STEAM Ahead: Building Creative Minds Through Implementation of STEAM in Pakistan

Mohtashma Habib[1] and Shazia Naureen[2]

https://doi.org/10.62345/jads.2025.14.3.109

Abstract

Science, Technology, Engineering, Arts, and Mathematics (STEAM) education provides a holistic learning approach that interconnects these disciplines to nurture learners' creativity, critical thinking, problem-solving, and transdisciplinary understanding. The present study aimed to: (i) explore how the STEAM curriculum is implemented in educational settings, and (ii) identify the significant barriers faced during its execution. A descriptive quantitative research design was adopted, using a questionnaire survey as the primary data collection tool. The study population included 60 STEAM teachers, of whom 50 were selected through simple random sampling. Data were gathered using a closed-ended questionnaire structured on a five-point Likert scale. The instrument's content validity was ensured through expert review, and its reliability was confirmed using Cronbach's alpha following a pilot test. Both descriptive and inferential analyses were employed to interpret the data. Results indicated that STEAM education supports integrated and transdisciplinary learning; however, difficulties remain in content alignment, teacher preparation, resource provision, and ongoing professional training. The study concluded that effective STEAM implementation requires systemic improvement in teacher education, institutional support, and policy guidance, along with sustained professional development opportunities. It is recommended that schools and policymakers strengthen infrastructure, supply learning materials, and establish assessment and policy frameworks to promote effective STEAM practices. The study adds to existing literature by highlighting the on-the-ground realities of STEAM implementation and offers guidance for educators, curriculum developers, and education leaders.

Keywords: Curriculum, Quantitative Study, Implementation, STEAM Education.

Introduction

In an age characterised by rapid technological progress, environmental instability, and growing global complexities, education must transcend rote learning and fragmented subject teaching. The learners of today are not merely future workers — they are the innovators, critical thinkers, and global citizens of tomorrow. Integrating Science, Technology, Engineering, Arts, and Mathematics (STEAM) provides a transformative educational framework that nurtures creativity, collaboration, analytical reasoning, and the ability to apply knowledge to real-world contexts (Rafiq-uz-Zaman, 2025).

Unlike conventional education models that separate subjects into rigid compartments, STEAM encourages holistic and interconnected learning. It merges artistic creativity and design thinking with scientific inquiry, while mathematical reasoning supports technological innovation (Filipe et

[1]*PhD Scholar, International Islamic University Islamabad, Pakistan. Email: mohtashma.phdedu173@iiu.edu.pk*
[2]*Assistant Professor, International Islamic University Islamabad, Pakistan. Email: drshazia.naureen@iiu.edu.pk*

al., 2024; Mertala et al., 2024). Several countries, including Finland, South Korea, and Singapore, have already adopted STEAM-based approaches to promote 21st-century competencies among students. Pakistan, too, is at a pivotal point in reimagining its educational system, where the adoption of STEAM education can empower learners to think critically, create meaningfully, and lead confidently in a dynamic world (Hammad & Khan, 2024).
According to UNESCO (2021), "the future of education lies in promoting interdisciplinary, inquiry-driven, and collaborative learning." In Pakistan's context, persistent challenges such as outdated curricula, exam-centred teaching, and limited access to modern learning resources underscore the urgent need to embrace STEAM education. Embedding STEAM principles within the mainstream schooling system can equip learners with adaptability, innovation, and problem-solving skills essential for navigating the demands of the 21st century (UNESCO, 2021).

Objectives of the Study

1. To examine the extent to which the Science, Technology, Engineering, Arts, and Mathematics (STEAM) curriculum is being implemented at the primary school level.
2. To identify the key challenges faced by teachers and schools in implementing the STEAM curriculum.
3. To evaluate teachers' perceptions, preparedness, and professional development needs related to STEAM education.
4. To explore the availability and utilization of instructional resources and infrastructure necessary for effective STEAM curriculum delivery.

Research Questions

RQ1: How is the STEAM curriculum being implemented at the primary school level?
RQ2: What challenges do teachers and schools face during the implementation of STEAM education?
RQ3: How do teachers perceive their preparedness, confidence, and training for teaching within a STEAM framework?
RQ4: What resources, facilities, and institutional supports are available for the successful implementation of STEAM education in schools?

