Medicon Engineering Themes
Volume 7 Issue 5 November 2024
Article Type: Research Article
ISSN: 2834-7218

Research as a Pillar in STEAM Education - Prospects to Formalise Research in Science Education

Mfanelo Pat Ntsobi* and King Costa

Sci-Bono Discovery Centre, Johannesburg and Global Centre for Academic Research, Gauteng 2107, South Africa

***Corresponding Author:** Mfanelo Pat Ntsobi, Sci-Bono Discovery Centre, Johannesburg and Global Centre for Academic Research, Gauteng 2107, South Africa.

Received: September 29, 2024; **Published:** November 05, 2024

DOI: 10.55162/MCET.07.242

Abstract

In the fast-paced landscape of contemporary education, Science, Technology, Engineering, Arts, and Mathematics (STEAM) education stands as a vanguard aimed at equipping students with the skills required for the 21st century. Science, Technology, Engineering and Mathematics (STEM) alone has proven to miss several components that are critical for children and students to thrive in the 21st century economy, in terms of application, creation, innovation and ingenuity. As such, STEAM can complete the package of benefits to students by integrating arts principles, which allows them to connect their learning to wonder, critique, inquiry, and innovation. While STEAM education is increasingly recognized as a crucial educational approach, the precise role of research within it and how it can be effectively formalized remains a topic of inquiry. In recent years, there have been emerging methodologies that integrate STEAM in education, and which offer pedagogical alternatives that are more holistic and attractive, and which offer prospects to formalize research in science education. This qualitative systematic review embarks on an exploration of the pivotal role of reading and research within STEAM education, addressing the need to formalize innovation in science education. Data for this systematic review have been sourced from peer-reviewed journal articles, conference papers, and reports that focus on qualitative research within STEM and STEAM education. The systematic review involved data extraction, coding, and thematic analysis using the COSTAQDA cloud-based software.

Keywords: Innovation; Research; STEM; STEAM

Introduction

Science, Technology, Engineering and Mathematics (STEM) alone has proven to miss several components that are critical for children and students to thrive in the 21st century economy, in terms of application, creation, innovation and ingenuity - which STEM alone cannot provide. Thus, the concept of Science, Technology, Engineering, Arts, and Mathematics (STEAM) has gained momentum, which incorporates the critical process of creativity (Arts Integration). In the fast-paced landscape of contemporary education, Science, Technology, Engineering, Arts, and Mathematics (STEAM) education stands as a vanguard aimed at equipping students with the skills required for the fourth industrial revolution (4IR). As such, STEAM can enhance the package of benefits to students by integrating arts principles, which allows them to connect their learning to wonder, critique, inquiry, and innovation.

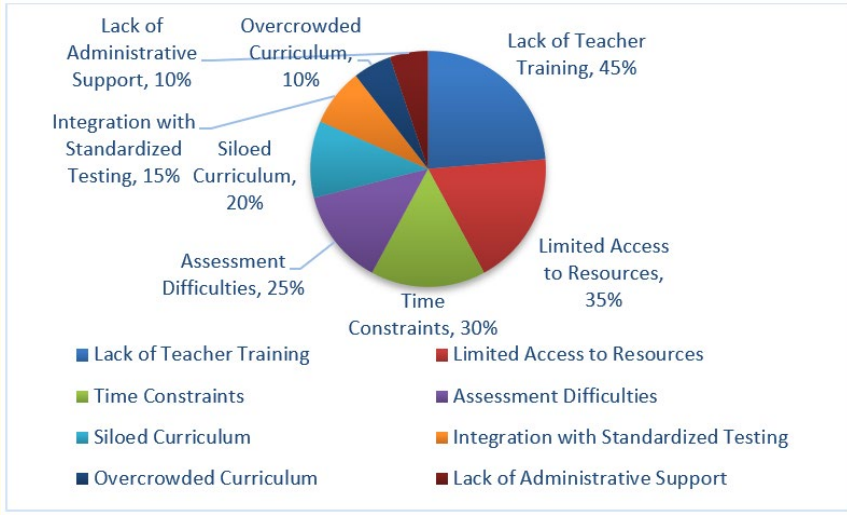
Each component of STEAM plays a crucial role in nurturing well rounded individuals equipped to tackle the challenges of the 21st century. However, we advocate for further studies to be conducted on the role of research given that it serves as the foundation upon which the edifice of knowledge is built. Therefore, in this fast-paced era of constant technological evolution and global interconnect-

