Decolonizing and Diversifying STEAM Education in Southern Africa: Frameworks and Pathways to Liberation

Chikuvadze P.
Makuvire C.
Sunzuma G.
Zezekwa N.

DeepScience

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Chikuvadze P.

Bindura University of Science Education, Zimbabwe

Makuvire C.

Bindura University of Science Education, Zimbabwe

Sunzuma G.

Bindura University of Science Education, Zimbabwe

Zezekwa N.

Bindura University of Science Education, Zimbabwe

DeepScience

Published, marketed, and distributed by:

Deep Science Publishing
USA | UK | India | Turkey
Reg. No. MH-33-0523625
www.deepscienceresearch.com
editor@deepscienceresearch.com
WhatsApp: +91 7977171947

ISBN: 978-93-49910-28-7

E-ISBN: 978-93-49910-20-1

https://doi.org/10.70593/978-93-49910-20-1

Citation: Chikuvadze, P., Makuvire, C., Sunzuma G., & Zezekwa N (2025). *Decolonizing and Diversifying STEAM Education in Southern Africa: Frameworks and Pathways to Liberation.* Deep Science Publishing. https://doi.org/10.70593/978-93-49910-20-1

Preface

In recent decades, Science, Technology, Engineering, the Arts, and Mathematics (STEAM) education has been heralded globally as a driver of innovation, economic growth, and societal advancement. Yet in Southern Africa and in many parts of the Global South STEAM education remains deeply entangled with colonial legacies, Western-centric frameworks, and structural inequities that marginalize indigenous knowledge systems, local histories, and diverse identities. This book, *Frameworks and Pathways to Liberation*, is an urgent response to the enduring problem.

This book represents the first of a two-part journey that interrogates, disrupts, and reimagines STEAM education from the perspective of the oppressed. It begins by laying a theoretical and philosophical foundation for a decolonial approach to STEAM learning one that is inclusive, ethical, and rooted in the lived realities of Southern African communities. By foregrounding Indigenous Knowledge Systems, culturally responsive pedagogies, gender inclusivity, and the social responsibilities of scientists and educators, the chapters herein challenge the assumption that science and technology are neutral or universally beneficial. At its core, this book asks: *Whose knowledge counts in the classroom? Whose voices are heard in the lab? And how can education serve as a tool for liberation rather than domination?*

The first chapter offers a conceptual framework for understanding STEAM education as a transformative force when it is critically examined and restructured. Chapter Two builds upon this by exploring decolonization strategies that elevate indigenous epistemologies and question the dominance of Eurocentric curricula. The third chapter turns to ethics, highlighting the profound responsibilities that come with power in scientific practice and education. Chapter Four illustrates how STEAM can be a vehicle for social justice, providing case studies that inspire and instruct. Finally, Chapter Five focuses on gender, addressing how identity and access are shaped by social and cultural dynamics that must be dismantled for true equity to emerge.

This book is intended for educators, curriculum designers, policymakers, researchers, and activists committed to rethinking what STEAM education can be in contexts of historical oppression and ongoing struggle. It invites readers to consider not just what is taught, but *how*, *why*, and *for whom*. *Frameworks and Pathways to Liberation* is both a critique and a call for action. It is a recognition that to change the future of science and technology in Southern Africa, we must first transform the way they are taught today.

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Deep Science Publishing
https://doi.org/10.70593/978-93-49910-20-1

Chapter 1: Theoretical Foundations of STEAM Education: A Framework for Effective Learning

1 Introduction

STEAM education, which includes Science, Technology, Engineering, Arts, and Mathematics, is increasingly recognized to be a revolutionary way of learning in Africa. As opposed to the conventional STEM models, STEAM integrates art and creative thinking, building a culture of innovation, critical thinking, and problem-solving skills. Theoretical underpinnings supporting STEAM education in the African context are presented in this chapter.

STEAM, the addition of the Arts to STEM, has been another pedagogical alternative to address creativity, risk-taking, cooperative participation, hands-on learning, and persistence in problem-solving (Belbase, et al., 2021). The STEAM model sets students up for the roles of future leaders, innovators, scientists, engineers, educators, entrepreneurs, and lifelong learners of the twenty-first century. STEAM is a comprehensive strategy of STEM integrating disciplinary fundamentals with the arts to develop interdisciplinarity-based mathematics, science, and technology education by using design thinking and inquiry processes (Stroud & Baines, 2019). STEAM is a teaching pedagogy as well as an innovation engine (Liao, 2019) and an education and community development paradigm shift globally. STEAM has increasingly been implemented in African countries (Digital Education Africa Network [DEAN], 2020; Kruger, 2019; Women Entrepreneurs for Africa, 2020).

STEAM education is a paradigm-breaking model that closes the gap between theory and practice, with an uninterrupted exchange between disciplines (Quigley et al., 2019). The inclusion of the arts in STEAM not only brings the disciplines together under an umbrella of wider, interdisciplinary coverage but also maintains their core essences, enabling learners to tackle real problems holistically (Quigley & Herro, 2019). The shift from STEM to STEAM is a paradigm shift from discipline-specific, content-driven education to an integrative, lifelong learning model (Yakman, 2019). The STEAM model integrates knowledge from Science, Technology, Engineering, Arts, and Mathematics as a canvas to enhance students' inquiry-based learning, critical thinking, and problem-solving skills. In practice, it focuses on experiential learning, collaboration, creativity, and innovative competencies that are essential to succeeding today (Taylor, 2016).

As opposed to traditional STEM methods, STEAM incorporates arts to encourage innovation, creativity, and deeper engagement in design thinking. The chapter discusses the conceptual and theoretical bases of STEAM education, primarily within the African school system. By incorporating artistic disciplines into STEM, the STEAM approach encourages creativity, collaboration, experiential learning, and resilience in addressing complicated challenges (Belbase et al., 2021). This transdisciplinary way hopes to produce students who are prepared for the future as designers, scientists, engineers, instructors, entrepreneurs, and critical thinkers ready to challenge the issues of the 21st century. STEAM does more than integrate arts into mathematics and science; it cultivates an integrated, combined model of learning that threads ideas across disciplinary subjects together via design-inquiry and experiential exploration (Stroud & Baines, 2019). It has been identified worldwide, including in African education programs, as a tool of community education reform and empowerment (Women Entrepreneurs for Africa, 2020; Digital Education Africa Network [DEAN], 2020; Kruger, 2019).

Instead of isolating the disciplines, STEAM offers interdisciplinarity that facilitates the use of knowledge in practical situations (Quigley et al., 2019). The combination maintains the individuality of each discipline but allows learners to address compound real-world problems in a one-track problem-solving approach (Quigley & Herro, 2019). STEM-to-STEAM is an overarching change in philosophy of teaching looking ahead to content-focused instruction to an interactive model of lifelong learning (Yakman, 2019). Focusing on science, technology, engineering, arts, and mathematics, STEAM enhances the problem-solving, thinking, and collaborative skills of the students to thrive in our globalized world (Taylor, 2016).

STEAM education transformed the way that students learn STEM by introducing an additional dimension that is focused on creativity and how the different disciplines relate to one another. Including arts introduced variety to the study of STEM prior to the trend of robotics taking off. Including the arts, STEAM makes it possible for the linking of students' learning in the field of STEM to creative and expressive elements. This paradigm change has extended the scope of traditional STEM learning, with emphases on innovation, inquiry, and critical thinking. In all respects, practically speaking, STEAM has not only improved but revolutionized its predecessor by being a more whole, creative, and inquiry-driven learning experience (Taylor, 2016).

1.1 Theories Guiding STEAM Education

Constructivism (Piaget, Vygotsky): Learning through Active Engagement

Constructivism is a predominant theory of education in psychology which postulates that learning is active and ongoing with the individual developing knowledge of the world from life and social interaction experiences. Learning does not just take place, where learners take information passively. Instead, learners actively create new knowledge based on their current experience and existing knowledge. It lies at the heart of STEAM education design as it embodies experiential learning, problem-solving and knowledge building and knowledge building through discovery and exploration.

Experiential Learning (Kolb)

Experiential learning refers to a philosophy of education that emphasizes the importance of learning from direct, first-hand experience and reflective practice. Founded on David A. Kolb's writings, the theory believes that effective learning happens when one goes through four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Instead of passively taking in information, students construct knowledge by actively engaging themselves with real-world tasks, analyzing the outcomes of those activities, and applying what they have learned to new situations. In STEAM learning, this method is especially effective because it facilitates active, project-based learning that connects educational principles with concrete, real-world problems (Bassachs et al., 2020). To Kolb, knowledge construction involves acquiring the ability to adapt to novel experience, understand it, and integrate those understanding through ongoing engagement with the learning environment.

Kolb's Experiential Learning Cycle sets learning as an ongoing process consisting of four stages. First, in Concrete Experience (CE), learners experience something directly, like a hands-on activity, an experiment, or a field study in STEAM education. Second, in Reflective Observation (RO), they think about the experience, taking into account what worked and what did not and discussing what was learned, like analyzing the result of an experiment or thinking about the design of a prototype. In Abstract Conceptualization (AC), students construct theories or concepts from their reflections, making sense of their experiences and grasping general ideas. Lastly, in Active Experimentation (AE), they use their new learning to experiment, adjust methods, and iterate through solving problems and hypothesis testing to achieve ongoing learning and adaptation (Kolb, 1984; Mater, 2023). These actions constitute a recursive loop of learning, each giving way to more questions and greater understanding. In STEAM education, students are able to do this again and again within a single activity or project, refining their concepts and methods as they proceed through real problems.

Multiple Intelligences Theory (Gardner)

Howard Gardner suggested that intelligence is not a single static score such as an IQ score but a wide and dynamic array of abilities. Such abilities comprise linguistic, logical-mathematical, spatial, musical, bodily-kinesthetics, interpersonal, intrapersonal, and naturalistic intelligences (Hasanuddin et al., 2022; Nyaaba et al., 2024). Rather, Gardner (1983) suggests that intelligence is multi-faceted and takes many forms, each of which will be able to identify different ways in which individuals will develop, process, and express their understanding of the world. Each individual, under this theory, has a unique set of intelligences, and these varied forms of intelligence affect the way in which students approach material, solve problems, and demonstrate proficiency in different subject matters.

Shahda et al. (2019) pointed out that one of the major aims of the STEAM approach is to provide multiple learning styles and multiple intelligences with support that engages students' senses, develops social skills, stimulates social growth, and generates cognitive and critical thinking abilities. STEAM learning also aims to bridge the school curriculum and real life and society so that the students can meet the emerging challenges of the modern world. In STEAM education, Multiple Intelligences Theory is a guiding framework for convincing teachers to implement varied and inclusive teaching practice (Pasedan & Nadeak, 2021). It acknowledges that students possess variable learning strengths as well as variable learning styles and meanings that one-size-fits-all education tends to fail. Rather, by using Gardner's intelligences within classroom instruction in STEAM, educators can open science, technology, engineering, arts, and mathematics for and to all students no matter what their learning abilities might be.

