT as part of STEM learning. The tools used by interviewees are described in the following excerpts:

> *(I) allow learners to use ICT. In the classroom. We use data projectors. Learners use that as simulations. The Phet simulation often helps learn this, even Geogebra.* (Zama)

> *I also used the resource of Internet very well, there's plenty of learning resources and videos on YouTube and the like, that can help one to fill in any gaps.* (Hunter)

> *Simulations in technology - encourage them (learners) to think about what will happen next.* (Phillipa)

Phillipa and Zama preferred the use of simulations when teaching mathematics and science. However, although participants did not emphasise the role of technology in their work during the interviews they did allude to this in a minor way. For example, Phillipa mentioned the use of software, Zama specified the use of Sketchpad and Hunter alluded to using computer programs. Assessing students using computer-based simulations can offer deep insights into what students understand and what they can do.[45]

DISCUSSION

This study sought to answer the following key question: "*What 21st century skills do teachers who are engaged in postgraduate studies develop as a result of their experiences of STEM education*?" While the intention was not to compare postgraduate STEM education experiences in South Africa and Mauritius, it is however important to highlight some interesting similarities and contrasts. Both nations recognize STEM education as significant for economic growth and its integration into their curricula. For Bill, 21st century skills were acquired when he participated in what he deemed to be meaningful activities, which

[43] Cassie F. Quigley et al., "Connected Learning in STEAM Classrooms: Opportunities for Engaging Youth in Science and Math Classrooms," *International Journal of Science and Mathematics Education* 18, no. 8 (December 21, 2020): 1441–63, https://doi.org/10.1007/s10763-019-10034-z.
[44] Joynes, Rossignoli, and Amonoo-Kuofi, "21st Century Skills: Evidence of Issues in Definition, Demand and Delivery for Development Contexts."
[45] Binkley et al., "Defining Twenty-First Century Skills."

were connected to real life, in practical work. This set the scene for collaborative work on pollination in plants, and the interpersonal domain with its 21st century skills associated with ways of working, were developed. Zama also privileged ways of working by using group work to teach about problem-solving. The pedagogic strategy that she used was to present the scenario of energy shortages in South Africa. The cognitive domain of 21st century skills was developed because problem-solving, by exploring the use of solar power to meet energy demands, was explored. This activity privileged 21st century skills related to ways of working, namely, communication and collaboration among learners.

South Africa grapples with disparities in access to resources and infrastructure, and this hinders equitable access to STEM education. In contrast, Mauritius has invested substantially in STEM infrastructure and teacher training, fostering a more level playing field. For example, in the cognitive domain, which refers to ways of thinking, participants mentioned the development of skills such as critical thinking, problem solving, innovation, and creativity. These were developed through experiences of active learning activities.[46] Chilisa had engaged in a research project in inorganic chemistry based on the application of the Kjeldahl method in food industries. Determining the protein content of milk is of enormous interest, not only to food technologists but to nutritionists as well. Milk and milk products provide nutrients which serve numerous functions and this information is significant to the food industry.[47] This project reveals that the application of cognitive 21st century skills is not restricted to basic or integrated science process skills. It transcends this because it is highly relevant to the food industry and enables people to make healthy nutritional choices. Ways of thinking, in this case, clearly intersect with the category of living in the world.

Hunter engaged in a research project about genome sequencing, and this contributed to the development of problem-solving, creativity, and critical thinking skills. He indicated that one had to tap into one's creative thinking to work with gene transfer. Importantly, he mentioned the application of this work to the science of forensics, and in this way, he linked this to the 21st century skills category "living in the world".