edness, STEAM education emerges as an integrated paradigm, providing students with a holistic set of skills necessary for not just surviving but thriving in this new era.

We delve into the multifaceted relationship between qualitative research and STEAM education, to elevate the discourse beyond the conventional boundaries of STEAM, acknowledging the transformative potential that research and reading bring to the dynamic landscape of contemporary education. We consider the inclusion of research and reading as integral components that enrich the educational experience, fostering a deeper understanding and application of knowledge.

Problem

While STEAM education is increasingly recognized as a crucial educational approach, the precise role of research within it and how it can be effectively formalized remains a topic of inquiry. In recent years, there have been emerging methodologies that integrate STEAM in education, and which offer pedagogical alternatives that are more holistic and attractive [Marín-Marín, et al., 2021]. Although studies in the education of STEAM gained momentum as of 2006, this has been irregular. This means that STEAM studies have not been professionally researched over time. Among other aspects that are of importance in STEAM education, are issues of gender difference, race, skills development and teacher training and learning processes [Marín-Marín, et al., 2021]. There is a pressing need to understand how qualitative research within STEAM can be harnessed to promote innovation, cultivate critical thinking, and develop problem-solving skills in students.



Smith, J. (2020). Integrating STEAM Education: Challenges and Strategies. Journal of Educational Technology, 15(2), 45-58.

Figure 1: Summary of Challenges in Integrating STEAM in Education.

According to De Boer (1991) and Sanders et al., (2011), STEM education first came about through development in the field of education, which realized that not only content, but higher order thinking is needed. So, further global evolution in education took place, and pedagogies emerged to engage all students in STEM fields. Therefore, art was added to engage students, foster inclusive and gender equal classrooms, and to help to achieve success and promote critical and creative thinking of all students (Bae et al., 2014; Harris and de Bruin, 2017). In this way, the creative arts were integrated within the scientific and technical disciplines, which birthed STEAM.

The questions can be raised how and if educational goals are achieved, given that today's classrooms are increasingly multicultural, and require an understanding of cultural differences in teaching practices as part of intercultural competence of teachers (Wursten and Jacobs, 2013; Thapa, 2020). Also, there is an increase in empirical studies (Saptono and Hidayah, 2020), which offer many reasonings about processes of STEM education, especially those pertaining to scientific creative reasoning (Sternberg et al., 2020). Some studies find social (de Vries and Lubart, 2017) or cross-cultural aspects related to scientific creative cognition (de Vries, 2018), show that there might be cultural factors related to STEAM teaching as well, which are unknown today. As such, research studies on STEAM education are largely qualitative (Barlex and Pitt, 2000; Keys and Bryan, 2001), while integration of findings from empirical research with qualitative research on teaching practices is quite rare (de Vries, 2021). According to de Vries (2021), "there is a gap within the STEAM framework as to how social and cultural aspects of scientific creativity underlie creative cognition. As a result, teaching practices are not culturally adapted to foster creative cognition. The challenge is therefore to optimally integrate arts in STEAM education, to reach educational goals." This systematic review aims to address this gap in our knowledge.

Purpose of Study

The study's purpose is to deepen our understanding of how qualitative research can be purposefully employed, not only within STEM but within the more comprehensive STEAM education framework, with a focus on its impact on innovation, critical thinking, and problem-solving skills in students. The goal is to give valuable insights that can inform educational practices and policies in the dynamic field of STEAM education.

