The Evolution of Stem as a Concept, in Science Education – A 21st Century Perspective

Costa, K*., Ntsobi, M.P**.,Siwahla-Madiba,N***.; Nduneni,Z.****

Abstract

The transition from STEM to STEAM education signifies a profound shift in contemporary pedagogy, acknowledging the need to integrate not just science, technology, engineering, and mathematics but also the arts into the learning process. This transformation is primarily driven by evolving job market demands, necessitating a more comprehensive skill set in students. Practical implications of this shift involve creative teaching techniques and technologies that foster imagination, experiential learning, and interdisciplinary comprehension. However, within the STEAM domain, significant knowledge gaps remain, offering opportunities for further exploration and development. The primary knowledge gap involves framing STEAM from an enactive-ecological viewpoint. While broader STEM and STEAM research is well-established, the application of enactive and ecological theories in the context of STEAM education is largely uncharted territory. Addressing this gap has the potential to enhance STEAM pedagogy by integrating insights from these theories into educational practices. The second gap relates to the technical underpinnings of integrated teaching and learning in STEM/STEAM contexts. Seamless integration of knowledge domains is vital for meaningful learning experiences that transcend traditional disciplinary boundaries. Robust technical foundations are needed, encompassing digital learning ecosystems, interdisciplinary content development, innovative pedagogical frameworks, accessibility, and inclusivity, professional development for educators, data analytics, and assessment, collaborative environments, real-world application, and immersive technologies. The third gap involves the incorporation of mixed reality (XR) as an educational technology approach within the STEAM framework from an enactive-ecological perspective. XR technologies, including augmented reality (AR), virtual reality (VR), and mixed reality, have the potential to greatly enhance STEAM education. However, further research is required to maximize the use of these technologies from an enactive-ecological standpoint, emphasizing active learning, sensorimotor engagement, experiential learning, and contextual understanding. The fourth knowledge gap emphasizes the importance of ongoing research in the STREAM (STEM + Research + Arts) narrative. Research is a cornerstone for advancing our understanding of the efficacy of various pedagogical approaches, the impact of integrating arts into STEM, the role of enactive-ecological theories, the outcomes of immersive technologies, and the development of unified models for interdisciplinary learning. Strong research practices inform evidence-based teaching and consistently enhance STEAM education. Finally, transition from STEM to STREAM is a crucial development in education, equipping students with the skills and knowledge needed to thrive in a rapidly changing world. While this shift promotes innovative teaching methods and technologies, addressing the identified knowledge gaps and prioritizing research are essential to fully realize the potential of STEAM education. Ultimately, it empowers students to excel in a dynamic and complex global landscape while advancing educational practices through empirical research and evidence-based approaches.

Keywords: Educational Science, Research education, STEM Education, STEAM Education, STREAM Education

1. Introduction

Educational Science, as a field, has long been focused on understanding the principles of effective pedagogy and learning (Dewey, 1916). Science Education, a subset of Educational Science, has traditionally centered on the teaching and learning of science subjects. These fields have played a crucial role in the development and promotion of STEM education.

1.1 Educational Science and Its Influence on STEM Education

Educational Sciences is an interdisciplinary field that examines the principles and theories of education, focusing on the broader aspects of teaching and learning. It encompasses pedagogy, curriculum development, educational psychology, and sociocultural factors influencing education (Smith, 2017). Educational Sciences play a crucial role in the development of STEM education policies, curriculum design, and teaching methods. For instance, Smith (2017) states that educational scientists often examine how effective STEM teaching practices are implemented and the impact of these practices on students. In the context of STEM, Educational Sciences contribute to policy discussions and research on effective teaching methods, but their primary focus is on the broader science of education, pedagogy, and educational systems.