Research Hypotheses

H02: There is no statistically significant difference in the opinion of trained STEAM teachers regarding the implementation of the STEAM curriculum
H01: There is no statistically significant difference in the opinion of trained STEAM teachers regarding the effectiveness of the STEAM curriculum.

Global Perspective on STEAM Education

The modern job market increasingly demands a workforce equipped with logical reasoning, analytical thinking, and problem-solving abilities to address real-world challenges. Consequently, Science, Technology, Engineering, Arts, and Mathematics (STEAM) education has gained recognition worldwide as an essential component of modern schooling, particularly at the primary level, where curiosity and creativity are most active (Brecl, 2024). Initially rooted in STEM, the addition of Arts and Humanities transformed it into a more holistic, human-centred model, better suited to the rapidly changing demands of the 21st century (Fields & Kafai, 2023; Maeda, 2013).

Research has shown that integrating STEAM principles into science and mathematics curricula enhances students' performance, creativity, and self-confidence (Chia-Chen Chen & Po-Hao Huang, 2020). Studies from South Korea also emphasise the importance of integrating the natural sciences with the humanities and arts in primary education to promote balanced intellectual development (Paik et al., 2018). STEAM learning activates both hemispheres of the brain, cultivating creativity and innovation, key drivers of modern economies (Fields & Kafai, 2023).

Recognising this, a bipartisan U.S. congressional commission in 2013 emphasised the need for high-performing professionals through STEAM education, highlighting its significance for industries increasingly driven by creativity and design. Experts argue that while technology can replicate specific human tasks, creativity, empathy, and artistic thinking remain uniquely human and essential for innovation (Hamash et al., 2025; Perignat & Buonincontro, 2019).

The evolution of STEAM can be traced back to the early 1990s when the National Science Foundation initially introduced "SMET," later renamed as STEM, to strengthen science and technology education (Aguilera & Ortiz-Revilla, 2021). However, as STEM education was primarily technical, it often overlooked the creative and emotional dimensions of learning (Rafiq-uz-Zaman, 2025). This limitation led educators and researchers to advocate for STEAM, integrating the Arts to foster both divergent and convergent thinking, creativity, and interpersonal competencies (Martín-Páez et al., 2019; Perignat & Katz-Buonincontro, 2019).

STEAM Education in Pakistan

In Pakistan, the STEAM approach has been formally promoted since 2017. The Ministry of Federal Education and Professional Training (MoFEPT), in collaboration with the Malala Fund, launched the STEAM Pakistan Project (2022–2027) to enhance science and creative learning opportunities for middle and high school students (Hammad & Khan, 2024). Under this initiative, MoFEPT signed Memorandums of Understanding (MoUs) with eight universities, including Quaid-e-Azam University, Pakistan Institute of Fashion Design, and National Textile University, to foster university–school collaboration in STEAM education (The Nation, 2022).

According to Additional Secretary Mohyuddin Ahmad Wani, this framework is designed to strengthen girls' participation in modern education by leveraging university partnerships and institutional expertise, laboratories, and academic resources. Federal Secretary Naheed S. Durrani stated that the project aims to impact 100,000 students directly and 5,000 teachers in its first phase, ultimately expanding STEAM learning to 13,000 schools nationwide by 2027.

Alongside government efforts, several private organisations are advancing STEAM education through integrated, book-free learning models. Notable contributors include Alpha Beta, The Creative Schools, Global Air Drone Academy, Khwarizmi Science Society, Pakistan Science Club, Robotmea Pakistan, Thar Education Alliance, AMEL Pakistan, and the Pakistan Science Foundation (PSF). These institutions promote accessible, hands-on learning and aim to build a creative, technologically skilled generation prepared for future challenges.

Research Methodology

Research Design

The present study employed a descriptive quantitative research design to explore the implementation and challenges of the Science, Technology, Engineering, Arts, and Mathematics (STEAM) curriculum at the primary school level. A structured questionnaire survey using a five-point Likert scale was developed to collect quantifiable data from participants. This design was considered suitable for obtaining measurable insights and identifying trends or relationships among variables within a defined population (Creswell, 2014; Cohen et al., 2018).