Sociocultural Theory (Vygotsky)

Vygotsky's sociocultural theory focuses on the powerful impact social interaction, culture, and language have on learning and teaching. Vygotsky (1978) contends that learning is social and that people acquire understanding and expertise by interacting with others, especially in common cultural environments. In contrast to the conventional views of learning that emphasize individualistic knowledge acquisition, Vygotsky's theory advocates for the importance of the social environment for cognitive growth. This idea is very applicable to STEAM education, where communication, cooperation, and collaborative problem-solving are characteristic aspects.

The significance of social mediation to cultural tools (e.g., symbols, language, and artifacts) and learning was highlighted in the theory. The tools enable cognitive development and equip learners with the ability to utilize higher order thinking. In STEAM education, this theory informs how teachers design learning environments that respect collaboration, mentorship, and social learning, allowing students to participate in meaningful interactions that construct a problem-solving and critical thinking within the science, technology, engineering, arts, and mathematics context.

Systems Thinking Theory

Systems Thinking Theory is a way of understanding interdependence and interrelatedness of elements in a whole system. As opposed to the linear approach, founded upon bounded elements and their linear cause-and-effect interactions, systems thinking is interested in the interaction between the constituents of a system as well as how interactions between the constituents affect the whole system. This systems view is essential in STEAM education as it assists learners in seeing that science, technology, engineering, arts, and math problems are not siloed but are interconnected as part of a web of systems.

Systems Thinking Theory thus prompts students to look beyond particular elements of a challenge to understand how they affect and are affected by other elements, both in their immediate surroundings and also in the wider societal, environmental, and worldwide environments. Through bridging disciplines in problem-solving and learning, systems thinking allows learners to gain a greater appreciation of the complexity they are exposed to in actual problems and challenges, and it allows critical skills like collaboration, problem-solving, and critical thinking on a systems scale. Experts (Peppler & Wohlwend, 2018; Danielson, et al., 2022) describe STEAM education as transdisciplinary education that transcends the constraints of separate disciplines to examine and solve challenging, real-world problems (Costantino, 2018).

One of the most significant examples of such transdisciplinary gain is systems thinking (Liao et al., 2016). With the inclusion of the arts, students are taught to look for connections, think from multiple perspectives, and cultivate such traits as empathy, critical and creative thinking, (Danielson, et al., 2022). These skills not only enrich STEM education but also make it possible for students to solve problems efficiently on a multidisciplinary level, pointing to STEAM's wider educational return beyond its benefit to STEM itself (Danielson, et al., 2022).

1.2 Developing a STEAM theoretical framework

In a bid to expand productive, inclusive, and contextually sensitive STEAM education models specifically among under-resourced and marginalized populations, there is a need to anchor educational practice in robust theoretical underpinnings. The establishment of a STEAM theory framework implies the incorporation of an assortment of education theories that favour active engagement, cultural sensitivity, social interaction, and interdisciplinary study. These types of theories have the tendency to shape the manner in which students construct knowledge, navigate their world, and make sense of problem-solving using a STEAM lens.

Figure 1.1 illustrates the interconnections among key learning theories such as Constructivism, Experiential Learning, Multiple Intelligences, Sociocultural Theory, and Systems Thinking and how each contributes to the broader goals of STEAM education. This framework highlights the synergies between these theories in promoting holistic learning experiences that are both learner-centred and socially grounded. By visualizing these relationships, the framework offers educators, policymakers, and curriculum designers a structured yet flexible foundation for implementing transformative STEAM education, particularly within the Southern African context. Figure 1.1 shows how the theories are interrelated and connected to STEAM education.

Constructivism and Social cultural theory (Jean Piaget and Lev Vygotsky)

Lev Vygotsky and Jean Piaget, the most influential constructivist theorists, argue that learning occurs when individuals actively engage with their environment. Piaget stresses that students develop their knowledge actively by stages of intellectual growth, whereas Vygotsky refers to the importance of social relationships in acquiring knowledge. Constructivist learning is more than just passively receiving facts, where students have to build on, adapt, and revise what they know already as they acquire new experience.

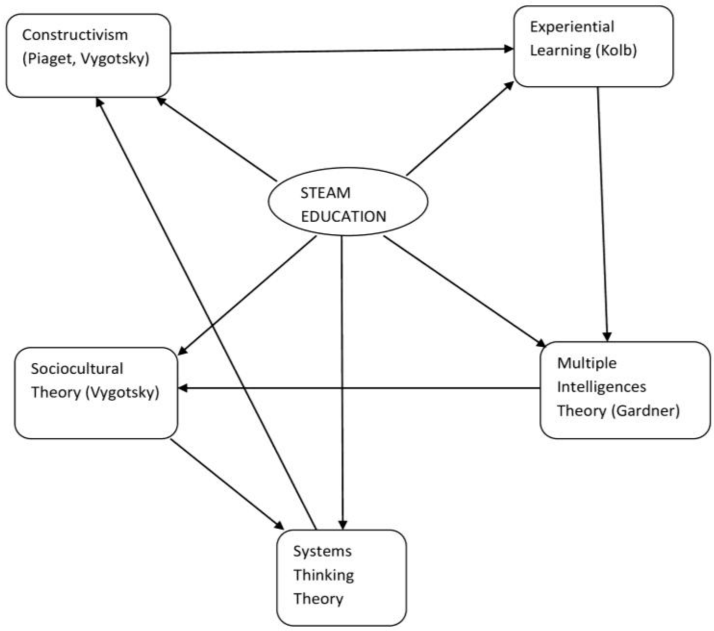

Fig 1.1 STEAM theoretical framework

Constructivism, in the context of STEAM learning, guides learners to construct their own knowledge by solving real problems directly (Nuraini & Muliawan, 2020). Instead of memorizing facts or performing tasks, learners are supposed to investigate ideas, formulate hypotheses, experiment, and reach a conclusion. The question-and-answer, problem-solving approach of STEAM activities reinforces this process by challenging students to solve problems, experiment, and develop projects using their understanding of scientific, mathematical, artistic, technological, and engineering concepts.

Constructivism is most suited to student-centered learning in which students must discover, query, and search on their own or in collaborative groups. It is exactly that which STEAM education promotes with the utilization of inquiry-based learning (IBL) and project-based learning (PBL) where students are presented with a problem to be solved that must be addressed with the application of knowledge across a variety of disciplines (Perignat & Katz Buonincontro, 2019). This method promotes critical thinking and deep understanding, as students are required to apply what they have learned to real-life problems.

Piaget's cognitive theory proposes that students develop through different stages of cognitive development sensorimotor, preoperational, concrete operational, and formal operational. Through each stage, students develop the capacity to think more abstractly and approach increasingly complex problems. STEAM education instructors can adapt activities to meet students' developmental stages, providing challenges relevant for their age and promoting cognitive development through experiential problem-solving. For instance, younger students engage in model-building or basic experiments, whereas older students carry out more abstract problem-solving activities.

Vygotsky emphasized the importance of language in cognitive development, as a primary tool for thought and communication. Through language, individuals can articulate their thinking, engage in dialogue with others, and internalize new concepts. In STEAM education, language is not only important for communication but also for reasoning and problem-solving. Discussions, debates, and collaborative work allow students to clarify their ideas, challenge assumptions, and refine their understanding of the material.

Vygotsky's concept of the Zone of Proximal Development (ZPD) describes the gap between a learner's current ability to perform a task independently and their potential ability when supported by someone more experienced, such as a teacher or peer. In STEAM education, this concept emphasizes the importance of collaborative learning and mentorship (Pande & Bharathi, 2020). Teachers and peers provide scaffolding, or support, to help students in bridging the gap between their current knowledge and the next level of understanding. Through guided interactions and collaborative problem-solving, students can achieve higher levels of thinking and understanding.

Vygotsky further points out that learning is also significantly shaped by social interaction and culture. Vygotsky contends that cognitive development is not only the individual's development but also shaped by the tools of culture like symbols, language, and artifacts inherited across generations and that structure the way people think, solve problems, and interact with their world and social interactions students have. These tools are essential to cognitive development and include literacy in written text, numbers and math symbols, technological apparatuses, and art skills. In STEAM, these cultural tools are essential to allow students to communicate ideas, reason, and work with the subject matter. For example, students can utilize mathematical formulas, computer code, or design programs as cultural tools that ease their learning and make complex STEAM ideas more comprehensible to them. In STEAM learning, this also gives more emphasis on collaboration, group work, and communication within the learning process (Pande & Bharathi, 2020). It is through talking through ideas, sharing perspectives, and collaborative problem-solving that it is learned. This not only extends further towards building knowledge but also improves communication, collaboration, and creativity skills are crucial to success in the new workplace.

Experiential Learning (Kolb)

Learning as a Process of Transformation: Kolb’s theory emphasizes that learning is a process of transformation, where learners continuously engage with their experiences, refine their understanding, and develop new skills (Kolb, 1984). Instead of simply absorbing information, students transform their experiences into knowledge through active engagement and reflection. In STEAM education, this means that students are made to explore, test, and modify their ideas as they work through projects or experiments.

Experiential learning put emphasis on active involvement of students in the learning process (Kolb, 1984, Mater, 2023). This active involvement is essential in STEAM, where learners engage in practical tasks such as building models, conducting experiments, designing solutions, and testing their ideas in real-world contexts. These activities require students to be critical thinkers, collaborators, and problem-solvers which are vital components of STEAM education.

Multiple Intelligences Theory (Gardner)

Gardner's nine intelligences in STEAM:

Logical-Mathematical is the ability to reason, solve problems, and think in numbers; crucial in mathematics and science in STEAM.

Linguistic - refers to communication and use of language; crucial in writing, reporting, and describing STEAM concepts.

Spatial - allows for visual thinking and manipulation of objects in the mind; beneficial in design, engineering, art, and robotics.

Bodily-Kinesthetics - deals with physical expression and learning through experience; crucial for experiments, model-making, and performance activities.

Musical - pertains to rhythm and recognition of sound; used in pattern recognition, audio production, and incorporating music in STEAM.

Interpersonal- deals with interpersonal relations and collaboration; crucial in group projects and collaboration in STEAM education.

Intrapersonal - pertains to awareness of self and independent thoughts; useful in motivation, reflection, and setting personal goals in STEAM activities.

Naturalistic - pertains to recognition of nature and ecosystems; useful in environmental science, biology, and sustainability-based STEAM projects.

Existential - addresses profound philosophical issues; can enrich STEAM by virtue of ethical debate about technology, science, and society.

Personalized Learning Paths: The theory of multiple intelligences inspires teachers to approach each student as an individual and to appreciate the diversity of student learning. Rather than emphasizing any one of just linguistic and logical-mathematical modes, teachers are motivated to see the complete range of intelligences in their classrooms. This enables them to be instruction-responsive and design learning experiences that fit the strengths of each learner. In STEAM education, it implies providing alternative ways and activities that appeal to several intelligences so that all learners can access the material and meaningfully participate.

Gardner's theory invites varied teaching practices that are sensitive to the multiple modes students learn. In a STEAM setting, this might involve applying an array of activities, such as:

Hands-on activities (to engage bodily-kinesthetics learners), Group discussions (to assist interpersonal intelligence), Imaginative visual aids (to assist spatial learners), Music and rhythm (to stimulate musical intelligence), and Written or verbal expression (to assist linguistic intelligence). Teachers can employ a variety of pedagogical techniques in an effort to create a diverse and interactive classroom setting wherein students will be able to learn as effectively as possible.