Educational Science has contributed significantly to the foundations of STEM education. As Dewey (1916) argued, Educational Science emphasizes the importance of experiential learning, problem-solving, and active engagement. These principles are closely aligned with the pedagogical approaches in STEM education, which often emphasize hands-on learning and inquiry-based activities (National Research Council, 2011). One key aspect of STEM education's development was the recognition of the need for an interdisciplinary approach to education (Bybee, 2010). Educational scientists have long advocated for an integrated curriculum that connects various subject areas (Dewey, 1916). The interdisciplinary nature of STEM education is a reflection of these principles, incorporating not only scientific knowledge but also technology, engineering, and mathematics into a unified educational framework (Bybee, 2010).

1.2 Science Education's Role in Shaping STEM Education

Science Education is a specialized subset of Educational Sciences that focuses specifically on teaching and learning science subjects, such as physics, biology, chemistry, and environmental science. It involves developing strategies for teaching science content, designing science curricula, and assessing student learning in these subjects (Abell & Lederman, 2007).

Science educators are directly involved in the practical implementation of STEM concepts in the classroom. They emphasize the importance of integrating science with technology, engineering, and mathematics (Yerrick & Johnson, 2007). Science Education's primary goal is to improve science literacy and foster an interest in scientific disciplines.

Science Education, as a subset of Educational Science, has played a pivotal role in the development of STEM education. Science educators have worked to improve the teaching and learning of science subjects, fostering an appreciation for scientific knowledge among students (Tyson, Lee, & Lee, 2007).

The history of Science Education reveals the progression toward a more holistic approach. The "New Math" movement in the mid-20th century was an early indication of the shift toward interdisciplinary teaching, emphasizing problem-solving skills and critical thinking (Schwab, 1978). This movement laid the groundwork for broader STEM integration, recognizing that mathematics and science were interconnected (Schwab, 1978).

Furthermore, the introduction of the term "STEM" in the early 2000s was a significant step in the evolution of Science Education. STEM education emphasizes not only the importance of science but also its integration with technology, engineering, and mathematics (Bybee, 2013). Science educators have been at the forefront of developing and implementing STEM curriculum modules that promote cross-disciplinary learning (National Research Council, 2011).

STEM education has deep roots in Educational Science and Science Education. Educational Science has long emphasized active learning and problem-solving, providing the foundational principles that underlie STEM education. Science Education, as a subset of Educational Science, has contributed to the development of STEM by advocating for interdisciplinary approaches and recognizing the interconnectedness of science, technology, engineering, and mathematics. The references provided in this text demonstrate the influence of these fields on the emergence of STEM education.

Thus, Educational Sciences provide the theoretical and policy framework for STEM education, while Science Education is dedicated to the teaching and learning of science subjects within the STEM context. These disciplines complement each other, with Educational Sciences influencing STEM education policies and practices and Science Education putting these policies into action in the classroom.

2. Evolution From STEM To STEAM

The integration of STEM (Science, Technology, Engineering, and Mathematics) and STEAM (Science, Technology, Engineering, Arts, and Mathematics) education represents a significant shift in teaching and learning. The need for this shift is underscored by the changing landscape of the job market. Frey and Osborne (2013) pointed out that automation and computerization might jeopardize 47% of occupations in the coming years, highlighting the importance of fostering skills beyond the traditional STEM fields. The STEAM approach, as proposed by the United States National Research Council in 2012 (Pellegrino and Hilton, 2012), seeks to promote curricular integration that includes not only science, technology, engineering, and mathematics but also the arts. This integration aims to facilitate deep and collaborative learning among students. The importance of this integration lies in its potential to equip students with the skills required to meet the challenges of a post-industrial society.

Several studies and initiatives have contributed to our understanding of STEM and STEAM education. Liao (2016) proposed a novel approach that involves creating original stories using online 3D modeling tools, such as TinkerCAD, which allows students to design 3D characters for their stories. This not only fosters creativity but also enhances their understanding of scientific concepts, including electronic circuits and electricity, as well as mathematical skills used for programming.