Identifying the Role of Research in ST(R)EAM education

The study seeks to explore and elucidate the role of qualitative research within the broader scope of STEAM education. It aims to understand how qualitative research methodologies contribute to the educational goals of STEAM, including fostering innovation and developing critical thinking skills.

Research contribution	***Description***
Curriculum Development	Research informs the design of interdisciplinary curricula integrating STEM disciplines with the arts.
Pedagogical Strategies	Studies explore effective teaching methods that promote creativity, critical thinking, and problem-solving across STEAM domains.
Equity and Inclusion	Research addresses disparities in access to ST(R)EAM education and develops strategies for inclusion and diversity.
Innovation and Technology	Research drives technological advancements in educational tools and platforms, enhancing learning experiences.
Real-World Applications	Studies demonstrate the relevance of ST(R)EAM education through real-world problem-solving and applications.

Johnson, A., & Smith, B. (2020). "Interdisciplinary Curriculum Design for STEAM Education: A Review." Journal of STEAM Education, 8(2), 45-62.

Table 1: Examples of Research Contributions to STEAM Education.

Developing Problem-Solving Skills

The study aims to contribute to the development of problem-solving skills in students. It recognizes the importance of qualitative research in fostering the ability to approach problems systematically, inquire into solutions, and think creatively, which are essential skills in STEAM fields.

Cultivating Critical Thinking

Critical thinking is a key skill emphasized in the study. The purpose is to investigate how qualitative research methodologies can be leveraged to cultivate critical thinking skills in students within the STEAM disciplines. This involves analysing how the research process itself contributes to the development of analytical and evaluative thinking.

Methods

Our exploration takes the form of a comprehensive qualitative systematic review, a meticulous journey through the extensive literature that probes the roles of reading and research within STEAM education. This methodological approach is tailored to synthesize a diverse array of insights, providing a robust foundation for comprehending the symbiotic relationship between qualitative research, reading, and the broader realms of STEAM education. This qualitative systematic review embarks on an exploration of the pivotal role of research within STEAM education, addressing the need to formalize innovation in science education. The methodological process followed the RETREAT Framework explicated below.

RETREAT Framework for Qualitative Evidence Synthesis

In this study, the RETREAT framework offered a structured and systematic approach to conducting qualitative evidence synthesis, as postulated in Costa and Costa (2024). By addressing risk mitigation, clarifying purpose, enhancing expertise, and ensuring theoretical coherence, researchers can significantly improve the quality and impact of their work in the realm of qualitative research. The RETREAT framework serves as a comprehensive guide for researchers engaged in qualitative evidence synthesis (QES), facilitating a structured decision-making process that enhances the quality of research outcomes (Costa & Costa, 2024). By delineating the QES journey into distinct stages, RETREAT ensures that researchers systematically address key considerations, thereby minimizing the likelihood of oversights that could compromise the integrity of the synthesis (Harten et al., 2020).

Clarity of Purpose

The initial stage of RETREAT underscores the importance of defining the purpose of the QES study. Establishing a clear and concise purpose is crucial as it sets the groundwork for the entire research endeavour. It ensures that researchers possess a thorough understanding of their goals and objectives, which in turn guides subsequent decisions and actions throughout the research process (Sandelowski & Barroso, 2007). Clarity of purpose not only streamlines the synthesis process but also aligns the research with the needs of stakeholders and the broader community. This principle help the authors craft a clear purpose statement as reflected in Section 3 above.

Theoretical Coherence

RETREAT emphasizes the significance of incorporating theoretical frameworks into the QES process. By aligning research with established theories, researchers achieve theoretical coherence, which enhances the rigor and depth of the analysis (Teddlie & Tashakkori, 2009). This alignment ensures that the synthesis is grounded in sound theoretical foundations, facilitating a more nuanced understanding of the phenomena under investigation. The integration of theory not only enriches the analysis but also contributes to the broader discourse within the field.