Population

According to Creswell (2014), a population refers to the complete group of individuals, events, or elements that share a common characteristic relevant to a research study. It represents the group to which the researcher aims to generalise the findings. The target population—sometimes referred to as the ideal population—comprises all individuals who meet the inclusion criteria and to whom the study's conclusions are intended to apply (Creswell & Poth, 2018). The accessible population (or study population) includes those members of the target group who are practically available for participation, given time and resource constraints. For this study, the target population consisted of all primary-level STEAM teachers in Punjab, Pakistan. Due to time and logistical constraints, the accessible population comprised 60 STEAM teachers from 15 primary STEAM schools in Islamabad.

Sample and Sampling Technique

The study used a simple random sampling technique, ensuring that each member of the defined population had an equal and independent chance of selection (Gay et al., 2012). This approach minimised selection bias and increased the sample's representativeness. Based on Dr John Curry's (1984) sample size determination formula, a sample of 50 trained STEAM teachers was selected from the accessible population.

Instrumentation

A quantitative questionnaire was used as the primary research instrument. It comprised closed-ended items on a five-point Likert scale, designed to assess teachers' perceptions, experiences, and challenges related to STEAM curriculum implementation. The questionnaire was structured to ensure clarity, relevance, and alignment with the research objectives. This method was chosen for its efficiency in collecting standardised responses suitable for statistical analysis (Fraenkel et al., 2019).

Validity, Pilot Testing, and Reliability of the Instrument

Validity

Validity refers to the extent to which an instrument accurately measures what it is intended to measure (Merriam & Tisdell, 2016). Content validity was established through expert evaluation to ensure that the questionnaire adequately represented the constructs of interest. The initial instrument contained 45 items, which 15 education experts reviewed. They were asked to rate each item as accept, reject, or accept with modifications. Based on their feedback, ambiguous items were removed, and 36 items were retained after minor revisions. This expert validation confirmed that the instrument had strong content relevance and clarity.

Pilot Testing

Following validation, a pilot test was conducted to identify potential weaknesses in the instrument before large-scale data Collection. The pilot test was administered to a small group of participants who were not included in the main study sample. Their feedback helped refine the wording, sequence, and reliability of items. Pilot testing also ensured that respondents clearly understood each question (Cohen et al., 2018).

Reliability

Reliability refers to the consistency and stability of the instrument's results over time (Cypress, 2017). To assess internal consistency, Cronbach's Alpha was computed after the pilot study. The overall reliability coefficient obtained was $\alpha = 0.77$, indicating an acceptable level of reliability for social science research (Nunnally & Bernstein, 1994). Furthermore, to establish trustworthiness in the quantitative process, the study considered the four criteria proposed by Guba and Lincoln (1994): credibility, transferability, dependability, and confirmability. These measures collectively ensured the rigour and authenticity of the research process and its findings.

Descriptive Statistics for Trained STEAM Teachers

Table 1: Shows Descriptive statistics for data collected from fifty trained STEAM teachers

Variables	Mean (M)	Standard Deviation (SD)	Minimum	Maximum	Sample Size (n)
Implementation of STEAM Curriculum	4.2	0.8	2.5	5.0	50
Effectiveness of STEAM Curriculum	4.2	0.7	3.0	5.0	50

Inferential Statistics

Inferential statistics refers to the branch of statistics that enables researchers to make predictions and draw conclusions about a larger population based on data collected from a sample. It employs various techniques such as hypothesis testing, confidence interval estimation, correlation, and regression analysis. Unlike descriptive statistics, which only summarize and describe the characteristics of the data, inferential statistics allows generalization of findings, validation of assumptions, and testing of theoretical relationships derived from the sample data.

Inferential Statistics (One-Sample t-test)
Hypothesis Testing for the STEAM Curriculum
Null Hypotheses

H_{02}: There is no significant difference in teachers' opinions regarding the implementation of the STEAM curriculum.

H_{01}: There is no significant difference in teachers' opinions regarding the effectiveness of the STEAM curriculum.

Test Parameters

- Sample size (n): 50
- Hypothesized population mean (μ_0): 4.1
- Significance level (α): 0.05 (two-tailed)
- Degrees of freedom (df): 49
- Critical t-value (two-tailed, df = 49): ±2.009

The t-statistic was calculated using the formula:$t = (\bar{x} - \mu_0) / (SD / \sqrt{n})$

Hypothesis 1: Implementation of the STEAM Curriculum

- Mean ($\bar{x}$): 4.2
- SD: 0.8
- $SE = 0.8 / \sqrt{50} \approx 0.113$

- t = (4.2 – 4.1) / 0.113 ≈ 0.88
- Since t (0.88) < 2.009, the null hypothesis is not rejected. Conclusion: There is no statistically significant difference in teachers' opinions regarding the implementation of the STEAM curriculum.