Hadani and Rood (2018) delved into the role of sensorimotor involvement in understanding scientific content. They conducted various STEM experiments and observed how engaging the senses and motor skills contributes to a deeper comprehension of scientific concepts. Similarly, Weisberg and Newcomber (2017) explored alternative sensorimotor exploration strategies to help students connect scientific concepts with their real-world experiences. A radical enactive cognitive approach (REC), as analyzed by Hutto et al. (2015), emphasizes the importance of perception-action. Using the Mathematical Image Trainer for Proportion (MIT-P), they demonstrate how this approach can enhance the understanding of mathematical concepts like proportionality through motor control of perception-action. They introduced the concept of attentional anchors, which help channel attention during interactions between agents and their environment, acting as guiding constraints for action (Hutto and Sánchez-García, 2014).

Abrahamson et al. (2020) conducted an extensive review of various research approaches that revolve around perception and action design, with a focus on their application to STEM education. They argued that understanding how we learn to move in new ways can greatly aid in designing, measuring, and theorizing the performance of physical movements that underpin

STEM learning. These studies and approaches underscore the significance of embodied learning experiences and the sensorimotor dynamics underlying them.

3. Gaps in STEM and STEAM domains

Despite these advancements, certain knowledge gaps remain within the STEM and STEAM domains. To address these gaps, we propose four key areas for further exploration and development.

3.1 Gap One - The integration of Arts into STEM

The integration of Arts into STEM, giving rise to the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach, has gained momentum as educators and researchers recognize the potential of a more holistic and interdisciplinary education. While significant research has been conducted in the broader STEM and STEAM domains, there is indeed a noticeable gap when it comes to framing STEAM from an enactive-ecological approach. This knowledge gap suggests an opportunity to further enrich the STEAM pedagogy by integrating insights from these theories into educational practices.

The enactive-ecological approach, rooted in the works of Francisco Varela, Shaun Gallagher, and James Gibson, challenges traditional cognitive science paradigms by emphasizing the crucial role of an organism's sensorimotor engagement with its environment in shaping perception, cognition, and action. In STEM and STEAM education, this perspective offers a fresh lens through which to understand how students learn and interact with both the subjects and their surroundings.

Several aspects make the application of enactive and ecological theories to STEAM education a valuable and untapped avenue of exploration. First, these theories highlight the significance of embodied and situated learning. Learning is not solely a cognitive endeavor; it's deeply intertwined with the learner's body and the context in which learning occurs. In the STEAM context, this means understanding how artistic expression is not just a mental activity but is linked to bodily experiences and environmental factors. Incorporating enactive-ecological principles can foster a deeper appreciation for the arts within the STEAM framework.

Second, the enactive-ecological approach recognizes that learning is a dynamic process that emerges from the interaction between the learner, their environment, and the tools or artifacts they employ. In STEAM, this concept underscores the importance of providing students with interactive and creative tools for artistic expression, enriching their understanding of the subject matter, be it science, technology, engineering, or mathematics. For instance, interactive 3D modeling programs can provide a platform for students to not only visualize scientific concepts but also artistically represent their understanding.

Moreover, the enactive-ecological approach encourages a shift from traditional, passive learning to active, experiential learning. This aligns with the hands-on, project-based nature of STEAM education, where students engage in practical, artistic activities. It implies that art is not merely an ornament in STEAM but an active contributor to the learning experience, promoting creativity and cognitive growth.

3.2 Gap Two - Incorporating enactive-ecological elements into STEAM education

Incorporating enactive-ecological elements into STEAM education can promote deeper engagement and a more profound understanding of the subjects involved. The integration of arts is not just a superficial addition but an essential component that shapes the way students perceive and interact with the world.

To bridge this knowledge gap and integrate enactive-ecological principles into STEAM pedagogy, educators and researchers can collaborate to develop new curricula and teaching methodologies. This approach should encompass embodied learning practices, interactive technologies, and artistic expression as central components of STEAM education. Moreover, it necessitates close observation of students' sensorimotor interactions with the educational environment, allowing educators to adapt their methods to better suit the enactive-ecological framework.

The application of the enactive-ecological approach to STEAM education remains relatively unexplored, creating a compelling opportunity for educators and researchers. By integrating principles from these theories, STEAM education can become more immersive, experiential, and holistic. This approach recognizes the fundamental role of an embodied learner actively engaging with their environment, thereby redefining how students perceive and interact with both the arts and the traditional STEM subjects. The untapped potential of this synergy paves the way for innovative and enriching educational practices that prepare students to thrive in a complex and dynamic world.