Ways of thinking also involved metacognitive awareness by connecting ideas of their own learning through self-reflection, and this was strongly developed among the participants.[48] Hunter was aware that mind maps and graphical representations enhanced his understanding, while for Zama, the use of visuals and working with many examples of mathematics problems increased her ability to learn. Bill's ability to reflect on previous strategies used in the project on pollination and to improve on this by using a greenhouse in the future, reveals his ability to self-correct. These skills are located in the intrapersonal domain. Philipa and Chilisa collaborated with outside experts to facilitate their learning, and these skills which are in the interpersonal domain, reflected ways in which they assumed responsibility for their learning. They underscored the value of collaboration, which is linked to "ways of working" in their learning.[49]

RECOMMENDATIONS

Several recommendations emerge from this study. First, a move away from content-centric towards issues relevant to specific contexts is recommended for the development of 21st century skills. This should be accompanied by a general shift from scientist-centric to citizen-centric approaches. The next recommendation has implications for policy, particularly in the context of both countries. In the South African context, the implementation of the policy related to Science and Mathematics education, as outlined in the National Development Plan, could be improved by considering which STEM experiences enhance 21st century skills.[50] Other initiatives, such as the Integrated National Strategy for Mathematics, Science, and Technology (MST) Education, which underscores STEM education in schools, could also be enriched by encouraging a more citizen-centric approach in STEM subjects. In the Mauritian context,

[46] Ji Shen, Shiyan Jiang, and Ou Lydia Liu, "Reconceptualizing a College Science Learning Experience in the New Digital Era: A Review of Literature," *Emerging Technologies for STEAM Education: Full Steam Ahead*, 2015, 61–79.
[47] R. Nagpal et al., "Milk, Milk Products, and Disease Free Health: An Updated Overview," *Critical Reviews in Food Science and Nutrition* 52, no. 4 (April 2012): 321–33, https://doi.org/10.1080/10408398.2010.500231.
[48] Quigley et al., "Connected Learning in STEAM Classrooms: Opportunities for Engaging Youth in Science and Math Classrooms."
[49] Shen, Jiang, and Liu, "Reconceptualizing a College Science Learning Experience in the New Digital Era: A Review of Literature."
[50] National Planning Commission, "National Development Plan 2030: Our Future-Make It Work," 2012.

the policy "Inspiring Every Child", which underscores formal and informal science education, can also be enhanced by adopting a more content-centric approach.[51]

Given the relatively lower socio-economic status of Global South countries, compared to Global North ones, it is further recommended that practical implementation of curricula in STEM subjects should be shaped to suit the context in which teaching and learning takes place. Simple investigations, which do not require complex or expensive resources, can be used within the Global South context, as was revealed in this study. Tapping into the knowledge repository of outside experts is valuable in the Global South context, to compensate for the relative shortage of sophisticated equipment and other costly resources.

CONCLUSION

The key focus of this study was to understand the participants' experiences of STEM education which incubated and nourished their potential for learning 21st century skills. Insights from the findings reveal several characteristics of these STEM experiences. First, there was a departure from traditional, didactic modes of teaching and learning and a move towards activity-based work. Participants who engaged in research-based project work, scenario-based problem solving work and practical experiments in computer or science laboratories developed several 21st century cognitive skills. These are associated with ways of thinking and include creativity, critical thinking and problem-solving. Second, the types of teaching and learning activities involved other students and stakeholders. Ways of working included 21st century interpersonal skills which were collaboration, communication, and teamwork. Third, tools for working included ICT, where Phet and other simulations, and software such as Geogebra and Sketchpad, were used. The skill of ICT literacy was hereby developed. Fourth, participants were conscious of which strategies worked and which ones did not, and this contributed positively to their learning. They were aware of what they would change in the future, to achieve more successful outcomes. This represented the development of metacognitive awareness, an intrapersonal skill where participants reflected on their learning and self-corrected. Fifth, participants associated their experiences of work in STEM disciplines with 21st century skills which are linked to living in the world. Social responsibility and environmental responsibility were 21st century competencies which were developed by cultivating sustainable food gardens. Mitigating climate change by teaching about decreasing deforestation reveals the development of global citizenship competencies. Social responsibility was also developed through research which was based on the analysis of milk proteins. The application of the science of genetics to forensics also signals the development of social responsibility competencies. This study revealed how, by adopting a transdisciplinary approach, and drawing on resources from the individual STEM disciplines to conduct research can generate opportunities for learners to do something new, to innovate, to create, to think critically, to communicate, to reflect, and to work collaboratively and ethically towards the greater good of the planet as a whole.