Rationale for using Qualitative Systematic Review with RETREAT

As we observe rapid changes in science education and evolution from STEM, innovative practices keep emerging as epicentre of this evolutionary trajectory. Innovative practices are those actions or activities through which new inventions are introduced into society. The systematic review approach, using RETREAT is well-suited for synthesising existing qualitative research, offering a robust method to gather insights from diverse sources and generate a comprehensive understanding of the role of research within STEAM education.

The crucial nature of this approach may be seen in the work of Perignat and Katz-Buonincontro, who conducted an integrative review of 44 articles on STEAM education from 2007 to 2018 on STEAM and its evolution. They find that despite the emergence of STEAM "as a popular pedagogical approach for enhancing students' creativity, problem-solving skills, and interest in STEM fields, the definitions and purposes of STEAM education remain ubiquitous." (2019: 31). In their study they "examined descriptions of the overall purpose of STEAM education, definitions of the STEAM acronym and the 'A' in STEAM, creativity as a learning outcome, elements of arts education, and arts education learning outcomes" (2019: 31). Further, they found that there were different definitions of the "STEAM concept," as well as "a variety of interpretations for the 'A' in STEAM," and "an overall lack of reported learning outcomes in the areas of creativity, problem-solving, and arts education." (2019: 31). Moreover, they found that there were transdisciplinary, interdisciplinary, multi-disciplinary, cross-disciplinary, and arts-integration methodologies. All these were recommendations provided to advance both research and practice in STEAM education. Data for this systematic review has been sourced from peer-reviewed journal articles, conference papers, and reports that focus on qualitative research within STEAM education. The systematic review involved data extraction, coding, and thematic analysis using the COSTAQDA cloud-based software.

Theoretical Framework

Our proposed theoretical framework is composed of four main components: constructivism, cognitive load theory, problem-based learning, and inquiry-based learning. All these component parts are connected directly to STEAM education.

Inquiry-Based learning

Inquiry-based learning is a cornerstone of STEM education. It aligns seamlessly with the investigative nature of scientific inquiry, technological problem-solving, engineering design processes, and mathematical exploration. Integrating Arts enhances inquiry-based learning by encouraging creative and interdisciplinary inquiries that bridge STEM and the arts.

Constructivism

STEAM education at its core aligns with constructivist principles by emphasizing hands-on learning, problem-solving and real-world applications. Through project-based learning, inquiry-based investigations, and authentic problem-solving experiences, students are encouraged to take ownership of their learning and connect theoretical concepts to real-world applications [Jonassen, 1999]. Collaborative learning environments in STEAM classrooms promote peer interaction and the co-construction of knowledge, enhancing students' problem-solving skills and fostering creativity (National Research Council, 2012).

Cognitive Load Theory

STEAM education often involves complex concepts and procedures. Understanding cognitive load theory helps educators design STEAM lessons that manage the cognitive load efficiently, ensuring that students can grasp intricate ideas without being overwhelmed. The addition of Arts in STEAM provides a creative avenue to present concepts, potentially reducing cognitive load through varied and engaging approaches.

Problem-Based Learning

STEAM education inherently involves problem-solving. Problem-Based Learning (PBL) is a natural fit, fostering the critical thinking and collaborative skills necessary for success in STEM fields. PBL offers a learner-centred approach that prepares students for the complexities of the modern world by equipping them with the problem-solving skills and mindset needed for success (Barrows & Tamblyn, 1980).