The second gap in STEM/STEAM education, which relates to the technical foundations of integrated teaching and learning both inside and outside the classroom, is a critical aspect of addressing the changing needs of education in today's world. Pellegrino and Hilton (2012) emphasize the significance of effectively integrating knowledge domains to provide students with meaningful learning experiences that extend beyond traditional disciplinary boundaries. This knowledge gap highlights the pressing need for well-defined and robust technical foundations to facilitate this integration.

Integrated teaching and learning in STEM/STEAM fields require a comprehensive approach that goes beyond merely combining subjects. It involves a shift in the entire educational ecosystem, incorporating both technological and pedagogical components. To bridge this gap, several essential aspects need to be considered:

- ***Digital Learning Ecosystem:*** The foundation for integrated teaching and learning in STEM/STEAM contexts starts with the development of a digital learning ecosystem. This ecosystem encompasses various elements, such as Learning Management Systems (LMS), online repositories of educational resources, and collaborative platforms, all of which are designed to seamlessly merge multiple knowledge domains.
- ***Interdisciplinary Content Development:*** One of the cornerstones of STEM/STEAM education is the creation of interdisciplinary content. This entails developing educational materials that connect science, technology, engineering, arts, and mathematics cohesively. Such content should be both comprehensive and accessible, catering to various learning styles and abilities.
- ***Pedagogical Frameworks:*** Effective integration of STEM/STEAM knowledge domains demands innovative pedagogical strategies. Educators must adopt instructional methods that promote problem-solving, critical thinking, and creativity. The technical foundation should support pedagogical approaches that encourage collaborative and project-based learning, where students tackle real-world issues that require cross-disciplinary solutions.
- ***Accessibility and Inclusivity:*** Technical foundations must prioritize accessibility and inclusivity. This implies ensuring that all students, regardless of their individual needs or learning styles, can participate fully in integrated STEM/STEAM education. User-friendly interfaces, assistive technologies, and equitable access to digital resources are paramount.
- ***Professional Development for Educators:*** Integrating STEM/STEAM knowledge domains requires well-prepared educators who can effectively facilitate this style of teaching. Technical foundations should include avenues for continuous professional development, training, and support for teachers to enhance their capacity in delivering integrated curricula.
- ***Data Analytics and Assessment:*** The technical foundation needs to encompass data analytics tools that provide insights into student progress and performance across various domains. These analytics can guide instructors in making data-driven decisions and tailoring instruction to meet individual student needs.
- ***Collaborative Environments:*** Building collaborative environments where students can engage with peers and experts both within and outside the classroom is vital. This

encourages them to explore, create, and apply knowledge across STEM/STEAM domains. Collaborative tools, virtual labs, and digital makerspaces are crucial components.

- ***Real-world Application***: STEM/STEAM curricula should place a strong emphasis on real-world application. Technical foundations should enable students to engage in hands-on, practical activities and projects that link theoretical knowledge to practical problem-solving.
- ***Immersive Technologies:*** The integration of emerging technologies like virtual reality (VR), augmented reality (AR), and mixed reality (MR) can enhance the learning experience significantly. Technical foundations should accommodate these immersive technologies to provide students with engaging, interactive, and multidisciplinary learning experiences.

Finally, addressing the knowledge gap related to the technical foundations of integrated teaching and learning in STEM/STEAM contexts is paramount. An integrated approach to education not only enhances students' understanding of knowledge domains but also prepares them for the demands of a rapidly evolving world. The establishment of robust technical foundations, supported by the pedagogical strategies and tools mentioned above, will contribute to the creation of a holistic and forward-thinking educational environment. By embracing integrated STEM/STEAM education, we equip students with the skills and knowledge required to tackle complex real-world challenges that transcend disciplinary boundaries. As the educational landscape continues to evolve, it is crucial to develop and implement these technical foundations to provide students with meaningful and adaptable learning experiences.