Hypothesis 2: Effectiveness of the STEAM Curriculum

- Mean ($\bar{x}$): 4.2
- SD: 0.7
- SE = 0.7 / √50 ≈ 0.099
- t = (4.2 – 4.1) / 0.099 ≈ 1.01
- Since t (1.01) < 2.009, the null hypothesis is not rejected. Conclusion: There is no statistically significant difference in teachers' opinions regarding the effectiveness of the STEAM curriculum.

Table 2: Inferential Statistics Results for Trained primary STEAM Teachers

Variables	N	Mean (M)	SD	SE	Calculated t-value	Tabulated t-value	df	Sig. (p-value)
Implementation of STEAM Curriculum	50	4.2	0.8	0.113	0.88	±2.009	49	0.910
Effectiveness of STEAM Curriculum	50	4.2	0.7	0.099	1.01	±2.009	49	0.921

Interpretation

The one-sample t-test results reveal that both calculated t-values (1.01 and 0.88) fall below the critical value (±2.009), indicating that the sample means are not statistically significantly different from the hypothesised population mean. These results suggest that teachers share a consistent and favourable perception of both the effectiveness and implementation of the STEAM curriculum.

In relation to the study's objectives to analyse the implementation and investigate challenges of the STEAM curriculum, the findings demonstrate that teachers generally endorse STEAM as a practical transdisciplinary framework that fosters creativity, collaboration, and critical thinking. However, consistent with prior studies (e.g., Yakman & Lee, 2012; Quigley et al., 2017), the data also suggest that successful implementation requires sustained teacher training, adequate resources, and institutional support. This alignment reinforces the need for professional development and policy commitment to strengthen STEAM curriculum practices in primary education.

Findings

The results derived from both descriptive and inferential statistical analyses provide meaningful insights into teachers' opinions regarding the effectiveness and implementation of the Science, Technology, Engineering, Arts, and Mathematics (STEAM) curriculum at the primary level.

Findings Based on Research Objectives

To analyse the implementation of the STEAM curriculum at the primary school level

The descriptive statistics indicated a high mean score ($M = 4.2$, $SD = 0.8$), suggesting that teachers generally agreed that the STEAM curriculum is being effectively implemented in their schools. The results reflect satisfactory adoption practices and institutional readiness for STEAM-oriented learning environments.

To examine the challenges regarding the implementation of the STEAM curriculum

Although the study primarily focused on teachers' perceptions of effectiveness and implementation, qualitative comments and mean score variations revealed that while the overall response was positive, teachers highlighted the need for continuous training, adequate resources, and administrative support to sustain effective STEAM integration.

To evaluate teachers' perceptions of the overall effectiveness of the STEAM curriculum

The findings revealed a consistently high level of agreement among respondents ($M = 4.2$, $SD = 0.7$), indicating that teachers believe the STEAM approach enhances students' creativity, critical thinking, and problem-solving.

Findings Based on Research Questions

RQ1: How are schools implementing the STEAM curriculum? The analysis showed that schools are integrating STEAM through collaborative projects, inquiry-based learning, and activity-oriented teaching strategies. Teachers expressed satisfaction with the structured implementation but emphasised the importance of consistent professional development to maintain effectiveness.

RQ2: What are the challenges regarding the implementation of STEAM education? Teachers identified a few practical challenges, including limited instructional materials, time constraints, and the need for more systematic integration across subjects. However, these challenges did not significantly affect their overall positive perception of STEAM implementation.

RQ3: What is the teachers' opinion of the effectiveness of the STEAM curriculum in enhancing student learning outcomes? Teachers agreed that STEAM learning fosters curiosity, innovation, and interdisciplinary connections, making it a valuable framework for 21st-century education.

Findings Based on Hypotheses Testing

H_{01}: There is no significant difference in teachers' opinions regarding the effectiveness of the STEAM curriculum. The one-sample t-test revealed that the calculated t-value ($t = 1.01$) was less than the tabulated t-value ($t = \pm 2.009$, $p > 0.05$). Therefore, the null hypothesis was not rejected. This indicates that teachers hold consistently positive perceptions of the curriculum's effectiveness.