Systems Thinking Theory

Systems thinking is grounded on the philosophy of holism, that the whole has properties which cannot be comprehended by examining the independent parts in isolation. That is, independent parts of a system cannot be understood independently because they influence and exchange information with one another in intricate patterns. In STEAM education, this view teaches students to consider issues from a variety of standpoints and disciplines, realizing that issues need a multidisciplinary solution. For example, when designing a sustainable city, students must consider not only engineering and technology but also the environmental impact, the social aspects, and the economic factors, each influencing the others.

Systems thinking emphasize the interconnections between various elements within a system. Every part of a system is linked to others, and changes in one part can affect the entire system. Feedback loops, both positive (reinforcing) and negative (balancing)are a central feature of systems. In a positive feedback loop, an action leads to an outcome that reinforces the action (e.g., a population increase leading to more resource use, which in turn encourages further population growth). In a negative feedback loop, an action triggers a response that counteracts the change (e.g., an increase in temperature causing a cooling effect). Systems thinking helps students understand that changes in one area can have cascading effects, and the impact of interventions needs to be carefully considered.

Emergence refers to the idea that complex behaviour or properties can arise from simple interactions between elements of a system. These emergent properties cannot always be predicted or understood by examining individual components. Systems thinking in STEAM assists students to understand that when different factors are combined, new, unexpected results can occur. For instance, the development of a new technology can have unexpected effects on the environment, economy, or societal factors that must be factored into the design process.

Mental models are mental representations or conceptual frameworks that people apply to understand how the world works. In systems thinking, they are used in problem-solving and decision-making. Mental models may be incomplete or wrong at times, causing misinterpretation or poor solutions. STEAM education encourages the development and refinement of mental models as students learn about complicated systems and cause them to think critically about their assumptions and change their method when new information is discovered.

Systems thinkers usually use visual aids such as systems maps, diagrams, and causal loop diagrams to represent the elements of a system and how they interact. The visual aids enable students to have a better sense of the structure and behavior of a system in a way that they can identify possible areas of leverage or intervention. Systems mapping may be conducted in class to demonstrate variable relationships within science lab work, engineering design, or social actions so students may observe the nature of systems and gain greater knowledge about their dynamics.

2 Weaving theories in STEAM education

Hands-On Learning

According to Thuneberg et al. (2018) and Perignat and Katz-Buonincontro (2019), the implementation of constructivist pedagogies in STEAM learning is needed in order to sustain students' sense of belonging, confidence, and autonomy, as these are essential in building their professional identities. STEAM learning environments are created to facilitate active, experiential learning, a mirror of the underlying principles of constructivist theory and consistent with the way in which students will naturally interact with and learn new information (Nyaaba et al., 2024). Constructivist theory lends itself quite easily to hands-on, inquiry-based STEAM activities. STEAM classrooms tend to be where students work on projects, experiments, and activities that encourage them to actively find out and build (Ishartono et al., 2021). For instance, students can create models to comprehend mathematical principles, perform experiments to validate scientific concepts, or create prototypes as a solution to an engineering problem. These enable students to acquire knowledge through experience and not learn from information transfer from a book or teacher.

Constructivist learning focuses on inquiry learning, which encourages learners to question, investigate, and research concepts to find answers. In STEAM teaching, this is made possible as it allows the student to interact with challenging real-world problems that promote analytical reasoning and the development of problem-solving skills (Wised & Inthanon, 2024). Students can explore questions such as: "How do we develop a renewable energy source?" or "What are the patterns in mathematics from nature?" The process of inquiry promotes curiosity, stimulates critical thinking, and leads students to form a deeper foundation of concepts.

Experiential learning is also complementary to PBL, which is one of the major STEAM education strategies. PBL keeps students immersed in long, multidisciplinary projects that mirror real-world problem-solving (Wised & Inthanon, 2024). Such projects give students an opportunity to apply what they learned in class to actual situations. For instance, a group of students may be involved in developing a clean energy system for a community, utilizing engineering, physics, and environmental science concepts. Using their own experiences in learning, probing outcomes, and refining their own designs, students are using the whole experiential learning cycle to gain knowledge of the subject.

Higher Problem-Solving

Multiple Intelligences challenges students to view problems from various perspectives. This builds critical thinking capacity and utilization of interdisciplinary knowledge in solving intricate problems. For instance, an environmental sustainability STEAM project may need students to use logical-mathematical intelligence in data processing, naturalistic intelligence in learning about ecosystems, and interpersonal intelligence in being excellent at working with collaborative solutions.

Systems thinking teach STEAM students to approach problems in a non-linear, holistic way, understanding that real-world problems are most often not linear and will probably be affected by numerous interconnected variables (Yakymenko, et al., 2020; Grace, 2021). In STEAM, problems usually involve solving challenges with intricate systems (Danielson, et al., 2022) such as coming up with a solution for green energy, addressing the effects of climate change, or designing a work of art that represents cultural heritage. Using systems thinking, students are able to deconstruct the intricacy of the problems into manageable parts while seeing the bigger picture. They learn to look back at the consequences of their choices, determine leverage points, and seek solutions that are effective, innovative, and sustainable.

Experiential learning in STEAM education assists students in connecting classroom education to the real world (Mater, 2023). Students learn the applicability of their learning by solving real-world issues and acquire skills for daily life. For instance, students involved in an engineering project to design a water filtration system may begin by making their prototype (Concrete Experience), reflecting on how their design worked and failed (Reflective Observation), making conclusions concerning the filtration principles (Abstract Conceptualization), and redesigning their system for efficiency (Active Experimentation). This hands-on experience allows students to observe the real effect of their work in real life and encourages them to think about how they can tackle challenging problems.

Cultural Context in Problem-Solving

Vygotsky's emphasis on the cultural aspect of learning highlights the significance of cultural context in problem-solving, especially in STEAM education. Given that various cultures hold different perspectives, systems of knowledge, and methods of problem-solving, educators can create STEAM projects that include diverse perspectives. This may involve conducting research on engineering solutions based on indigenous knowledge or learning how various cultures solved scientific or artistic problems. By incorporating cultural context in STEAM curriculum, the students have a wider and richer grasp of the topic, with an understanding of the fact that creativity and innovation are affected by various backgrounds. Collaborative Problem-Solving

Since Vygotsky brought into focus the social nature of learning; STEAM classrooms are themselves frequently collaborative problem-solvers.

The students learn to collaborate in solving real-world problems, using their knowledge and skills to find the solutions. This collaboration makes peer learning easier, where peers can learn from the strengths of one another and assist the group to succeed. The peer interaction also makes the students think about their own method and thinking, resulting in better, richer comprehension (Wised & Inthanon, 2024). Social communication by Vygotsky is the most appropriate for STEAM education's collaborative context. In STEAM classrooms, learning is more likely to be done in groups to solve problems, carry out experiments, or work on projects (Liao, 2016). When working in groups, students can share information, leverage one another's ideas, and acquire crucial interpersonal skills. Collaborating with others makes learners learn from peer-to-peer guidance and others' strengths. For instance, the students working on a project for robotics will include one student who has programming ability, another one with excellent engineering, and a third with designing skills. Working together, every one of the students contributes the field they excel in, and the knowledge pool of the team is enhanced. Systems thinking in itself is a team effort as it involves the students working as teams to grasp and solve sophisticated systems (Grace, 2021).

In STEAM programmes, the students usually finish group work wherein effective communication and teamwork are crucial in their success. Systems thinking ensures that the students realize that they must offer diverse viewpoints and areas of specialization so that a problem can be resolved effectively (Yakymenko, et al., 2020; Danielson, et al., 2022). For instance, when coming up with a new technology, the students can be asked to collaborate with other individuals who possess engineering skills, mathematics skills, user experience design skills, and sustainability skills. Systems thinking puts emphasis on the fact that collaboration will only be effective if an individual knows the system as a whole and where each of them fits in the system. Scaffolding and Mentorship

To implement Vygotsky's scaffolding ideas, STEAM classroom teachers scaffold and aid students through challenging material.

Teachers and mentors provide the support required to enable students to manage challenges independently, reducing support step by step as students become more confident and skilled. Scaffolding is useful in assisting students to move from easier to more challenging tasks, so that they are challenged but not overwhelmed. Vygotsky's approach placed greater stress on mentorship and expert support in the learning and teaching process. STEAM learning may include it in the sense of teachers offering scaffolding, as students also look for external mentorship from field experts like industry, university, or community experts. Mentorship assists students in overcoming hindrances and extracting information that could be difficult under a classroom-only experience. For example, students working on a design project may be mentored by an engineer in their community who can explain to them how engineering principles are applied in everyday life. Such mentorships offer students a chance to learn more, pose questions, and build confidence in themselves.

Cognitive Development Through Interaction with Experts

Vygotsky's theory is also suggested to be that learners learn cognitive skills by collaborating with more-knowledge individuals. In STEAM education, learners benefit from collaboration with specialists who are able to provide knowledge about complex issues or real-world applications of STEAM concepts. For example, a visiting speaker from a technology firm may explain how a software program is developed, or an artist may demonstrate how mathematical principles are used to design. These interactions provide students immediate access to real-world experience and viewpoints, increasing their knowledge and motivating them to continue exploring the STEAM fields.

Interdisciplinary Learning

The experiential approach promotes interdisciplinarity, whereby students synthesize information from numerous STEAM disciplines (Liao, 2016). An assignment to design and construct a building and study its effect on the environment, for instance, calls for synthesizing engineering, mathematics, science, and art concepts. Such an integrated experience is also how the world works in actuality because most challenges tend to call for cross-disciplinary solutions. Through experiential learning, students are more empowered with the understanding of how various disciplines converge to address complex issues. Multiple Intelligences Theory ensures that students with varying learning styles are accommodated by providing different means of learning

STEAM education inherently encourages interdisciplinary learning since it incorporates science, technology, engineering, arts, and mathematics. Systems thinking takes this integration a step further by encouraging students to value the way that knowledge in a number of disciplines overlaps and informs each other (Yakymenko, et al., 2020). For example, when solving an environmental problem, mathematics can be applied to analyze numbers, science in an effort to understand ecologic process, engineering for the design of sustainable mechanism, technology as a tool for executing innovative solutions, and art to present them in visual or performance form. By recognizing the interconnections of these subjects, students get a fuller sense of the problem at hand and how to approach problems with a multi-faceted strategy (Grace, 2021).

Construction of Meaning through Dialogue

Learning is a social construct constructed in dialogue and meaning negotiation, according to Vygotsky. In STEAM education, this is especially useful when students are working with problems that have to be solved with creative thinking and critical thinking. Through discussion and debate with one another, students express themselves, challenge their presuppositions, and think about other people's thoughts. For instance, in design thinking, students can discuss possible solutions to a social issue and think about how different strategies will or will not work out. Discussion helps them build a richer picture of the problem and better think.

Linguistic Intelligence is the capacity to use language effectively for communication, storytelling, and understanding written and spoken information. Students with strong linguistic intelligence excel in reading, writing, and verbal expression. This intelligence supports learning in all STEAM disciplines, especially in areas that require clear communication, such as explaining scientific findings or writing reports (Bardají Carrillo, 2022).