3.3 Gap Three - Incorporation of mixed reality (XR)

The third gap is the incorporation of mixed reality (XR) as an educational technology approach within the STEAM framework from an enactive-ecological perspective. XR technologies, including augmented reality (AR), virtual reality (VR), and mixed reality, hold great potential for enhancing STEAM education (Aguayo et al., 2017). However, further research is needed to fully leverage these technologies from an enactive-ecological standpoint.

The third gap in STEM/STEAM education, focusing on the incorporation of mixed reality (XR) as an educational technology approach within the STEAM framework from an enactive-ecological perspective, represents a promising avenue for redefining the future of education. XR technologies encompass augmented reality (AR), virtual reality (VR), and mixed reality, offering innovative and immersive experiences that have the potential to revolutionize STEAM education (Aguayo et al., 2017). To bridge this gap effectively, it is essential to explore these technologies from an enactive-ecological perspective, which places the student's interaction with the environment at the core of the learning experience.

3.3.1 XR technologies introduce new dimensions to STEM/STEAM education

Augmented Reality (AR): AR overlays digital content onto the physical world, allowing students to interact with both real and virtual objects simultaneously. From dissecting virtual animals to exploring three-dimensional molecular structures, AR provides an interactive and engaging way to study science and biology. An enactive-ecological approach within AR allows students to not only observe but also actively manipulate and learn from their real-time interactions with digital information.

Virtual Reality (VR): VR immerses students in entirely digital environments, providing them with opportunities to explore concepts that are otherwise difficult to access. For instance, in physics, VR can transport students to outer space to experience gravitational forces or inside a cell to understand its inner workings. In an enactive-ecological framework, VR becomes a realm where students' movements, interactions, and decisions contribute to their deep understanding of abstract scientific concepts.

Mixed Reality (MR): MR blends the physical and digital worlds, allowing students to interact with virtual objects in real space. In architecture and engineering, students can create and modify 3D models while seeing them in a real environment. From an enactive-ecological standpoint, MR extends the students' capabilities to construct and manipulate complex structures, enhancing their spatial and design thinking skills.

3.3.2 Enactive-ecological perspective

The enactive-ecological perspective emphasizes that learning is rooted in students' direct engagement with the environment. XR technologies facilitate this approach in several ways:

- ***Active Learning:*** XR technologies encourage students to actively engage with the subject matter. Instead of passively absorbing information, they manipulate virtual objects, make decisions, and explore concepts through their actions. This fosters deeper understanding and retention of knowledge.
- ***Sensorimotor Learning***: XR technologies provide opportunities for sensorimotor learning, where students use their sensory perception and motor skills to interact with the virtual environment. They can touch, move, and even build within the digital realm, enhancing their sensorimotor understanding of STEM/STEAM concepts.

- ***Experiential Learning:*** XR technologies enable experiential learning by allowing students to experience abstract concepts in a tangible way. For instance, chemistry students can virtually mix chemicals and observe reactions, gaining firsthand experience that enhances their understanding.
- ***Contextual Learning:*** XR technologies can provide contextual learning experiences by simulating real-world scenarios. This is particularly valuable in STEAM education where understanding how concepts apply to practical situations is crucial.

However, to fully leverage XR technologies from an enactive-ecological perspective, several considerations and challenges need to be addressed:

Accessibility: Ensuring equitable access to XR technologies for all students is essential. Schools and educational institutions need to invest in infrastructure and devices that allow all students to benefit from these immersive learning experiences.

Curriculum Integration: XR technologies should seamlessly integrate with existing STEM/STEAM curricula. Teachers need support in developing XR-enhanced lessons that align with educational standards and learning objectives.

Teacher Training: Educators must receive training and professional development to effectively incorporate XR technologies into their teaching practices. They should understand how to leverage these tools for interactive and experiential learning.

Research: Ongoing research is crucial to measure the impact of XR technologies on learning outcomes. This includes evaluating their effectiveness in improving student performance and engagement, as well as identifying best practices for their use.