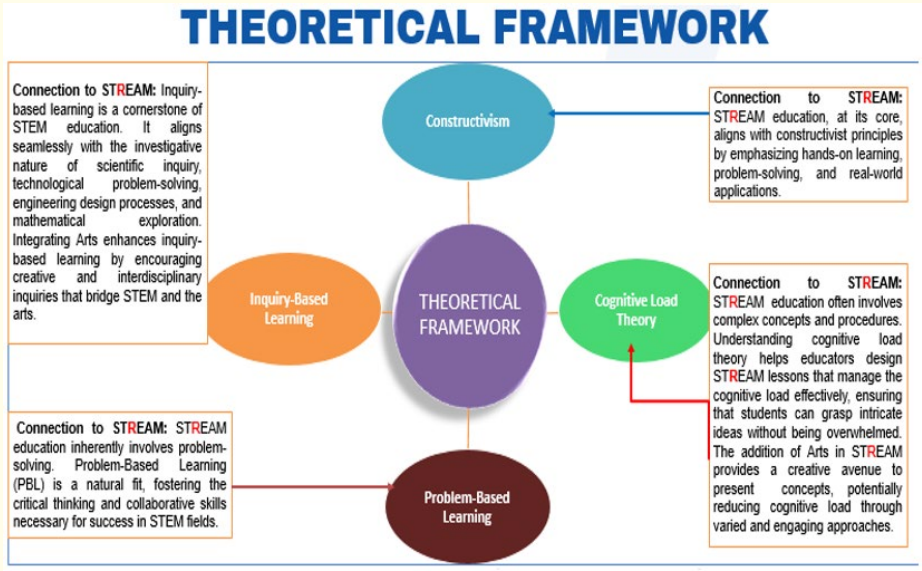
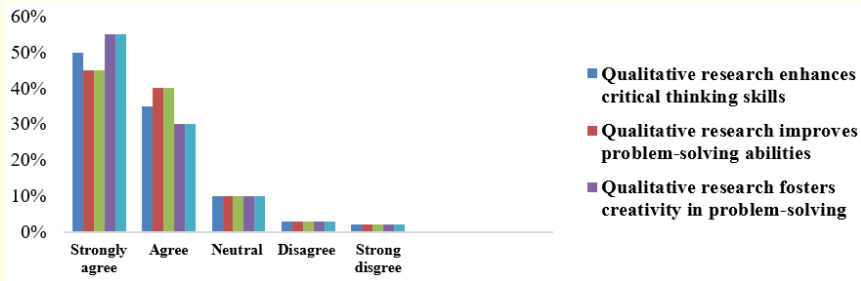


Figure 2: Theoretical Framework (Ntsobi & Costa, 2024).

Critical Analysis

Formalisation of Qualitative Research in STEAM Education and Complex Problem Solving



Smith, C., & Brown, D. (2020). "Understanding Complex Problem Solving in STEAM Education: A Qualitative Inquiry." International Journal of STEAM Studies, 6(2), 45-58.

Figure 3: Impact of Qualitative research on Complex Problem Solving.

In the ever-evolving landscape of education, the integration of STEM and STEAM with research is not just a progressive step; it is a change in thinking. Within this comprehensive framework, qualitative research emerges as a critical and transformative element, playing a pivotal role in enhancing education and addressing complex problems. This essay explores why qualitative research is essential in STEAM education and how it becomes a catalyst for effective problem-solving in the intricate tapestry of contemporary learning.

Understanding Qualitative Research

Qualitative research is a methodological approach that seeks to explore, interpret, and understand complex phenomena through the lens of context, culture, and human experience. It is particularly adept at unravelling the intricacies of human behaviour, motivations, and the dynamic interplay of variables. In the context of STEAM education, which emphasizes a multidisciplinary and integrated approach, qualitative research becomes an invaluable tool for gaining deeper insights into the nuanced relationships between science, technology, engineering, arts, mathematics, research, reading, and the learners themselves.

Tailoring Education to Individual Needs

One of the primary advantages of qualitative research in STEAM education lies in its ability to tailor learning experiences to individual needs. Unlike quantitative methods that focus on numerical data and standardized assessments, qualitative research delves into the qualitative aspects of learning - the personal narratives, motivations, and unique challenges that each learner brings to the educational landscape.

In the context of complex problem-solving, understanding the diverse perspectives and learning styles within a STEAM environment is crucial. Qualitative research facilitates the identification of individual strengths, preferences, and areas of improvement. This personalized insight allows educators to design interventions that cater to the specific needs of learners, fostering a more inclusive and effective learning environment.