Develops Critical Thinking and Analytical Skills

Students who apply systems thinking are encouraged to think critically and analytically about how different components of a system interact and influence each other (Grace, 2021). They learn to ask questions like, "What are the unintended consequences of this action?" or "How will this change affect other parts of the system?" These analytical skills are critical for success in STEAM disciplines, where students must consider multiple variables, assess risks, and evaluate the potential outcomes of their decisions. For example, when designing a sustainable city, students must think about the interconnections between urban planning, transportation, energy use, and the environment. An advantage of systems thinking in STEAM education is its ability to help students consider the long-term impacts of their actions (Grace, 2021). Systems thinking foster an understanding that solutions to complex problems should not only work in the short term but also be sustainable over time. In STEAM, this is particularly relevant when students are designing technologies, systems, or products that could have far-reaching consequences. For instance, in designing a new technology, students are required to consider how it would impact society, the environment, and the economy presently and in the future.

Spatial intelligence is the capacity to think and reason visually such as identifying pattern, shape, and space and is central to topics such as geometry, design, architecture, and engineering. Highly spatial students excel in visualizing and mentally manipulating objects, which are applicable in topics such as robotics and art. For instance, a highly spatial student can perform well in a STEAM program that involves hands-on and visual methods (Habibi, 2023).

Encourages Global and Environmental Awareness

Systems thinking enables students to appreciate that most of the greatest issues of the contemporary world, including climate change, resource degradation, and social injustice, are global in nature and need to be addressed through concerted effort by a number of sectors and disciplines. STEAM education encourages students to take a sense of responsibility toward global and environmental sustainability, understanding that each action and decision they make has serious consequences. By systems thinking, students gain the ability to understand world systems, value their interdependencies, and suggest solutions to enable a sustainable and more equitable world.

Reflection as a Learning Tool

Reflection is an essential element of experiential learning. Kolb emphasizes that students need to reflect on the experience so that they can solidify their learning. In STEAM classes, reflection comes in numerous forms: students will journal, discuss in groups, or report out in a presentation to share what they've observed (Bassachs, et al., 2020). Reflection causes students to reflect back on what did work, what didn't, and why. It allows them to make sense of their learning and link their experiences to broader concepts, leading to deeper learning and retention.

Personalized Learning and Ownership

Personalized learning is facilitated by experiential learning. The students can be held responsible for learning through taking up projects which suit their capabilities and interests. Within STEAM learning, such a tactic translates to higher levels of interest and motivation since the students directly perceive that their output is being implemented and are inspired to pursue inquiry (Bassachs, et al., 2020). The freedom to experiment, erase mistakes, and analyze mistakes enables the students to take ownership of the learning process and be sure of their capability.

Inclusion and Differentiated Instruction

Recognizing that students have various learning styles, Multiple Intelligences Theory espouses differentiated instruction, an essential component to address the individual needs of the learners in a STEAM classroom. Teachers can create assignments and activities that are intelligent-sensitive, providing every student with a chance to shine and contribute to the best of their abilities. For example, students who are more familiar with the written word can provide reports or make presentations, while students who are outstanding in the learning of kinesthetics can create three-dimensional models or engage in experiential experiments.

Creativity and Innovation

Creativity is demanded of STEAM education since students are often tasked with resolving complex, ill-defined problems (Quigley & Herro, 2016). Gardner's theory justifies this in that students need to identify their creative abilities in various ways. A better music student might resolve it by using sound in a solution, whereas a more interpersonal student might solicit feedback from others and introduce cooperative tactics. The diversity of approaches evokes creativity and challenges students to think widely. Holistic Learning

Multiple Intelligences theory also aligns with the holistic approach of STEAM education, where students must think as a whole and integrate knowledge from subjects. By teaching to different intelligences, instructors invite students to address problems in a more comprehensive and holistic way, so that they are not only learning content but also developing valuable life skills such as communication, collaboration and critical thinking.

Conclusions

Incorporating theories of education into STEAM education enhances the learning experience through increased knowledge, creativity, and engagement. Combining constructivism, experiential learning, Multiple Intelligences, Vygotsky's sociocultural theory, and systems thinking facilitates hands-on, inquiry-based, and collaborative learning that mirrors the actual-world complexity of STEAM disciplines. The theories focus on the significance of cultural context, mentorship, discourse, and reflection, allowing learners to build critical thinking, problem-solving, and innovative skills. Ultimately, this theoretical grounding ensures that STEAM education is not only interdisciplinary and inclusive but also empowering cultivating learners who are prepared to address global challenges with insight, creativity, and purpose.

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Deep Science Publishing
https://doi.org/10.70593/978-93-49910-20-1

Chapter 2: Decolonising Science, Technology, Engineering, Arts and Mathematics curriculum in higher education

1 Introduction

The advent of the industrial revolution in Europe created the need to find cheap resources. As a result, Europeans made long trips to Southern Africa to explore and exploit the resources (Enslin & Hedge, 2024). This led to the colonisation of Southern African countries. These countries were expected to operate under the socio-political and fiscal ideologies of the colonisers. This was done through cultural displacement, language replacement, segregation, poor development, etc. Southern Africa as a community was subjected to colonialism, which witnessed Western higher education employing a strategy that contributed a negative cognitive and ontological status to the indigenous knowledge systems (Odora-Hoppers, 2001). This process happened in two folds: domineering physical spaces and bodies of the indigenous citizens. Thus, the indigenous citizens' exposure to Western science impacted how they viewed nature (Le Grange, 2016). This was made possible through the creation of an education system that nurtured the indigenous students to accept that their livelihood was narrow-minded and irrational (wa Thiong'o, 1986). For instance, the colonial higher education had the following elements:

- learning is mostly grounded on traditional approaches to learning that nurture false comprehension
- theory and practice were divorced in curricula's practices, and organisation
- learning mostly grounded in Western-based literature

- complete marginalisation of Indigenous Knowledge Systems (IKS) (Maringe et al., 2021).

The process of colonisation transformed the indigenous learning that was entrenched in cultural history (Abdi, 2009). The colonisers considered the practices of oral societies as being rooted in the past and deficient of other innovative possibilities. This made the indigenous learning approaches unattractive and unacceptable. In turn, this made the indigenous learning approach incompatible with the modalities of the colonial education system. Thus, the new pedagogy guiding teaching and learning in the colonial era was premised on cultural disarticulation, epistemological domination, and the implantation of mediocrity (Bhurekeni, 2020). This was against the idea of advancing the needs of the students in teaching and learning activities. This was against the backdrop that the colonial education system was fixated on advancing the so-called neutral and objective scientific elements of knowledge. This placed much emphasis on exposing students to knowledge, which was divided into subject-matter (Kanu, 2011). Hence, the dominance of colonial education devalued IKS (Hare & Davidson, 2019), due to inadequate relationships between knowledge areas and context-based indigenous knowledge areas.

According to (Lovesey 2012), the colonisers went to the extent of prohibiting the use of indigenous languages as students interact in teaching and learning activities. This resulted in slavery consciousness, which made students not believe in their history. In other words, they are not ‘liberated consciousness’ to be aware of colonialism and their pursuit for liberation (wa Thiong’o 1981). This had ramifications for students' freedom and constitutionalism. Upon the attainment of independence, most of Southern Africa's higher education systems inherited colonial structures, including ways of thinking and doing. Hence, the education system continued to replicate Western knowledge in learning institutions, long after the dismantling of the empire (Heleta, 2016). Hence, this chapter explores the historical context and colonial legacy, and conceptualisation of decolonisation of STEAM curriculum in Southern Africa and its rationale. In this chapter, an attempt is made to reflect on the strategies used in decolonising the STEAM curriculum in Southern Africa's higher education. In addition, possibilities around decolonisation of the STEAM curriculum from Westernisation and Eurocentrism of the curriculum are discussed. In addition, this chapter focuses on the challenges encountered in the decolonisation of the STEAM curriculum in Southern Africa's higher education system.

2. Historical context and colonial legacy in Southern Africa

The education systems introduced during the colonial era were rooted in European values and scientific paradigms. These largely ignored or suppressed indigenous ways of knowing and learning. Even post-colonial higher education in most Southern African countries continued to be structured along these colonial lines, perpetuating the dominance of Western knowledge. Thus, the legacy of colonialism also left a legacy of unequal access to treasured and pertinent education, especially for marginalised communities. The curricula and research agendas often fail to reflect the lived experiences, needs and aspirations of the indigenous populations. It is in this context that the indigenous knowledge and voices that have been silenced for long are now fighting to counter and recounter the hegemonic Western science knowledge in a bid to decolonise the mind and re-navigate the path of the STEAM curriculum towards a decolonisation turn.

Thus, the STEAM curriculum is crucial to this process of dismantling Western science in Southern Africa's higher education systems. Hence, this chapter is embedded in decolonial argumentation that is grounded in an ethical and political framework. This is seen as advancing the ethos of addressing socio-cultural and cognitive injustices in Southern Africa's higher education system (Walsh, 2010). Hence, the need to decolonise the STEAM curriculum in Southern Africa through deep and sustained efforts. In this regard, the next section looks at the conceptualisation of decolonisation in the background of the STEAM curriculum.

3 Conceptual understanding of decolonisation of STEAM curriculum in Southern Africa

It's important to acknowledge that Most African nationalists and freedom fighters in the post-World War II period were preoccupied with wrestling economic and political power from the colonisers. However, this did not withstand their desire to decolonise their countries through placing them in the hands of indigenous citizens (Mbembe 2015). It's prudent to note that decolonisation of higher education was not integral to that idea since the indigenous citizens had been incapacitated in various forms. With the advent of independence, the calls to decolonise the higher education curriculum grew louder as it is considered the bedrock of the region's development, as it provides knowledge, skills, and attitudes (Ajani, 2019). In other words, the higher education curriculum in its current format is dominated by Western knowledge, where worldviews and courses or modules exclude indigenous knowledge systems. This has also been perpetuated by the belief that most Southern African communities are treating higher education as the bedrock in their quest to produce citizenry responsive to the needs of their society (Nkrumah, 1963). This concurs with Nelson Mandela, cited in Du Plessis (2021), who postulated [e]ducation as the most influential armament for transforming the entire, inferring that quite a lot of changes and accomplishments, as well as decolonisation, can be accomplished through the curriculum.

It is against this background that Southern Africa's higher education is pursuing the agenda of conceptualising decolonisation of the STEAM curriculum within the higher education exchange of ideas. This has drawn the stakeholders' demand to put the topical issue around the decolonisation of the STEAM curriculum in the Southern African higher education system. In this case, decolonisation should be viewed as an intricate concept, and it does not denote self-determination entirely in Southern Africa. It consists of a country's political freedom as well as the assertion of its indigenous cultures and the rectification of colonial forces' historical wrongs. Thus, it focuses on knowledge, curriculum and cultural consequences of colonialism and its damage to the students' minds (Enslin & Hedge, 2024). The procedure of decolonisation is complex and multidimensional, involving the interruption of colonial structures and the country regaining control of its resources and institutions. Thus, decolonisation is more than a political event and includes the wide-ranging and all-embracing process of enlightening and mental autonomy for those colonised (Fanon, 1963). Decolonisation has been articulated in quite a lot of concepts; nevertheless, decolonising the STEAM curriculum in Southern Africa remains an issue of concern.