BIBLIOGRAPHY

Aslam, Sarfraz, Abdulelah A Alghamdi, Nisar Abid, and Tribhuwan Kumar. "Challenges in Implementing STEM Education: Insights from Novice STEM Teachers in Developing Countries." *Sustainability* 15, no. 19 (2023): 14455.

Avendano, Laura, Jessica Renteria, Sarah Kwon, and Kamal Hamdan. "Bringing Equity to Underserved Communities through STEM Education: Implications for Leadership Development." *Journal of Educational Administration and History* 51, no. 1 (January 2, 2019): 66–82. https://doi.org/10.1080/00220620.2018.1532397.

Banerjee, Pallavi Amitava. "A Systematic Review of Factors Linked to Poor Academic Performance of Disadvantaged Students in Science and Maths in Schools." *Cogent Education* 3, no. 1 (December 31, 2016): 1178441. https://doi.org/10.1080/2331186X.2016.1178441.

Barta, Géza. " Solarz, MW: The Global North-South Atlas. Mapping Global Change." *Hungarian Geographical Bulletin* 69, no. 1 (2020): 76–78.

Belchior-Rocha, H., Rosário J. Mauritti, Paiva Monteiro, and Luis Carneiro. "21st Century Skills and Digital Skills, Are One and the Same Thing?" *Edulearn20 Proceedings, IATED*, 2020, 2752-2758.

[51] National Education Trust, "Inspiring Every Child," January 15, 2024, https://www.nationaleducationtrust.org/inspiring-every-child.

Binkley, Marilyn, Ola Erstad, Joan Herman, Senta Raizen, Martin Ripley, May Miller-Ricci, and Mike Rumble. "Defining Twenty-First Century Skills." *Assessment and Teaching of 21st Century Skills*, 2012, 17–66.

Care, Esther, Patrick Griffin, and Barry McGaw. *Assessment and Teaching of 21st Century Skills*. Springer, 2012.

Carlgren, Ingrid. "Powerful Knowns and Powerful Knowings." *Journal of Curriculum Studies* 52, no. 3 (May 3, 2020): 323–36. https://doi.org/10.1080/00220272.2020.1717634.

Cengelci, Sümeyye, and Eray Egmir. "The Effect of 21st Century Learner Skills and Metacognitive Awareness on Early Teacher Identity." *Shanlax International Journal of Education* 10 (2022): 270–83.

Cohen, L., L. Manion, and K. Morrison. *Research Methods in Education*. Routledge, 2018.

Commission, National Planning. "National Development Plan 2030: Our Future-Make It Work," 2012.

Darling-Hammond, L, M LaPointe, D. Meyerson, M. T. Orr, and C Cohen. "Preparing School Leaders for a Changing World: Lessons from Exemplary Leadership Development Programs." Stanford, CA, 2007.

Fomunyam, Dr Kehdinga George. "Towards Enhancing Science, Technology, Engineering, and Mathematics (STEM) Education: A Case for Higher Education in Africa.," 2021.

Hillermann, Emma, Miloš Savić, and Rama Kothapalli. "The Effect of STEM Research Experiences on Fields of Interest and Career Paths." *International Journal of Science and Mathematics Education* 22, no. 5 (June 2, 2024): 1107–26. https://doi.org/10.1007/s10763-023-10409-3.

Hsieh, Betina. "Professional Identity Formation as a Framework in Working with Preservice Secondary Teacher Candidates." *Teacher Education Quarterly* 43, no. 2 (2016): 93–112.

Joynes, Chris, Serena Rossignoli, and Esi Fenyiwa Amonoo-Kuofi. "21st Century Skills: Evidence of Issues in Definition, Demand and Delivery for Development Contexts," 2019.

Kahn, Michael. "Science, Technology, Engineering and Mathematics Education." Paper presentation]. 4th HRDC summit: Skills required for the 21st century …, 2021.

Kahn, Michael, and Joshua Oghenetega. "Origins and Destinations Known: A Tracer Study of International African Doctoral Graduates from South Africa's Universities." *Industry and Higher Education* 35, no. 5 (October 27, 2021): 559–69. https://doi.org/10.1177/0950422221989645.