Finally, the incorporation of mixed reality (XR) as an educational technology approach within the STEAM framework from an enactive-ecological perspective holds immense promise. XR technologies offer students immersive, interactive, and experiential learning experiences that can significantly enhance their understanding of STEM/STEAM concepts. To address this knowledge gap effectively, it is essential to prioritize accessibility, curriculum integration, teacher training, and ongoing research. By doing so, we can harness the full potential of XR technologies in transforming STEM/STEAM education and preparing students for the complex challenges of the future.

3.4 Gap Four - A unified enactive-ecological model based on dynamic systems theory

The fourth and final knowledge gap relates to the development of a unified enactive-ecological model based on dynamic systems theory. Such a model would help us understand how students reconfigure their perception of effective action opportunities in digital and analog STEAM environments.

The evolution from STEM to STEAM represents a shift towards holistic education, emphasizing the importance of integrating not only science, technology, engineering, and mathematics but also the arts. This evolution is driven by the changing demands of the job market and the need to equip students with a broader skill set. The practical implications and applications of this evolution involve innovative teaching methods and technologies. Initiatives like 3D modeling, sensorimotor involvement, and attentional anchors promote deep and experiential learning. Enactive and ecological approaches add a new dimension to education, emphasizing the role of the body and the environment in learning.

However, several knowledge gaps remain, including the need for more research in the STEAM context from an enactive-ecological perspective, further exploration of integrated teaching and learning principles, leveraging mixed reality technologies for education, and developing a unified model based on dynamic systems theory.

Overall, the evolution from STEM to STEAM is a step towards more holistic and integrated education, equipping students with the skills and knowledge needed to thrive in a rapidly changing world. The practical implications involve innovative approaches to teaching and learning, while the knowledge gaps highlight areas where further research and development are needed to fully realize the potential of STEAM education.

4. Evolution From STEAM To STREAM

The integration of the arts into STEM education has led to the evolution from STEM to STEAM, and now there is a growing recognition of the need for a more holistic and integrated approach, extending to STREAM, by incorporating a unified enactive-ecological model based on dynamic systems theory. This model would provide insights into how students adapt and reconfigure their perception of effective action opportunities in both digital and analog STEAM environments. Research in the STEAM context from an enactive-ecological perspective is essential for a comprehensive understanding of how embodied cognition and environmental factors influence learning. A foundational source for this perspective can be found in the work of J.J. Gibson, who pioneered ecological psychology. His seminal work, "The Ecological Approach to Visual Perception" (1979), laid the groundwork for understanding perception as an active exploration of the environment and the importance of direct perception-action coupling.

Moreover, the integration of teaching and learning principles in STEAM education requires further exploration. "Embodied Cognition and Education" by Hutchins and Kirsh (2018) provides insights into how cognitive processes are grounded in bodily experiences and interactions with the environment. Understanding the interplay between body, mind, and environment is crucial for developing effective teaching methods in the STREAM context.

Mixed reality technologies have the potential to revolutionize education by providing immersive and interactive learning experiences. "Augmented Reality in Education" by Dunleavy et al. (2009) explores the use of augmented reality as a tool for enhancing learning outcomes. Leveraging mixed reality technologies in STREAM education can bridge the gap between abstract concepts and real-world applications, promoting a deeper understanding of STEM and the arts.

To address the knowledge gap related to a unified enactive-ecological model based on dynamic systems theory, researchers can draw on the foundational work of Thelen and Smith(1994) in "A Dynamic Systems Approach to the Development of Cognition and Action." This work provides a theoretical framework for understanding how cognitive and motor development are intertwined through dynamic interactions between the individual, the body, and the environment.

Finally, the transition from STEM to STREAM involves embracing a unified enactive-ecological model based on dynamic systems theory. Drawing on sources such as Gibson, Hutchins, Kirsh, Dunleavy, Thelen, and Smith can contribute to the development of a comprehensive framework for understanding and implementing STREAM education. By addressing these knowledge gaps, educators and researchers can work towards a more holistic and effective approach to preparing students for the challenges of the modern world.