The contemporary structure of the STEAM curriculum in higher education cannot provide students with the necessary competencies sought in the 21st century. This phase requires students to be equipped with multifaceted knowledge, skills and values to enable them to be functional in diverse situations (Robinson, 2020). Hence, an increase in the quest for decolonisation of the STEAM curriculum in higher education, irrespective of the costs. In this chapter, decolonisation of the STEAM curriculum is argued through an approach that counters the validity of dominant forms of Western science knowledge by placing indigenous science knowledge on an equal status (Granados-Beltran, 2016). It's important to acknowledge that the indigenous citizens have diverse knowledge, skills and values for knowledge production. In this regard, decolonisation is viewed as a phenomenon which extends explanations to the contests faced by the indigenous citizens (Uleanya et al., 2019). This calls for the enactment of decolonisation policies targeted at adding more value to the students' knowledge and lives. At the centre of these policies are the concerns of the indigenous citizens around how best they can integrate the diverse knowledge bases. This points toward the calls to decolonise the STEAM curriculum with the view to encouraging workable development in Southern Africa.

Decolonisation in the STEAM curriculum incorporates the procedure of decolonising knowledge and skills acquisition in the Southern African setting. Thus, decolonisation of the STEAM curriculum in Southern Africa is indispensable for realising intellectual justice as colonisation gave rise to the destruction of the indigenous citizens' language and knowledge (Le Grange, 2015). The foundations of decolonisation consist of deconstruction and reconstruction; self-determination and social justice; internationalisation of indigenous experiences; and language (Vandeyar 2020). The need for decolonisation is a rethink of the curriculum for tomorrow, a shift from Western learning experiences for the students. This implies the significance of the STEAM curriculum in achieving decolonisation in the Southern African higher education as a whole in policies and curriculum.

Meanwhile, Sium et al (2012) aver that decolonisation of the STEAM curriculum is a practice, which is always in conflict with colonial ways of reasoning and acting. The colonial ways of reasoning enforce and make some systems rigid or stereotyped. Seemingly, Alfred (2009) opined that decolonisation can only be experienced when indigenous people hold their indigenous practices in esteem and put them into action through formal and informal settings. Corntassel (2012) stated that indigenous people must restructure colonial policies, institutions, structures, beliefs, among others, to ensure the continued existence of indigenous cultures and communities. Decolonising the STEAM curriculum in Southern Africa involves rethinking and restructuring the way these subjects are taught to address historical and ongoing inequities.

Broadly, decolonisation of the STEAM curriculum in Southern Africa is aligned with Freire's (1970) critical pedagogy and Mezirow's (1996) concept of transformative education. Thus, the emancipatory strand of decolonisation of the STEAM curriculum is rooted in Freire (1973) and/or Habermas (1972), wherein consciousness-raising via critical reflection. In other words, critical reflection tries to alter the thoughts, feelings, actions, and consciousness of students. Hence, this alters how the students see and behave in their indigenous environment. From another angle, the critical-reflexive strand of the decolonisation of STEAM curriculum aligns with Mezirow's (1996) concepts of meaning schemes, meaning perspective, and changes. With the extra-relational and developmental strands of the decolonisation of STEAM curriculum being associated with holism, sensitivity and level-headedness. Hence, decolonisation of the STEAM curriculum is viewed as a process of developing students' critical awareness of themselves and their environment. This involves deconstructing a colonial mentality around the compartmentalisation of knowledge.

Resultantly, knowledge is reconstructed through a holistic approach that integrates STEAM disciplines into the higher education curriculum. This produces an all-inclusive comprehension of the ever-evolving political, social, historical and cultural environment. Using an interdisciplinary perspective, STEAM education helps students in higher education to see the world as a whole rather than as a collection of individual pieces. Thus, the STEAM curriculum in higher education can be created through a discipline-based approach for integrating multifaceted disciplinary knowledge into a new 'whole.' Therefore, this creates an interdisciplinary STEAM curriculum space favourable for adopting transformative pedagogies to assist students in acquiring relevant competences and awaken their creative self-awareness. In addition, it enhances students' moral and spiritual awareness and empowers them to practice environmentally responsible behaviour. In this regard, decolonisation of the STEAM curriculum creates spaces that enable students to shift their consciousness and profound learning experiences.

Therefore, decolonisation of the STEAM curriculum is not to move away from Western knowledge in totality (Adebisi, 2016). However, it is an attempt to strike a balance between IKS and Western knowledge, which has dominated the STEAM curriculum in Southern Africa’s higher education. Thus, this whole process is a reflection of the emerging indigenous paradigm that advances the need to give importance to the infusion of indigenous knowledge in STEAM in Southern Africa’s higher education systems. Decolonising the STEAM curriculum points towards restructuring the curriculum such that it can provide students with knowledge that enables them to act and think as indigenous citizens in the context of their diversities.

In the decolonised STEAM curriculum, IK has a role to engage students with knowledge and activities which endorse critical and logical thinking. This enables students to be able to respect and articulate their realities in the context of diversity (Maseko, 2018). Additionally, students can articulate issues in their quest to realise the existence of multiplicity in Southern Africa. In this case decolonised STEAM curriculum is important to students who are considered agents of transformation in Southern Africa. This concurs with Adebisi (2016:451), who postulated that:

Decolonisation of education, knowledge and thought does not ask us to rewrite history but should allow us Africans the academic freedom to finally write ours, as equal intellectual members of the human race.

The above implies that decolonization of STEAM curriculum in higher education in Southern Africa is to expose students to the knowledge, skills and values, which are lifelong and pertinent to circumstances in their situations The purpose of the decolonized STEAM curriculum is to expose students to essential and suitable competences, which can make them comprehend their environment (Le Grange, 2020). Prominent voices on decolonisation from Southern African scholars contextualise decolonisation in diverse standpoints. Thus, decolonising the STEAM curriculum is a move from Westernised science knowledge, skills and values, which depicts imperialism in Southern Africa (Mbembe, 2015). In addition, Ndlovu-Gatsheni (2015) opines that decolonisation is a procedure of learning to unlearn most Westernised scientific theories, principles and concepts to re-learn the STEAM curriculum grounded in Western and indigenous scientific principles and concepts. It affirms Southern Africa as a genuine epistemic base from which higher education students can view and appreciate the environment around them. This is made possible through advocating for the STEAM curriculum to nurture students around socio-cultural issues as a way of raising their awareness about social ills (Le Grange, 2018). Hence, the STEAM curriculum in higher education is expected to showcase high levels of reflection with emphasis on equity and diversity. This calls for a STEAM curriculum in higher education to transform students' mindsets through inculcating in them concerns to do with inclusiveness and empowerment.

It is in this context that decolonisation of the STEAM curriculum is considered as an approach focused on an action-oriented higher education learning process. This gives rise to consciousness that covers issues to do with strands like emancipatory, developmental, extra-relational and critical reflective (Le Grange, 2019). These bring about the need to critique knowledge from Western structures, as well as didactic approaches that are used in facilitating the acquisition of relevant competences to replicate the indigenous framework (Ryan & Tilbury, 2013). Therefore, the decolonised STEAM curriculum tends to be an ideal in providing higher education students with relevant competences based on the realities around them. This, in turn, will make higher education students open to varied circumstances, as the STEAM curriculum empowers them to espouse and pose between the circumstantial content and global subtle settings in realties.

4 Strategies to Decolonise Southern African higher education's STEAM curriculum

At the centre of most post-colonial states is the issue concerning the decolonisation of their higher education system with specific reference to the STEAM curriculum.

Hence, this issue has been the subject of debates with divergent opinions regarding the need for the decolonisation of the STEAM curriculum in Southern Africa (Uleanya et al., 2018). It is against this context that this section explores some of the strategies that can be employed by higher education institutions in Southern Africa to decolonise the STEAM curriculum.

4.1 Inclusive pedagogy in STEAM curriculum

Inclusive pedagogy is one of the strongest decolonial approaches to decolonising the STEAM curriculum in Southern African higher education. This is supported by the institutions of higher education accepting inclusive and equitable pedagogies. This involves developing spaces of learning that allow all the students to be included and accounted for, and where there is respect and acknowledgment of diverse ways of learning and knowing. Inclusive pedagogy involves the following essential elements:

- Culturally responsive teaching and learning - this is where the cultural orientations of students are brought into the teaching and learning process. Using examples, case studies, and materials drawn from the students' experiences and culture helps teachers make the STEAM curriculum more familiar and appealing.
- Social identity awareness - lecturers are taught to identify and address different social identities of their students, including race, ethnicity, gender, and socio-economic status. Awareness of social identity gives a more diverse learning and teaching environment where students feel supported and valued.
- • Addressing implicit stereotypes and bias - inclusive pedagogy encompasses actively working towards the identification and eradication of implicit biases and stereotypes that might influence learning and teaching. This can include micro-aggression and stereotype threat identification training, which can compromise student performance and interest.
- Instructional differentiation - this is where the instructional strategies are designed to address the needs of the students by exposing them to multiple means of accessing the information, interacting with learning materials and expressing understanding. By doing so, the lecturers with it can ensure that the students have the capacity to excel in teaching and learning.
- Stakeholder involvement - involving the community and families in learning and teaching activities ensures that the curriculum is appropriate and inclusive of students' cultures. This may be through community-based projects and collaboration with local agencies.

- Lecturer professional development - lecturers need continuous, effective development to implement inclusive pedagogy. Workshops and training can assist lecturers in developing desired skills to deliver culturally responsive and inclusive learning spaces.

This promotes critical thinking and challenging the status quo of power relations and orders of knowledge. This can be achieved by opening the STEAM curriculum design process to the broader community of stakeholders and ensuring that it reflects the rich cultural diversity of Southern Africa. This not only enhances the achievement of learning and students' engagement but also social justice and equity in the STEAM curriculum.

4.2 Redesign the STEAM curriculum

This is one of the main decolonising strategies of the STEAM curriculum, and it involves rethinking and rearranging the curriculum content for instruction to improve and integrate the Southern African knowledge systems, views, and cultural contexts. This section interrogates key fundamentals of this approach:

- IKS - integrating IKS and technologies into the curriculum helps to validate and preserve local cultures. These can encompass indigenous technologies, local farming practices and indigenous environmental knowledge.
- • Contextual appropriateness - ensuring the curriculum is appropriate to the local context and responds to the explicit needs and concerns of the community. This can include employing local examples and case studies in teaching resources.
- Interdisciplinary approaches - encouraging interdisciplinary learning that bridges the STEAM curriculum and social sciences, humanities and local studies. This enables students to see the relevance of STEAM education in day-to-day lives and its social context.
- Language inclusion - integrating local languages into the STEAM curriculum can make learning more accessible and familiar to students. This can include translating educational content into local languages and promoting the use of local languages in class.
- Community involvement - engaging with local communities in the curriculum design process ensures that the education provided is aligned with community values and needs. This may involve community-based projects and collaboration with local organizations.

- Critical pedagogy - promoting critical thinking and challenging the prevailing accounts and perspectives. This enables students to gain a more nuanced understanding of science and technology, history, and their impact on society.