Fostering a Culture of Curiosity and Inquiry

Qualitative research is inherently aligned with the spirit of curiosity and inquiry. In STEAM education, cultivating these qualities is paramount. Through qualitative methods such as interviews, focus groups, and participant observations, educators can stimulate a culture of curiosity, encouraging students to question, explore, and discover.

By incorporating qualitative research approaches, educators can design learning experiences that tap into students' natural inclination to inquire and investigate. This not only enhances their understanding of STEAM concepts but also nurtures a mindset that is essential for addressing complex problems. The ability to ask meaningful questions, explore multiple perspectives, and engage in open-ended inquiry is a direct result of the qualitative research-infused educational experience.

Promoting Critical Thinking and Problem-Solving Skills

Qualitative research is fundamentally rooted in critical thinking - the ability to analyse, interpret, and evaluate information in a nuanced manner. In the STEAM context, where complex problems often transcend disciplinary boundaries, critical thinking is a cornerstone skill.

Qualitative research methods, such as thematic analysis and in-depth interviews, provide students with opportunities to engage in analytical thinking. They learn to decipher patterns, identify underlying themes, and extract meaning from qualitative data. These skills are directly transferable to complex problem-solving scenarios, where the ability to analyse multifaceted issues and propose innovative solutions is paramount.

Encouraging Interdisciplinary Collaboration

STEAM education emphasizes the integration of diverse disciplines, encouraging students to explore the intersections between science, technology, engineering, arts, mathematics, research, and reading. Qualitative research, with its holistic and contextual approach, serves as a bridge between these disciplines.

By engaging in qualitative research projects, students are exposed to the interdisciplinary nature of real-world problems. They learn to appreciate the interconnectedness of various fields and develop the capacity to collaborate across disciplines. This interdisciplinary

mindset is crucial for addressing complex problems that often require multifaceted solutions.

Addressing Real-World Complexity

Complex problems, by their very nature, are multifaceted and dynamic. They require solutions that go beyond rote memorization or standardized procedures. Qualitative research equips students with the tools to navigate this complexity.

In a STEAM education enriched with qualitative research, students are exposed to real-world scenarios where problems do not have one-size-fits-all solutions. They learn to grapple with uncertainty, ambiguity, and the evolving nature of complex issues. This prepares them for the dynamic challenges they may face in their future careers, where the ability to adapt, iterate, and engage with complexity is essential.

Results

The systematic review uncovered recurring themes, challenges, and successful strategies related to qualitative research within STEAM education which provide valuable resources for educators, curriculum developers, and policymakers, allowing them to better integrate research into STEAM education. STEAM is an emerging field of theory, research and practice that is aimed at incorporating the arts into STEM learning (Mejias et al., 2021). Educators endeavor to embrace the arts as an inclusive and authentic approach to engage youth in STEM, however, STEAM is still relatively ambivalent and weakly theorized because it is deployed in theory, pedagogy, and practice in ways that are ambiguous and potentially problematic. However, there is transformative learning potential through STEAM in pedagogical and instrumental forms (Mejias et al., 2021). What is important is to ensure that neither STEM nor arts are privileged over the other, but that both should be given equal weight.

Educational reform has increasingly taken an interdisciplinary and transdisciplinary learning approach in schools. STEAM is shifting educational paradigms toward art integration in STEM subjects (Bertrand & Namukasa, 2020). So, real world problems that address complex or multistep questions offer opportunities to integrate disciplines across both science and arts. The main findings of the study by Bertrand and Namukasa (2020), pertain to students learning and developing perseverance and adaptability, as well as transferable skills. The originality of the study is that it identifies both the enablers and the tension that require ongoing engagement with stakeholders, such as focus groups, which have the potential to impact change in teaching and teacher development, as well as in related policies (Bertrand & Namukasa, 2020).