Lees, Nicholas. "The Brandt Line after Forty Years: The More North–South Relations Change, the More They Stay the Same?" *Review of International Studies* 47, no. 1 (January 16, 2021): 85–106. https://doi.org/10.1017/S026021052000039X.

Loveless, Avril. "Creativity, Technology and Learning–a Review of Recent Literature," 2007.

Msimanga, Audrey, and Anthony Lelliott. "Talking Science in Multilingual Contexts in South Africa: Possibilities and Challenges for Engagement in Learners Home Languages in High School Classrooms." *International Journal of Science Education* 36, no. 7 (May 3, 2014): 1159–83. https://doi.org/10.1080/09500693.2013.851427.

Nagpal, R., P. V. Behare, M. Kumar, D. Mohania, M. Yadav, S. Jain, S. Menon, et al. "Milk, Milk Products, and Disease Free Health: An Updated Overview." *Critical Reviews in Food Science and Nutrition* 52, no. 4 (April 2012): 321–33. https://doi.org/10.1080/10408398.2010.500231.

National Education Trust. "Inspiring Every Child," January 15, 2024. https://www.nationaleducationtrust.org/inspiring-every-child.

National Research Council. *Assessing 21st Century Skills: Summary of a Workshop* . Washington, DC: National Academies Press, 2011.

Quigley, Cassie F., Dani Herro, Calli Shekell, Heidi Cian, and Lori Jacques. "Connected Learning in STEAM Classrooms: Opportunities for Engaging Youth in Science and Math Classrooms." *International Journal of Science and Mathematics Education* 18, no. 8 (December 21, 2020): 1441–63. https://doi.org/10.1007/s10763-019-10034-z.

Reade, Carol, William J Reckmeyer, Mathew Cabot, Dennis Jaehne, and Mark Novak. "Educating Global Citizens for the 21st Century: The SJSU Salzburg Program." *Journal of Corporate Citizenship*, no. 49 (2013): 100–116.

Rifandi, Ronal, and Yosi Laila Rahmi. "STEM Education to Fulfil the 21st Century Demand: A Literature Review." In *Journal of Physics: Conference Series*, 1317:012208. IOP Publishing, 2019.

Shana, Zuhrieh, and Enas S Abulibdeh. "Science Practical Work and Its Impact on High Students' Academic Achievement." *JOTSE* 10, no. 2 (2020): 199–215.

Shen, Ji, Shiyan Jiang, and Ou Lydia Liu. "Reconceptualizing a College Science Learning Experience in the New Digital Era: A Review of Literature." *Emerging Technologies for STEAM Education: Full Steam Ahead*, 2015, 61–79.

Solarz, Marcin Wojciech. "'Third World': The 60th Anniversary of a Concept That Changed History." *Third World Quarterly* 33, no. 9 (October 12, 2012): 1561–73. https://doi.org/10.1080/01436597.2012.720828.

Thi To Khuyen, NGUYEN, Nguyen Van Bien, Pei-Ling Lin, Jing Lin, and Chun-Yen Chang. "Measuring Teachers' Perceptions to Sustain STEM Education Development." *Sustainability* 12, no. 4 (2020): 1531.

Union, African. "Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024)." *Science & Technology African Union Commission, Ed*, 2014.

Voogt, Joke, and Natalie Pareja Roblin. "A Comparative Analysis of International Frameworks for 21 St Century Competences: Implications for National Curriculum Policies." *Journal of Curriculum Studies* 44, no. 3 (June 2012): 299–321. https://doi.org/10.1080/00220272.2012.668938.

Wallis, Claudia, and Sonja Steptoe. "How to Bring Our Schools Out of the 20th Century." *Time Magazine*, 2006.

Wan Husin, Wan Nor Fadzilah, Nurazidawati Mohamad Arsad, Oziah Othman, Lilia Halim, Mohamad Sattar Rasul, Kamisah Osman, and Zanaton Iksan. "Fostering Students' 21st Century Skills through Project Oriented Problem Based Learning (POPBL) in Integrated STEM Education Program." In *Asia-Pacific Forum on Science Learning & Teaching*, Vol. 17, 2016.