This necessitates the necessity to reimagine the STEAM curriculum so that it can be used to incorporate more diverse and inclusive voices and experiences. That is, reconfiguring the STEAM curriculum with the above components, lecturers can create a more empowering and inclusive learning experience for Southern African students. It is a question of shifting away from Eurocentrism and incorporating more African thinkers and viewpoints. This will not only improve the learning outcomes and student engagement but also ensure neutrality and social justice in institutions of higher learning.

4.3 Representation and diversity of the STEAM curriculum

This strategy is key in decolonizing university education's STEAM curriculum by making it possible for students to relate to the curriculum and are accorded dignity during learning. Some of the components of this strategy are:

- Diverse role models - celebrating contributions by scientists, engineers, artists and mathematicians of a variety of backgrounds can inspire pupils and demonstrate to them that they are able to achieve within the STEAM curriculum no matter what.
- Inclusive curriculum - creating a curriculum that accepts multiple perspectives and inputs from multiple philosophies. This can include using case studies, examples, and accounts from history of underrepresented populations.
- Equal access - to provide equal access to the STEAM curriculum at the college level, regardless of background. This can be by offering support and resources for students from underrepresented groups so that they are able to excel.
- Supportive learning environment - to ensure that the classroom is an inclusive and respectful place for all students. This includes eliminating bias, stereotypes, and microaggressions that will interfere with student engagement and performance.
- Mentorship programmes - establishing mentorship programmes, which match students with professionals in various fields. The programmes can provide advising, sustenance and engagement to students.
- Policy and advocacy - promoting policies that favor diversity and inclusion in the STEAM program. This involves funding for programmes that enable

underrepresented students as well as programs that seek to eliminate barriers to participation.

By laying emphasis on representation and diversity, teachers can design a representative and inclusive process for curriculum development of STEAM. This not only helps the students belonging to the marginalised sections but also enriches their teaching and learning process by exposing them to various points of view and ideas.

4.4 Ethical aspects in STEAM curriculum

These aspects are actively engaged in decolonising the STEAM curriculum to ensure that the learning process is inclusive, equitable and respectful of different knowledge systems and perspectives. Some of the most important aspects of ethical considerations are elaborated below:

- Equity and access - ensuring equal access to the STEAM curriculum for all students irrespective of background. This includes eliminating systemic barriers that can keep marginalised groups from being able to fully participate in the STEAM curriculum.
- Cultural sensitivity - ensuring cultural sensitivity in the curriculum and instructional practices. This includes respecting and valuing the cultural backgrounds of all students and integrating indigenous knowledge and perspectives into the learning process.
- Environmental stewardship - encouraging environmentally conscious practice and environmental stewardship in the STEAM curriculum. This entails instilling within the students the moral implications of science and technology advancement on the environment.
- Academic integrity - making high expectations of academic honesty and integrity. This entails instilling within the students the significance of maintaining ethical standards of research practice and responsible use of technology.
- Social justice - incorporation of social justice issues into the STEAM syllabus. This involves fighting against stereotypes and prejudices, accepting diversity and inclusion, and ensuring benefits of scientific and technological progress are shared equally.
- Community engagement - engaging the neighboring communities in learning to ensure that the syllabus is applicable and useful to society. This involves community-level projects and collaboration with local organizations.

By incorporating these ethical values into the STEAM curriculum, educators can construct a more equitable, inclusive, and socially responsible learning and teaching environment. Not only does this kind of approach enhance student engagement and learning outcomes, but it also advances social justice and educational equity.

4.5 Institutional policies within the STEAM curriculum

This is the cornerstone for decolonizing the STEAM curriculum by adopting policies that advance inclusivity, equity, and integrating indigenous knowledge systems into institutions in order to come up with a more inclusive learning environment. Some of the defining features of this approach include:

- Policy development and implementation - Institutions can develop policies which in precise terms facilitate decolonization of the STEAM curriculum. This would involve policy guidelines for including indigenous knowledge, promoting cultural inclusivity and facilitating equality of access to resources and opportunities.
- Diversity and inclusivity programmes - institutionalisinng programmes that are inclusive and diverse in the institution. It can include instituting committees to monitor implementation of inclusive mechanisms.
- Recruitment and retention - recruitment and retention policies to entice and hold on to students, teachers and human resources with diverse backgrounds. These affirmative action policies, underrepresented group scholarships and aid schemes to encourage their success.
- Professional development - professional development for the staff and faculty members on subjects of decolonization, cultural sensitivity, and inclusive pedagogy. This assists in building a more informed and empathetic academic community.
- Research and funding - providing research funding that investigates indigenous knowledge systems and their applications in the STEAM curriculum. This can assist in building a knowledge base that informs a decolonised STEAM curriculum and fuels innovation.
- Community outreach - policies to promote partnership with the community at large to render the STEAM curriculum suitable and useful to the community. This may involve research projects by the community, partnerships with local agencies, and participation of the community in decision-making.

This makes decolonising the STEAM curriculum a material and theoretical phenomenon. This can be done through adopting such strategies that have the capacity to make the teaching and learning in STEAM inclusive and fair as well as embracing the diversity of Southern African cultures. Not only is this to the advantage of the learners coming from disadvantage communities but it also enhances learning among all the students.

Incorporating Indigenous Knowledge into STEAM curriculum

Incorporation of Indigenous Knowledge Systems and views is necessary in the STEAM curriculum. This entails acknowledging and appreciating traditional practices, languages, and paradigms, which have been excluded in STEAM curriculum development. This will provide an equal and relevant learning experience, which empowers learners and is empathetic to the ever-changing Southern African cultural heritage. STEAM curriculum can enhance the students' experience by offering them a variety of viewpoints along with increased levels of engagement with local cultures and environments through:

- Place-Based Learning - this helps students to understand the relevance of the STEAM curriculum to their communities and environments.
- Collaborative STEAM curriculum design - this involves working with the communities to co-create curriculum content to ensure the knowledge shared is accurate, respectful and relevant.
- Language inclusion - the inclusion of indigenous languages into the STEAM curriculum is relevant, since language is considered a carrier of culture and knowledge. Therefore, its inclusion can enhance the STEAM learning experience.

From the above discussion, it can be extracted that these strategies are constructive with the thrust of promoting the reputation of infusing higher education students' social experiences and societal circumstances with the STEAM curriculum (Rhea et al., 2012). This is fundamental to the infusion of IK within the STEAM curriculum in higher education. Therefore, this goes further than just acknowledging the existence of indigenous principles, as these strategies proffer the need to actively incorporate indigenous standpoints, histories, and languages into the fabric of the STEAM curriculum in higher education.

That is, such practices guarantee that indigenous beliefs are not deterministic in nature only but are embedded into the narrative of STEAM curriculum, thereby providing students with an integrated image of their actual identity. Thus, decolonizing the

STEAM curriculum in is not just a recognition of indigenous belief in Southern Africa's higher education curriculum; instead, it is the foundation for the integration of IK into the very fabric of pedagogy and learning. Furthermore, this emphasizes the establishment of an appreciation and respect for the invaluable contributions of local communities to the country's heritage. This is a compelling attestation to the revolutionary potential of the STEAM curriculum in college education, far beyond mere cerebral interests to become a force that drives radical changes in society towards an impending future viewed through an expansive social mindfulness and unwavering inclusivity.

5 Proposed framework for decolonising Southern African higher education's STEAM curriculum

Decolonisation of Southern African higher education's STEAM curriculum is one of the most important steps towards the recovery of indigenous knowledge systems as well as the contextualisation of education within local histories and contexts. The section outlines the suggested framework for decolonising higher education's STEAM curriculum

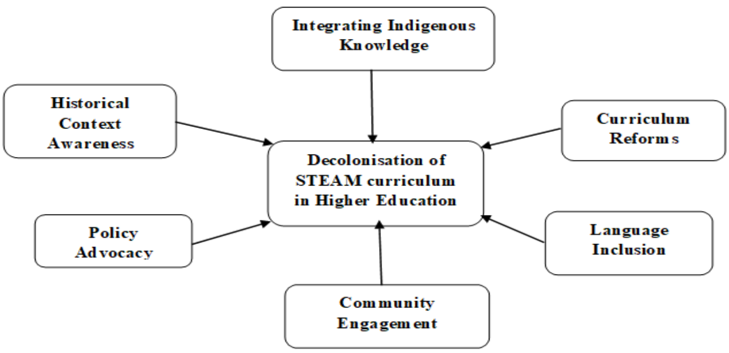

Fig. 2.1: Proposed Framework for Decolonising STEAM curriculum in higher education

IK integration subverts Eurocentric epistemologies by putting at center stage African mathematical, artistic, and scientific practices so that research and pedagogy are guided by indigenous methodology. Curriculum change remakes learning materials to incorporate African innovation and histories to deconstruct colonial frames which exclude indigenous knowledge systems. Language integration is key in accessibility to the STEAM curriculum since learning through indigenous languages maximizes understanding and supports rich elaboration of ideas grounded firmly in indigenous society.

Community outreach strengthens collaboration between institutions of higher education and local communities with the objective of ensuring that education addresses real-world issues while validating traditional knowledge. Policy advocacy is also crucial in implementing such initiatives, encouraging government and academic dedication to systemic reform. Historical consciousness plays an additional role as it provides a foundation for understanding past injustices but guides future paths by giving precedence to African-centred pedagogy. Decolonization of the STEAM curriculum at the tertiary level in Southern Africa requires an inclusive approach that integrates Indigenous Knowledge (IK), curriculum reform, language integration, community participation, policy mobilization, and sensitivity to historical context to realize an education system that is culturally responsive and regionally relevant. These forces, collectively, pledge to combat the colonial traditions and promote an expansive, place-based STEAM curriculum in universities that is attuned to Southern Africa's diversity.

6 Challenges encountered when decolonising the STEAM curriculum in Southern Africa's higher education

Decolonising STEAM in the context of tertiary education is a multifaceted and complicated process with many obstacles standing in its way:

- Resistance to change - there is always resistance from a variety of stakeholders, i.e., students, faculty, and administrators, who might be used to conventional curricula and instruction approaches. Such resistance is likely to be based on either a lack of understanding or appreciation for the need for decolonisation.
- Lack of funding - the process of decolonizing curricula for STEAM education needs gigantic amounts of investments in financial terms to pay for curriculum reformulation, lecturers' workshop facilitation, and designing new learning materials. Limited-resource setting universities cannot adequately find money to put towards making such massive expenditures.
- Institutional inertia - institutional systems also contain ingrained practices and structures that are averse to change. Institutional inertia and bureaucracy have the potential to slow down or prevent the institutionalization of novel, decolonised STEAM curriculum practice.
- Curriculum building - developing a decolonized STEAM curriculum based on the true indigenous knowledge system and context is no easy feat. It would

involve indigenous researchers and communities and extreme caution for traditional and emerging knowledge systems.

- Continuing professional education and training - lecturers have to be equipped with culturally responsive teaching and the reformed STEAM curriculum of the higher education institution. Ongoing professional education and support might prove challenging to uniformly implement.
- Evaluation and testing - the present tools of testing and methods used may be ineffectual or inappropriate to utilize with the decolonized STEAM curriculum. The implementation of suitable test techniques, that measure learning, is an intriguing challenge.
- Balancing global and local knowledge - while there is a requirement to incorporate indigenous and local knowledge, there is also a requirement to ensure that students are provided with knowledge and skills that can be applied globally. Balancing the two may be challenging.
- Socio-political context - even the general political and social underlying may further dictate efforts in decolonizing the STEAM curriculum. Political resistance to alteration which is as challenging to status quo or national identity in some instances might be viable.