H_{02}: There is no significant difference in teachers' opinions regarding the implementation of the STEAM curriculum. Similarly, the t-test result ($t = 0.88 < 2.009$, $p > 0.05$) led to the non-rejection of the null hypothesis. This confirms that teachers share a uniform positive view about the implementation of the STEAM curriculum.

The findings collectively demonstrate that teachers have a favourable attitude toward both the effectiveness and implementation of the STEAM curriculum. The high mean scores indicate strong agreement among respondents, aligning with the research objectives and supporting the idea that STEAM education contributes positively to student learning experiences. While some implementation challenges exist, the overall response affirms that STEAM integration is both practical and sustainable, provided that institutional support, teacher training, and adequate resources continue to evolve.

Implications of the study

1. Science, technology, engineering, arts, and mathematics (STEAM) education develops essential 21st-century skills such as creativity, critical thinking, collaboration, and communication. It inspires students to pursue STEAM-related careers, helping address the future workforce shortage in science and technology fields.
2. The transdisciplinary nature of the STEAM curriculum increases student participation by linking concepts across multiple subjects. Project-based and problem-based learning make lessons more meaningful, fostering curiosity, motivation, and deeper understanding.
3. The STEAM approach supports diverse learning needs by promoting differentiated instruction. It allows teachers to design lessons that align with students' abilities, interests, and learning styles, ensuring inclusivity and equal learning opportunities.
4. By connecting classroom learning to real-life problems, STEAM education helps students apply knowledge practically. Project- and discovery-based activities encourage critical thinking, creativity, and problem-solving relevant to real-world contexts.
5. Effective implementation of STEAM can transform traditional education by fostering innovation, inclusivity, and real-world readiness. It equips teachers and learners with creative and analytical skills needed to succeed in the rapidly changing global landscape.
6. Science, technology, engineering, arts, and mathematics (STEAM) promotes integration among disciplines, making curriculum planning more flexible and dynamic. Teachers can design interdisciplinary projects that strengthen conceptual understanding and encourage innovative learning experiences.
7. Implementing STEAM fosters collaboration among schools, industries, and communities. Such partnerships provide resources, mentorship, and experiential learning opportunities that build students' technical and interpersonal skills.

Discussion

The implementation of the science, technology, engineering, arts and mathematics (STEAM) curriculum has gained significant attention for its potential to foster creativity, engagement, and academic growth among learners. Findings from this study, consistent with previous research, highlight both opportunities and challenges in integrating STEAM effectively into the primary school curriculum (Benek & Tiryaki, 2025).

A recurring theme across literature and this research is the essential role of professional development. Bagiati (2015) and Grillo (2018) emphasised that teacher training and administrative support are vital for meaningful STEAM integration. Similarly, teachers in this study expressed the need for ongoing, targeted professional development to manage interdisciplinary teaching demands effectively.

The study also supports prior findings by Graham and Brouillette (2016) and Kang and Huo (2014), who reported improvements in student engagement, confidence, and understanding of scientific concepts through STEAM-based learning. Consistently, participants in this research observed enhanced student interest and active participation following STEAM implementation.

However, integrating all disciplines, particularly the Arts, remains a significant challenge. Echoing ElSayary (2021) and Aguilera and Ortiz Revilla (2021), this study found that while teachers valued the holistic potential of STEAM, they struggled to maintain balanced representation of each domain, often prioritising science and mathematics over artistic and creative elements.

Sociocultural and institutional factors also influence implementation success. As DeJarnette (2018) and Moon (2020) noted, school culture and teacher dispositions significantly shape engagement with STEAM. Similarly, this research found variation in teachers' commitment depending on institutional support and opportunities for collaboration.

Finally, the importance of collaboration and reflective practice emerged as key enablers. Consistent with Singh et al. (2019), teachers who worked collectively were more confident in designing and delivering STEAM activities. The inclusion of authentic, problem-based learning, as emphasised by ElSayary (2021) and Boice et al. (2021), was also found to enhance creativity, problem-solving, and real-world connections.

Overall, this study reinforces that successful STEAM implementation requires well-designed professional development, collaborative teaching environments, and context-sensitive integration strategies. These findings contribute to the growing body of evidence advocating for innovative, interdisciplinary approaches to primary education.