With respect to curriculum development within STEAM programs, according to Jia, Zhou and Zheng (2021), "'Maker' education is a new type of educational practice which aims to foster creativity. It views learning as a shared, social process based on the design and production of physical objects (Halverson and Sheridan, 2014). It assumes that the joy of creation can stimulate students' curiosity (Anderson, 2012). Maker education focuses on the use of technical tools and equipment but is less concerned with developing knowledge of scientific concepts and principles (Dougherty, 2012)".

According to Kim and Kim (2018), STEAM education using the Maker approach is well-suited for classroom learning in the Fourth Industrial Revolution, which incorporates multidisciplinary STEM education in classroom teaching, in a way that prioritizes design over processing by including application of digital technology (Jia et al., 2021). This method enables students to learn through trial and error. However, Maker education is still lacking in interdisciplinary, is still shallow and unintegrated (Chachra, 2015 in Jia et al., 2021). In contemporary society, learners are expected to synthesize large amounts of information in an interdisciplinary context to tackle complex and real-world issues.

Therefore, STEAM is intended to cultivate the ability of students to solve these problems through interdisciplinary thinking. However, while Maker education advances technological innovation and creativity, it tends to neglect the scientific principles that are underpinned in these processes. Therefore, one example of the modification of curricula is the trend in incorporating STEAM education. The objective is to move from "what content do we need to know" towards "how can we support learners in the process of inquiry"

(Quigley et al., 2020: 499). The challenge, however, is that there is limited research in STEAM teaching practices. What is important is for teachers to design STEAM curricula that is problem-based in a way that promotes student enquiry, which is an approach that facilitates discipline integration, teacher facilitation, and authentic tasks.

Conclusion

This systematic review aims to provide a comprehensive understanding of the role of qualitative research in ST(R)EAM education. By synthesizing existing knowledge, it can offer insights that guide curriculum development, pedagogical practices, and the integration of research into STEAM programs. Research serves as the catalyst for innovation, the fuel for curiosity, and the foundation for progress in STEAM education. By fostering a culture of inquiry, experimentation, and discovery, research not only expands our understanding of the world but also empowers the next generation of thinkers, creators, and problem solvers who will shape the future of science, technology, engineering, arts, and mathematics. It is through the continuous pursuit of knowledge that we illuminate the path to new frontiers, ensuring a brighter and more dynamic future for STEAM education and the world at large.

In the realm of STEAM education, qualitative research emerges not as an isolated methodology but as a transformative force that permeates the very fabric of learning. It tailors education to individual needs, fosters a culture of curiosity and inquiry, promotes critical thinking and problem-solving skills, encourages interdisciplinary collaboration, and equips students to address the real-world complexity of the 21st century.

As we navigate the ever-evolving landscape of education, it is imperative to recognize the symbiotic relationship between qualitative research and STEAM. Together, they pave the way for a generation of learners who not only understand the intricacies of science, technology, engineering, arts, mathematics, research, and reading but are also adept at applying this knowledge to solve the complex problems that define our interconnected world. In embracing the power of qualitative research within STEAM education, we embark on a journey towards a more dynamic, inclusive, and effective educational paradigm.