It calls for the concerted efforts of the stakeholders such as the educators, administrators, policymakers and the community. Through concerted efforts, it is possible to formulate an inclusive and equitable STEAM curriculum in the higher education system.

Conclusions

Decolonising STEAM curriculum in Southern African higher education is a complex process aimed at undoing previous imbalances and creating an inclusive and more pertinent education system. This is achieved by incorporating IKS and cultural insights into the STEAM curriculum to enable the students to appreciate the relevance of education to their lives and indigenous societies. An additional critical element of decolonizing the STEAM curriculum is curricula redesign in moving from Eurocentric approaches to the utilization of textbooks and study materials by indigenous authors and local examples and contexts. It highlights the adoption of effective leadership and facilitation policies required to drive the decolonization of the STEAM curriculum to enable the incorporation of various perspectives and systems of knowledge. This calls for interaction with local communities and individuals through their provision of feedback, something that would be intellectually taxing and yet culturally adequate. This, in the process, calms critical questioning and analysis of existing knowledge constructs so that students achieve an in-depth grasp of the STEAM curriculum as well as the world in general. This nurture a more self-motivated and collaborative teaching and learning environment. By addressing these areas, Southern Africa’s higher education can create an inclusive and empowering STEAM curriculum in a higher education system that reflects the diverse histories and cultures of its citizenry.

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Deep Science Publishing
https://doi.org/10.70593/978-93-49910-20-1

Chapter 3: Gender perspectives in STEAM education: Addressing equity and inclusion in higher education

1 Introduction

Picture a world in which, regardless of cultural, gender, and social background, every child stands on an equal footing in their pursuit of Science, Technology, Engineering, Arts, and Mathematics (STEAM) education (Babaci-Wilhite, 2020). However, in Southern Africa, these at times create barriers for STEAM to act as a catalyst for innovation and inclusive growth. Hence, a need to challenge these barriers through championing diversity in lecture rooms, workshops and laboratories (Batty & Reilly, 2023). This has the potential to unlock a future where STEAM education reflects the rich tapestry of talent that is embraced by Southern Africa. It is in this context that this chapter explores how espousing gender perspectives in STEAM education not only empowers students but also kindles the shared potential of Southern Africa. Thus, this chapter is an attempt to unravel strategies and solutions that can shape this transformative movement in this diverse and vibrant Southern African region. It can be acknowledged that historically, societal norms and deeply rooted stereotypes have often dictated who gets to participate in STEAM education. Women in particular face systemic challenges that hinder their participation in STEAM education. But their untapped talents and innovative perspectives are critical to development policy.

This chapter shows how a gender lens can reshape STEAM education systems in southern Africa. Inclusive strategies to address inequalities, equal access to resources and mentoring, and safe learning environments are proposed. The article highlights some successful programs and initiatives in southern Africa that aim to empower learners. It shows how empowering women and men can break stereotypes and bring about revolutionary progress in STEAM education. This justifies the development of a gender-neutral education that fosters curiosity and ability in learners to achieve the goal of promoting interest and ability. This chapter not only explores the challenges, but also lays out proactive strategies to engage various stakeholders such as lecturers, policy makers, students, industry and trade, and associations to promote change in the inclusion of women and men in STEAM education.

2 Historical context and gender disparities in STEAM in Southern Africa

Historically gender disparities in STEAM education are intensely intertwined with the socio-cultural, and political progression (Burnard et al., 2020). Therefore, patriarchal customs and morals have subjugated societal structures, reducing females to domestic roles. This limited their participation and progression in formal education and professional careers. This segregation stretched to STEAM education, which is alleged to be a male-dominated area, requiring methodical proficiency and originality (Huang, 2021). This was further entrenched by the colonial education system, which prioritised male students' progression in studies over females (Hare, 2017).

The rise of industrialization and urbanization in the 20th century began to challenge traditional gender roles (Spain, 2014). This laid the foundation for increased female participation in the labour market, albeit to a limited extent. Women began to gain access to education and career opportunities in various fields. However, institutional barriers led to discrimination against women and limited access to resources. This was further exacerbated by apartheid policies that limited educational opportunities for marginalized groups, including female students (Fiske & Ladd, 2004). Therefore, the connection between race and gender led to more inequality and further limited female students' access to STEM education.

The post-apartheid era marked a turning point for most Southern African countries as governments developed and implemented policies to promote gender equality (Eynon, 2017). Their constitutions enshrined the ideals of equality and non-discrimination and paved the way for initiatives to promote women's education and empowerment. Relevant stakeholders and educational institutions-initiated programs to combat gender inequality, such as scholarships, mentoring programs, and anti-stereotype campaigns (Adeniyi et al., 2024). Despite these efforts, progress has been uneven as social norms and values continue to influence the advancement of women in STEM education. As a result, women continue to face stereotypes that discourage them from pursuing STEM careers, thereby widening the gender gap. For example, women do not have equal access to resources, have limited opportunities for leadership positions, and cultural barriers still exist. The historical context of gender disparities in STEAM education in Southern Africa is deeply rooted in the region's cultural, social, and political history.

Hence, this historical context of gender disparities in STEAM education in Southern Africa underscores the need for sustained efforts to achieve equity (Chisom, Unachukwu & Osawaru, 2024). This not only benefits individuals but also enriches.

3 The role of gender stereotypes in STEAM education

In this chapter, gender stereotypes are considered as one of the key factors prompting gender inequalities in STEAM education in Southern Africa. According to Akbar (2022); Alam and Alfian (2022), from an early age, children are socialised into gender roles, which often profile their sensitivities to their abilities and potential in various spheres of life. For example, girls are often discouraged from pursuing subjects that are considered 'masculine,' with boys, on the other hand, being encouraged to explore scientific and technical interests (Chikuvadze & Matswetu, 2013; Verma, 2024). Hence, these stereotypes have the potential to limit females' confidence in their abilities to participate in STEAM education. It is significant to acknowledge that studies (Ampartzaki et al., 2022; McNally, 2020; Siani & Harris, 2023) have shown that females often perform as well as males in STEAM education, but they tend to have lower self-confidence and less interest in pursuing STEAM-related careers due to societal expectations. This can lead to inequalities in academic achievement and the development of confidence and interest in STEAM education (Renström, Gustafsson Sendén & Lindqvist, 2021).

4 The importance of role models and mentorship in STEAM education

In this chapter, the provision of female students with strong role models and mentors is considered one of the most effective ways to combat gender inequalities in STEAM education. For example, female scientists, engineers, and artists can inspire the next generation of females by signifying that accomplishment in STEAM education is achievable. Therefore, role models can help break down stereotypes and show females that they can achieve great things in STEAM education. In addition, Fifolt and Searby (2010) highlighted that students who have mentors in STEAM education are most likely to progress in their studies and pursue careers in these disciplines. Therefore, females need mentors who can share similar experiences, and this can help them circumnavigate contests and build networks and skills necessary to thrive in male-dominated STEAM education environments.

4.1 Inspiration and motivation

In STEAM education, role models serve as powerful examples that can break barriers and stereotypes. In other words, role models have an incomparable influence on encouraging and encouraging females to participate in STEAM education. These have the potential to reinforce in female students the belief that they too can accomplish success despite operating under the guidance of a somewhat patriarchal system. In addition, the role models counteract the feelings of self-doubt or exclusion, which female students at times experience in male-dominated environments. This lays the foundation for the female students' desire to thrive in the male-dominated environments.

The role models personify resilience and perseverance, thereby showcasing real-life narratives of how female students can navigate barriers in STEAM education (Stoddard, 2022). These chronicles, in turn, are expected to encourage and prepare female students with approaches for steering their STEAM education expeditions. This creates a shared connection, which strengthens the message that success is accessible to everyone and bridges the gap between possibilities and realities. This whole scenario nurtures optimism and makes available indications that hindrances can be stepping stones towards fostering a growth mindset among female students in STEAM education. In other words, role models illustrate the transformative influence of females' depiction and the endless possibilities within STEAM education.

4.2 Supporting and guiding female students in STEAM education

The complex expedition which female students endure in STEAM education entails appropriate guidance and support from role models and mentors. In other words, through their vast experience and profound knowledge base they serve as a treasured compass to the female students in STEAM education. This tailored advice, support and guidance help female students to make decisions concerning their academic and professional journey in STEAM. In this regard this sort of personalised support accords female students with the opportunity to identify their strengths and weaknesses in their participation in STEAM education.

The gap between female students' theoretical learning and its application has the potential to be bridged through sharing experiences with role models and mentors. This assists female students to gain a deeper understanding of the possibilities in STEAM [related professions and organisations. For example, a mentor in engineering-related disciplines can explain intricate details of the expectations of their day-to-day work, thus transforming textbook knowledge into relatable and tangible experiences (McCullough Hedelin, 2024). This link nurtures critical thinking and inspires female students to tackle complex problems creatively. This also enhances learning that paves the way for professional opportunities by levelling the playing field in STEAM education. Hence, the relationship between mentors and mentees fosters a positive feedback loop.

4.3 Building confidence

In STEAM education, mentorship plays a transformative role in building self-confidence among female students. Thus, mentors' support and inspiration empower female students to confront the barriers head-on, nurturing flexibility and a willingness to push beyond their comfort zones. This tends to help female students navigate setbacks and uncertainties (Chen et al., 2024). This is due to the mentors who instil a sense of self-belief in female students in male-dominated STEAM environments. It's significant to acknowledge that female students face some societal stereotypes, which undermine their confidence, and this makes them feel less suited for STEAM education.

Hence, a need for mentors to counteract this narrative by affirming female students' potential in STEAM education by reinforcing a positive self-image. This helps female students to resist the urge to conform to limiting stereotypes and embrace their individuality and ambition. In other words, this encourages female students to take risks by exploring new ideas, experimenting with innovative solutions and pushing the boundaries of their knowledge (Yoo, Truong & Jung, 2023). This is made possible as mentors share their experiences as to how they traversed through challenges and made failures stepping platforms rather than setbacks. Thus, mentors create a safe and supportive space, which fosters open communication as female students can share their concerns and express their aspirations freely. This empowerment becomes a catalyst for building a strong foundation of female students' self-assurance in overcoming obstacles and improving their participation in STEAM education.

4.4 Career pathways

It is crucial to acknowledge that in STEAM education; mentors are considered a critical catalyst for bridging the gap between academia and related professional careers. This is made possible by offering female students access to invaluable opportunities and insights concerning their participation in STEAM education. Thus, mentors leverage their connections with the industry exposes them real-world experiences. In turn it accords female students with the opportunity to share hands-on experiences with those who have walked the same pathways. This enhances female students' understanding of the theoretical knowledge and practical skills development in relation with workplace dynamics (Dagunduro et al., 2024). This creates a firm foundation female students' future professional life in STEAM-related disciplines.