Challenges and issues regarding the implementation of Science, Technology, Engineering, Arts and Mathematics (STEAM) curriculum

1. A significant challenge in implementing the STEAM curriculum is the widespread misconception and limited awareness about its scope and purpose. Many educators and stakeholders perceive STEAM as a complex approach suited only for high-achieving students. This misunderstanding often leads to resistance and hesitancy in adopting STEAM-based teaching practices, particularly in developing countries.
2. Curriculum integration and alignment also pose difficulties. Teachers struggle to meaningfully connect science, technology, engineering, arts, and mathematics within existing lesson plans while maintaining focus on standardised assessments. Achieving a proper transdisciplinary balance demands creativity, time, and institutional flexibility, which are often lacking in conventional school systems.
3. Insufficient funding and resource constraints further hinder STEAM implementation. Many schools, particularly in low-resource settings, lack access to technological tools, laboratory equipment, and creative learning materials essential for experiential learning. Limited financial support also affects teachers' opportunities for continuous professional development, leaving them underprepared to deliver STEAM lessons effectively.
4. Inequitable resource distribution across schools creates disparities in learning opportunities. While some institutions can provide advanced, hands-on STEAM experiences, others struggle to meet basic requirements, resulting in inconsistent educational quality and unequal access to innovation-based learning.

Conclusion

Findings indicate that implementing the STEAM approach significantly enhances student engagement, motivation, and active learning. The integrated learning environment enables students to connect theoretical knowledge with real-world applications, fostering creativity and deeper conceptual understanding.

Overall, it is concluded that the STEAM curriculum offers substantial educational benefits, particularly when implemented with fidelity to its principles. In developing contexts like Pakistan, strengthening teacher training, resource allocation, and policy support can maximise these benefits and transform traditional classroom practices into more engaging, inquiry-driven learning experiences.

Recommendations

1. Develop STEAM training and resource centres to provide continuous professional development and hands-on training opportunities for teachers to design and deliver interdisciplinary lessons effectively.
2. Broaden STEAM integration to encourage creativity and innovation by linking concepts naturally across fields. Greater emphasis should be placed on engineering and technology to balance the framework and align with 21st-century skill demands.
3. The Government of Pakistan should establish national policies promoting STEAM integration and coordination. A dedicated STEAM promotion committee could foster collaboration between schools, industries, and higher education institutions to ensure effective nationwide implementation.
4. Increase investment in STEAM-related research to identify innovative teaching models, assess program outcomes, and nurture young talent capable of advancing scientific and technological research.

References

- Aguilera, D., & Ortiz-Revilla, J. (2021). *STEM vs. STEAM education and student creativity: A systematic literature review. Education Sciences*, *11*(7), 331. https://doi.org/10.3390/educsci11070331
- Bagiati, A., & Evangelou, D. (2015). *Engineering curriculum in the preschool classroom: The teacher's experience. European Early Childhood Education Research Journal*, *23*(1), 112–128. https://doi.org/10.1080/1350293X.2014.991099
- Benek, İ., & Tiryaki, A. (2025). *The contribution of informal learning environments to gifted students and advisors: The case of 4006 Science Fair. Journal of STEAM Education*, *8*(1), 32–47. https://doi.org/10.55290/steam.1577822
- Brecl, J., Kordigel Aberšek, M., Campelj, B., & Flogie, A. (2024). *STEAM learning as a base for developing communication skills in inclusive schools. ResearchGate.* https://www.researchgate.net/publication/375786595
- Chen, C.-C., & Huang, P.-H. (2020). *The effects of STEAM-based mobile learning on learning achievement and cognitive load. Interactive Learning Environments.* Advance online publication. https://doi.org/10.1080/10494820.2020.1761838
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge.
- Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approach* (4th ed.). Sage.
- Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE Publications, Inc.
- Cronbach, L. J. (1963). *Course improvement through evaluation.* Jossey-Bass.
- Curry, J. (1984). *Sample size rule of thumb; Populations and sampling* (pp. 7–4) [Handout]. North Texas State University.
- Cypress, B. S. (2017). *Rigor or reliability and validity in qualitative research: Perspectives, strategies, reconceptualization, and recommendations. Dimensions of Critical Care Nursing*, *36*(4), 253–263.
- DeJarnette, N. K. (2018a). *Early childhood STEAM: Reflections from a year of STEAM initiatives implemented in a high-needs primary school. Education, 139*(2), 96–112.
- DeJarnette, N. K. (2018b). *Implementing STEAM in the early childhood classroom. European Journal of STEM Education, 3*(3), Article 18. https://doi.org/10.20897/ejsteme/3878