Yin, R. K. *Case Study Research and Applications: Designs and Methods* . 6th ed. London: SAGE, 2018.

ABOUT AUTHORS

Ronicka Mudaly is an associate professor in the Science and Technology Education Cluster at the University of KwaZulu-Natal in South Africa. A quest for a science and mathematics education which is socially just inform her pedagogy. Her current interests include research approaches from a Southern Theoretical lens, indigenizing education, environmental education, and gender studies. She is a member of several research associations (SAERA, SAARMSTE, SASO) which focus on science and mathematics education and has in excess of 34 accredited publications in books and journals. Visit https://soe.ukzn.ac.za/staff-profile/science-and-technology-education/ronicka-mudaly/.

Bongani Ndlovu is a Lecturer in Science and Technology Education at the University of KwaZulu-Natal, specializing in chemistry education. He holds a PhD in Chemistry Education and is an active member of SAERA, ESERA, and SAARMSTE. His research interests primarily focus on professional teacher development, specifically exploring the relationship between topic-specific pedagogical content knowledge (TSPCK) and teacher-related science content knowledge (TerSCK). He has published few articles and one book chapter around professional development of pre-service teachers.

Tamirirofa Chirikure is a lecturer in science education at the University of Botswana. He is invested in inclusive science education which guides his teaching. He is an affiliate of SAARMSTE, Zimbabwe Research Network (ZRN), and Teacher Education Network (TEN). His research interests include inclusive STEM education, practical work in science, and approaches to learning. Visit https://scholar.google.com/citations?user=7nWcT-gAAAAJ&hl=en

Doras Sibanda is a Senior Lecturer at the School of Education at the University of KwaZulu-Natal. She completed her PhD in Chemistry Education at the same university and is an active member of the Science

and Technology Cluster, the Representative Community Engagement, and organizations such as SAARMSTE and ESERA. Her skills and expertise encompass Science Teaching, Teacher Training, Pedagogy, Education, Teaching and Learning, Learning Sciences, Science Education, Heat Transfer, Curriculum Development, and Professional Development. Dr. Sibanda's teaching focus is on Science Education, and her research interests include Chemistry Education, Mentoring Science Teachers, Inquiry-Based Science Teaching, Pedagogical Content Knowledge, and Creativity in Africa. She is also passionate about STEM Education, Teacher Development, and Curriculum Decolonization.

Merventharan Perumal Moodley is a lecturer in the Science and Technology Education cluster at the University of KwaZulu-Natal. He specialises in Technology Education at all levels of the Schools curriculum. His research and teaching interests include, Mechanical Technology systems, Engineering Graphics and Design, assessment and visualisation. He is involved with Umalusi at an external level ensuring national standards for examinations and professional development of pre-service teachers at the university.

Fawzia Bibi Narod, Associate Professor, is presently the Head of the department of Science Education at the Mauritius Institute of Education, where she has more than 20 years' experience in teacher education, curriculum development and educational research. In addition to teaching and coordination of courses and programmes, she is actively engaged in research in education and development of curriculum and curriculum materials. She has been actively engaged in several research projects in Education as Principal Investigator or as member of the research team. She has also regularly presented research papers in international conferences (both face-to-face and virtual) and has published a large number of research papers and book chapters in peer-reviewed journals and internationally edited books. Her research interests include STEM Education, Chemistry Education, Science Education Mechanistic Reasoning and Online / Remote Teaching. Dr Narod has also supervised several PhD and MA research students for the University of Brighton (UK) and University of KwaZulu Natal (South Africa) and has recently engaged in MPhil supervision at the MIE. Dr Narod has also contributed to the SAARMSTE Research School for Mathematics, Science and Technology Education as Facilitator.

Vickren Narrainsawmy is a lecturer in the Science Education Department at the Mauritius Institute of Education. He holds an MSc in Organic Chemistry and a Master of Education, M.Ed. degree. Besides teacher education and development of curriculum and curriculum materials at the primary and secondary levels, with a particular focus on science education, chemistry education, and climate change education, he is actively engaged in educational research. His research interests include mechanistic reasoning, inquiry learning, remote teaching, and STEM education.