References

1. Anderson C. “Makers: The New Industrial Revolution”. Crown Business (2012).
2. Arts Integration. STEAM Designed and Enacted: Understanding the Process of Design and Implementation of STEAM Curriculum in an Elementary School.
3. Bae JH., et al. “The effects of science lesson applying STEAM education on creative thought activities and emotional intelligence of elementary school students”. Korean Elementary Science Education 33 (2014): 762-772.
4. Barlex D and Pitt J. “Interaction: The Relationship Between Science and Design and Technology in the Secondary School Curriculum”. Engineering Council (2000).
5. Barrows HS and Tamblyn RM. “Problem-based learning: An approach to medical education”. Springer Publishing Company (1980).
6. Bertrand MG and Namukasa IK. “STEAM education: student learning and transferable skills”. Journal of Research in Innovative Teaching & Learning 3.1 (2020): 43-56.
7. Chachra, D.: Why I Am Not a Maker. The Atlantic (2015).
8. Costa K and Costa A. “Qualitative Evidence Synthesis Using COSTAQDA”. In: J. B. C. N. M. K. J. C. A. Ribeiro, ed. Computer Supported Qualitative Research. WCQR 2024. Lecture Notes in Networks and Systems, vol 1061. Cham: Springer (2024): 51-77.
9. De Boer EG. “A History of Ideas in Science Education”. New York, NY: Teachers College Press (1991).
10. Vries H. “Cultural differences of scientific creativity: A relation with tolerance of ambiguity/uncertainty: An empirical study with children in Luxembourg, France, Thailand, India, and Russia (Ph.D. dissertation)”. Sorbonne Paris Cité. Paris, France (2018).
11. De Vries H. “Space for STEAM: New creativity challenge in education”. Frontiers in Psychology 12 (2021).
12. De Vries HB and Lubart TI. “Scientific creativity: divergent and convergent thinking and the impact of culture”. Journal of. Creative. Behavior 53 (2017): 145-155.

13. Dougherty D. "The maker movement". Innovations. Technology. Governance. Globalization 7 (2012): 11-14.
14. Halverson ER and Sheridan K. "The maker movement in education". Harvard. Educational. Review 84 (2014): 495-504.
15. Harris A and de Bruin L. "STEAM Education: fostering creativity in and beyond secondary schools". Aust. Art Educ 38 (2017): 54.
16. Jia Y, Zhou B and Zheng X. "A Curriculum Integrating STEAM and Maker Education Promotes Pupils' Learning Motivation, Self-Efficacy, and Interdisciplinary Knowledge Acquisition". Frontiers in Psychology 12 (2021).
17. Johnson A and Smith B. "Interdisciplinary Curriculum Design for STEAM Education: A Review". Journal of STEAM Education 8.2 (2020): 45-62.
18. Jonassen DH. "Designing constructivist learning environments". In C. M. Reigeluth (Ed.), Instructional-design theories and models: A new paradigm of instructional theory. Lawrence Erlbaum Associates 2 (1999): 215-239.
19. Keys CW and Bryan LA. "Co-constructing inquiry-based science with teachers: essential research for lasting reform". Journal of Research in Science Teaching 38 (2001): 631-645.
20. Kim JO and Kim J. "Design of maker-based STEAM education with entry programming tool". Advanced. Science Letters 24 (2018): 2088-2093.
21. Marín-Marín JA., et al. "STEAM in education: A bibliometric analysis of performance and co-words in Web of Science". International Journal of STEM Education 8 (2021): 41.
22. Mejias S., et al. "The trouble with STEAM and why we use it anyway". Science Education 105.2 (2021): 209-231.
23. National Research Council. A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. National Academies Press (2012).
24. Perignat E and Katz-Buonincontro J. "STEAM in practice and research: An integrative literature review". Thinking Skills and Creativity 31 (2019): 31-43.
25. Quigley CF., et al. "STEAM Designed and Enacted: Understanding the Process of Design and Implementation of STEAM Curriculum in an Elementary School". Journal and Science Education and Technology 29 (2020): 499-518.
26. Sanders M., et al. Integrative STEM (Science, Technology, Engineering, and Mathematics) education: contemporary trends and issues. Secondary Education. Research 59 (2011): 729-762.
27. Saptono S and Hidayah I. "Scientific creativity: a literature review". Journal of Physics: Conference Series 1567 (2020): 022044.
28. Smith C and Brown D. "Understanding Complex Problem Solving in STEAM Education: A Qualitative Inquiry". International Journal of STEAM Studies 6.2 (2020) 45-58.
29. Thapa S. "Assessing intercultural competence in teacher education: a missing link". in Visions for Intercultural Music Teacher Education (Cham: Springer) (2020): 163-176.
30. Wursten H and Jacobs C. "The impact of culture on education. Can we introduce best practices in education across countries?". ITIM International 1 (2013): 1-28.

Volume 7 Issue 5 November 2024