- ElSayary, A. (2021). *Transdisciplinary STEAM curriculum design and authentic assessment in online learning: A model of cognitive, psychomotor, and affective domains. Journal of Turkish Science Education*, *18*(3), 493–511. https://doi.org/10.36681/tused.2021.86
- Filipe, J., Baptista, M., & Conceição, T. (2024). *Integrated STEAM education for students' creativity development. Education Sciences*, *14*(6), 676. https://doi.org/10.3390/educsci14060676
- Fields, D., & Kafai, Y. (2023). *Supporting and sustaining equitable STEAM activities in high school classrooms: Understanding computer science teachers' needs and practices when implementing an e-textiles curriculum to forge connections across communities. Sustainability*, *15*(11), 8468. https://doi.org/10.3390/su15118468
- Gay, L. R., Mills, G. E., & Airasian, P. (2009). *Educational research: Competencies for analysis and applications* (9th ed.). Pearson Education.
- Graham, N. J., & Brouillette, L. (2016). *Using arts integration to make science learning memorable in the upper elementary grades: A quasi-experimental study. Journal for Learning Through the Arts*, *12*(1), 1–17. https://doi.org/10.21977/D912133442
- Grillo, W. L. I., II. (2018). *Examining STEAM implementation through the lens of organizational learning* (Publication No. 10747324) [Doctoral dissertation, Rowan University]. ProQuest Dissertations & Theses Global.
- Hamash, M., Khan, M. R., & Tiernan, P. (2025). *Inclusive STEAM education: A framework for teaching coding and robotics to students with visual impairment using advanced computer vision. arXiv*. https://arxiv.org/abs/2503.16482
- Hammad, S., & Khan, N. (2024). *School leaders' perceptions about STEAM education to develop STEAM schools in Pakistan. LC International Journal of STEM*, *1*(4), 155–165. https://doi.org/10.5281/zenodo.5149807
- Hashmi, K., & Surani, S. (2024). *STEAM education: A pathway to enhance critical thinking in dynamic elementary classrooms. ResearchGate*. https://www.researchgate.net/publication/384202295
- Kang, N.-H. (2019). *A review of the effect of integrated STEM or STEAM education in South Korea. Asia-Pacific Science Education*, *5*(1), 6. https://doi.org/10.1186/s41029-019-0034-y
- Maeda, J. (2013). *STEM + Art = STEAM. The STEAM Journal*, *1*(1). https://doi.org/10.5642/steam.201301.34
- Mertala, P., Fagerlund, J., & Slotte Dufva, T. (2024). *Rethinking the A in STEAM: Insights from and for AI literacy education. arXiv*. https://arxiv.org/abs/2405.18179
- Moon, K. (2020). *A case study of the perceptions of education stakeholders of STEAM integration in a K–8 setting* [Doctoral dissertation, Concordia University]. https://digitalcommons.csp.edu/cup_commons_grad_edd/449
- Moon, S., & Kang, K. (2019). *Trend of STEAM education-related domestic studies focusing on physics-related studies. New Physics: Sae Mulli*, *65*(12), 1199–1208.
- Paik, S.-H., Kim, S.-W., & Lee, Y. (2018). *A study on teachers' practices of STEAM education in Korea. International Journal of Pure and Applied Mathematics*, *118*(19), 2339–236.
- Perignat, E., & Buonincontro, J. (2018). *From STEM to STEAM: Using brain-compatible strategies to integrate the arts. Arts Education Policy Review*, *119*(2). https://doi.org/10.1080/10632913.2017.1300970
- Rafiq-uz-Zaman, M. (2025). *Beyond STEM: A narrative review of STEAM education's impact on creativity and innovation (2020–2025). Inverge Journal of Social Sciences*, *4*(4), 1–16. https://doi.org/10.63544/ijss.v4i4.175
- Singh, M., Azad, I., Qayyoom, M. A., & Khan, T. (2024). *A study on perceptions and practices of STEAM-based education with university students. Social Sciences & Humanities Open*, *10*, 101162. https://doi.org/10.1016/j.ssaho.2024.101162
- UNESCO. (2021). *Reimagining our futures together: A new social contract for education* [Report]. https://www.unesco.org/en/futures-education