Mentors facilitate the expansion of transformative networking prospects for female students through female students to STEAM-related vocations and organisations (Conradty & Bogner, 2020). This is made possible with the assistance from mentors who share insider knowledge concerning emerging prospects and trends in industry. In other words, it gives the female students a competitive edge as they are prepared to be in control of their professional ambitions (Kadji-Beltran et al., 2014). This creates in female students a sense of belonging to possible STEAM-related careers or employment. In addition, mentors can be effective role models since they can share tangible roadmap to female students on how best to overcome obstacles in STEAM-related careers (Guenaga et al., 2022). Through these interactions, mentors can demystify by breaking down the phases of transitioning from STEAM education to the real-world of work into actionable steps.

4.5 Enhancing diversity and inclusion

By engaging role models and mentors with diverse STEAM -related career experiences it can play an important role in embedding into female students the ethos of inclusivity (Mirza & Meetoo, 2018). This challenges stereotypes and permits female students to recognize that STEAM-related careers are accessible to all those interested irrespective of one's background. Thus, it rips to shreds the understanding that STEAM education is a sanctuary for an explicit demographic group, thereby advancing a sense of partnership, assortment of thought and impartiality within the academic environments. This is made possible through exposing female students to role models with varied experiences, which augments their learning environments. For instance, a role model from a disadvantaged background can share experiences on how her cultural heritage shaped the approach to finding solutions to encountered gender-related challenges (Hassan, 2020). This creates a platform where ideas on how best can challenges concerning gender inequalities in society can be broken down to foster spaces where females feel valued. In other words, this influences dynamism and partnership among students from varied backgrounds and gender. This advances the notion that the inspiration of role models and mentors goes past individual female students. Instead, it generates an environment, which nurtures a sense of inclusivity in terms of procedures and guidelines in STEAM education.

4.6 Engraining lifelong learning in female students

In STEAM education role models can perform a transformative character in inculcating in female students the spirit of lifelong learning (Behera et al., 2025). This encourages female students to accept the idea that knowledge is ever-evolving and this entails them to be inquisitive and upbeat in the search for new knowledge. This equips them with the mindset that enables them to navigate transformations in these technological advancements and scientific discoveries. In this context, role models through their own experiences create the mentality in female students that obstacles are growth opportunities (Lockwood, 2006). This calls for female students to be resilient when confronting barriers in their pursuit of STEAM education. Therefore, this creates a sense of self-confidence and the ability to recover from failures as they pursue STEAM education, which often demands experimentation and iterative problem-solving.

In addition, role models instil in female students' minds curiosity as an attribute that enables them to ask questions, interrogate unconventional ideas and delve deeper into issues (Harlan, 2018). This fosters in the female students a culture of inquiry and discovery, thereby connecting scientific concepts and principles with real-world applications. Hence, this transforms the learning space from a passive one into an environment that sparks active pursuit for lifelong understanding. This empowers the female students as they can set personal goals. Thus, role models cultivate in female students the will to own their learning journey in STEAM education through developing a reading culture and accessing resources independently. This autonomy assists female students in preparing for real work environments where initiative and adaptability are highly valued (Parenrengi et al., 2025). In other words, role models advance the notion that female students' success in STEAM education and beyond should be grounded in blending academic learning with essential life skills. This helps female students to develop into self-motivated and confident individuals who are resilient, curious and passionate to face challenges that extend beyond the classroom (Zacarian & Silverstone, 2020). This shapes female students into lifelong students and innovators or problem-solvers.

5 Gender-inclusive pedagogy and curriculum design in STEAM education

This section looks at inclusive pedagogy in STEAM education as an art that challenges traditional gender norms and creates opportunities for all students. In other words, this promotes gender equity in STEAM education. Thus, gender-inclusive pedagogy in this chapter is considered an approach that recognises and addresses the diverse gender identities and experiences of students in teaching and learning (Vijayan, 2024). This centres on the following:

- Ensuring that all students see themselves reflected in both the content they study and the instructional methods used.
- Using language that is not gender biased and avoids reinforcing traditional gender norms.
- Tailoring instructional methods to the diverse needs of all students in STEAM education.

Therefore, a gender-inclusive curriculum incorporates content and learning experiences that challenge the existing gender stereotypes and promote equality. It should have the following:

- Integrating the stories and contributions from diverse genders helps all students to view STEAM education as accessible to all genders.
- Inspiring all students to pursue STEAM education through ways that do not reinforce traditional gender roles.
- Promoting gender inclusivity through supporting all students in their quest to understand the connections between the different areas of STEAM education.
- Safeguarding that instructional materials, textbooks, and other resources used in STEAM education are not gender biased.

This calls for the existence of a curriculum design that advocates the development of scientific and artistic competencies in both boys and girls. This is made possible through the use of instructional methods that encourage all students, regardless of gender, to explore new ideas and face challenges as they explore their environment (Grant & Sleeter, 2008). In this case, collaboration is seen as a cornerstone of inclusive STEAM education as it involves group projects and peer learning opportunities. This enables female students to work together and share ideas with their male counterparts. In other words, this creates space that enables both female and male students to learn from each other's experiences and perspectives. This fosters the development of both social skills and a sense of community within the learning environment, which enables students to feel comfortable participating in learning activities (Bateman et al., 2022). It involves addressing and challenging any unfair behaviour or language when it arises. For this to be successful, teachers need to be competent enough such that they can implement inclusive pedagogy effectively in STEAM education.

Hence, the need for teachers to be equipped with relevant skills through workshops to enable them to use differentiated instruction and interdisciplinary approaches in STEAM education. For instance, hands-on learning and collaborative projects can help break down challenges between academic interests and gender. In addition, gender-neutral materials that do not perpetuate gender stereotypes have a significant influence on female students' views of what is possible for them to succeed in STEAM education (Ferreira, Silva & Gomes, 2025). This entails incessant learning and reflection on the part of the teachers such that they can acclimatize themselves with approaches that match the increasing desires of their students in STEAM education.

In inclusive STEAM education the assessment techniques need to be flexible and insightful of students' assorted capabilities. In this regard lecturers are encouraged to use presentations, inquiry-based, portfolios, and project-based assessments. These accord students the platform to demonstrate their understanding of the given activities in line with their abilities. In this regard, lecturers need to make it a point that the selected assessment techniques do not disadvantage the female students. Feedback the students should be focused on their positives and areas of enhancement without buttressing gendered expectations (Heybach & Pickup, 2017). Hence, through the use of diverse assessment techniques all students have greater chances of thriving in STEAM education.

6 Gender-inclusive policy initiatives in STEAM education

In Southern Africa, efforts to reduce the gender gap in STEAM education have grown from strength to strength in recent times. Thus, policy initiatives fostering equity and inclusivity in different facets of life have been advanced. For instance, governments and other interested stakeholders have provided programmes and funding to address gender inequalities in communities (Maeder et al., 2024). This has resulted in the call for the indulgence of diversity-focused policy initiatives targeted at creating an environment where female students can thrive in STEAM education. In the case of STEAM education scholarships, mentorship opportunities for female students were introduced to support and empower them. In pursuit of their careers, female students in engineering-related programmes can be awarded scholarships supported under the Women in Engineering programmes. The Campaign for Female Education is another programme at the centre of transforming social views female students' participation in STEAM education (Soto et al., 2024). These empowerment programmes and projects are at the core of the fight in reducing existing gender gap in STEAM education in Southern Africa.

In spanning the gender gap in STEAM education, mentorship programmes have been acknowledged as an essential strategy to provide students with career guidance, sustenance and motivation (Van den Brink & Benschop, 2014). In addition, exposing female students to female characters in STEAM-themed video games, television shows, and movies inculcates in them a sense of 'we feeling' in STEAM education (Hawkins et al., 2019). These initiatives not only provide representation but also create relatable role models that inspire confidence and ambition. The collective influence of these policy initiatives not only benefits underrepresented female students but also enriches STEAM education as a whole, driving progress and innovation.

7 Proposed Gender Equity Framework on STEAM Education in Southern Africa

The proposed framework has five major components that contributes to reduction of the Gender-gap in STEAM education. These include the three-tier transformative pedagogical proposal for STEAM education that reflects the co-creation of knowledge by the trainee teachers.

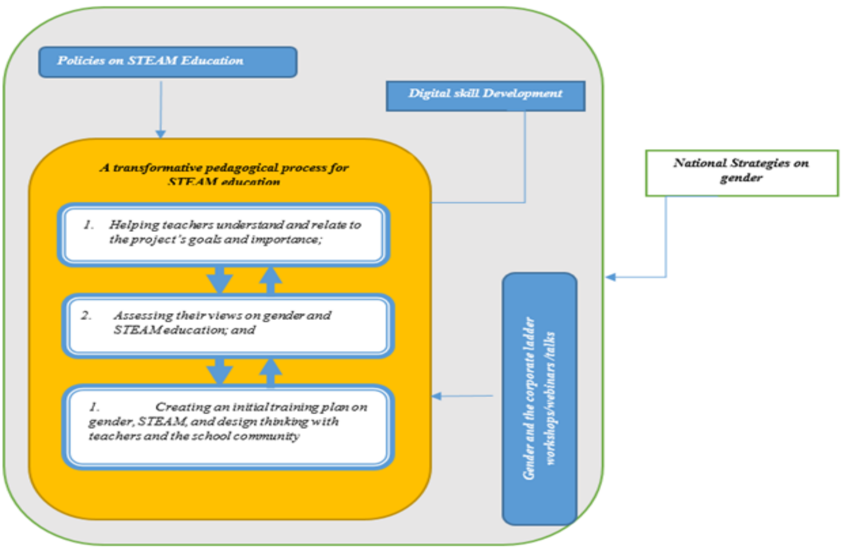

Figure 1: A proposed framework for STEAM education

The above figure considers teaching as a reflective process that requires one to reflect and be self-aware to adapt strategies that promotes continuous learning and professional growth. Hence, the bidirectional arrows. Secondly to invoke the creativity and innovative skills, there is need for digital skill development in trainee teachers where they would have to integrate technology in their STEAM teaching. For that to happen, one has to understand the potential of technology and has the digital competence to effectively use. The third on involves the workshops/ Talks/ Webinars on Gender and corporate leadership on STEAM education. This component draws on role models in the STEAM fields to address the trainee teachers and also serve to offer career guidance and give them hope that where there is a will there is a way. Sharing their (role model) experiences would inspire and motivate the workshop participants. The fourth component are the policies on STEAM education from the relevant ministries of Higher Education that need to be implemented in institutions of Higher Education and Teachers Colleges. At national level, we have gender strategies that have to be interpreted at different levels and implemented to eliminate the gender biases and stereotypes that hinder the progress of STEAM Education.

Conclusion

Achieving gender equity and inclusivity in STEAM education in Southern Africa requires a comprehensive approach that addresses cultural, social, and institutional barriers. Cultural norms often discourage female participation in STEAM education, necessitating community engagement and awareness campaigns to challenge stereotypes and promote inclusivity. Though success has been recorded in policy inventiveness, more still needs to be done to guarantee all students' progression in STEAM education. In addition, there is need for institutions to foster confidence and ambition through exposing female students to mentorship and role models. Thus, these should form part of the systematic reforms and gender inclusive curricula to drive female students' increased access to resources and opportunities. Hence, the creation of a supportive and inclusive environment can unlock female students' diverse talents. This augments STEAM education with innovative stances, which can propel Southern Africa's socio-economic and technological advancement.

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