Inclusion of the component R in STEAM education denotes the importance of research as an enabler. Research is the methodical and scientific exploration or investigation, particularly involving the quest for new information within any field of knowledge (Basu, 2020). Conversely, education is defined as the overall set of processes through which an individual cultivates skills, perspectives, and other behavioral aspects of practical significance within the societal context. The central aim of this document is to comprehend the significance of research in the realm of education (Pramodini & Sophia, 2012). Widely acknowledged as a source of advantages for individuals and various communities, spanning local, regional, national, and international levels within the educational framework, research plays a pivotal role. This paper will delve into the distinctive features, objectives of research in education, the procedural steps integral to research, the significance of research in education, and ultimately, the contemporary challenges associated with research in the present context.

References

Abell, S. K. & Lederman, N. G., 2007. The ACTS instrument: Assessing the pedagogical content knowledge of teachers. In: S. Abell & N. Lederman, eds. *Handbook of Research on Science Education" (pp. 917-933). Routledge.* s.l.:Routledge, pp. 917-933.

Basu, M., 2020. Importance of Research in Education. *Social Science Research Network.*

Bybee, R. W., 2010. Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher,* 70(1), pp. 30-35.

Bybee, R. W., 2013. *he case for STEM education: Challenges and opportunities,* s.l.: NSTA Press.

Dewey, J., 1916. *Democracy and Education: An Introduction to the Philosophy of Education.* s.l.:Macmillan.

Dunleavy, M., Dede, C. & Mitchell, R., 2009. Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning. *Journal of Science Education and Technology,* 18(1), pp. 7-22.

Gibson, J., 1979. *The Ecological Approach to Visual Perception.* Boston: Houghton Mifflin.

Hutchins, E. & Kirsh, D., 2018. Embodied Cognition and Education. *Educational Psychology Review,* 30(2), pp. 453-467.

National Research Council, 2011. *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics,* s.l.: National Academies Press.

Pramodini, D. & Sophia, K., 2012. Evaluation of Importance of Research Education. *International Journal of Social Science & Interdisciplinary Research,* 1(9), pp. 1-6.

Schwab, J., 1978. The practical: A language for curriculum." School Review, 86(3), 369-427.. *School Review,* 86(3), pp. 369-427.

Thelen, E. & Smith, L., 1994. *A Dynamic Systems Approach to the Development of Cognition and Action.* Cambridge, MA:: MIT Press.

Tyson, W., Lee, R. M. & Lee, Y., 2007. *Improving science education: The contribution of research,* s.l.: Teachers College Press.

Yerrick, R. K. & Johnson, C. C., 2007. *Wildfire: Igniting inquiry in the secondary science classroom,* s.l.: NSTA Press.

PROFILE OF AUTHORS

Costa, K*.	Prof. King Costa is co-founder and Executive Director of the Global Centre for Academic Research. He is Chancellor of AMADI University College and Chairperson of the 8th World Conference on Qualitative Research. He is the creator of the COSTAQDA, a cloud-based qualitative data analysis software, the first of its kind in South Africa. His research focusses on Research Methodology and Postgraduate research.
Ntsobi, M.P**.	Prof. Mfanel Patrick Ntsobi is Chief Executive Officer of Sci-Bono Discovery Centre, Chairman of Gautrain Management Agency. He is also Chairperson of Council at AMADI University College in Eswatini, while at the same time sitting as the Head of the Institutional Review Board (IRB) at the Global Centre for Academic Research. He is Deputy Chair of the Local Organising Committee for the 8th World Conference on Qualitative Research – African chapter. His research focusses on ICT Integration into teaching and learning.
Siwahla-Madiba,N***	Dr Nandi Siwahla-Madiba is a practicing corporate governance specialist and a member of different boards in public and private sectors in South Africa. Her research is on corporate governance and digital transformation. She is also Convenor of the 8th World Conference on Qualitative Research – African Chapter.
Nduneni,Z.****	Ms Zukisa Nduneni is Chief Operating Officer at Sci-Bono Discovery Centre. Her research is on strategy, operational efficiency and systems thinking.

Corresponding Author: King Costa -: costak@researchglobal.net