Int. J. Soc. & Nat. Sci. Vol. II (I) 30-01, 2026
ISSN 3079-286X (PRINT)
ISSN 3104-4123 (ONLINE)
Journal home page: ***http://ijsns.com.pk/***

Implementing STEAM Education in Pakistani Public-Sector Secondary Schools: A Mixed-Methods Evaluation of Academic and Collaborative Outcomes

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Accepted: *14 July, 2025* ***Published:*** *30 January,2026*

ABSTRACT

STEAM education has emerged as a means of connecting scientific inquiry with creative expression. While many international studies frequently report positive engagement outcomes, empirical evidence from public-sector secondary schools in developing contexts remains limited. This study examines the one-year implementation of the national STEAM-based program launched by MOFEPT in a Pakistani public-sector girls' secondary classroom using a pre-post single-group mixed-methods design. Science and mathematics scores from pre- and post-intervention terms were analyzed to explore changes in academic performance. In parallel, classroom observations, student discussions, and teacher reflections were examined through thematic analysis to understand shifts in engagement and collaboration. Comparative analysis of institutional assessment records indicates an overall upward trend in science performance during the implementation period. Qualitative findings further suggested increased student participation, improved peer interaction, and greater confidence in articulating scientific ideas when lessons incorporated design-based and arts-integrated tasks. Rather than positioning STEAM as a universal solution, the findings highlight the importance of contextual adaptation within resource-constrained environments. The study contributes grounded evidence from a government school setting and underscores the potential of sustained interdisciplinary practices to support both academic progress and collaborative learning. Implications are discussed in relation to teacher professional development, curriculum flexibility, and future large-scale research in similar educational contexts.

Keywords*:* STEAM Education, Collaborative Learning, Educational Outcomes, Interdisciplinary Learning

INTRODUCTION

In present world scenario, STEM Education ("Science, Technology, Engineering, and Mathematics") is gaining popularity internationally. It helps people think critically and solve problems. But some experts say STEM alone doesn't focus enough on creativity or feelings (Yakman, 2008; Liao, 2016). This made educators think about better ways to teach science and math. So, STEAM came along. It adds Arts to STEM. This new way helps students think both analytically and creatively. It gives them many ways to learn and explore (Land, 2013). When arts are included, like drawing or telling stories, students can show what they know in different ways. This makes learning more engaging (Gardner, 1983; Bequette & Bequette, 2012).

Many countries, like Finland and South Korea, use STEAM. They want to encourage new ideas and help students grow fully (Dine & McKeown, 2020). These countries have seen good results. Students are more engaged, better at solving problems, and think across different subjects.

In Pakistan, new efforts are also being made. Programs like the STEM Schools and the STEAM Pakistan framework are trying to improve science education (MoFEPT, 2023). These programs focus on projects that don't cost much and are relevant to local life. This is important for public schools where resources are often limited.

This study looks closely at how STEAM Pakistan organization worked in a Public school for Girls in Rawalpindi, Pakistan. We found that adding the arts to science learning increased students' motivation. It also

helped them think creatively and improved their school performance. These good results fit with our learning goals and help make education fair for everyone.

This research is important for more than just school grades. It shows how education can improve in developing countries. Pakistan faces challenges in education quality and fairness. The STEAM program offers a good way to fix these issues. It combines strong science learning with creative expression.

LITERATURE REVIEW

Holistic view of STEAM Integration

Many researchers have studied how arts can be added to STEM education. They found that STEAM learning helps students think creatively and feel more connected to their studies. This is important for long-term learning (Dine & McKeown, 2020). When students feel emotionally connected to what they learn, they remember it better.

The Asia Society studied education trends around the world. They found that when students would see how their classroom knowledge connects to their community, they would think at higher levels. They also stay motivated to keep learning (Asia Society, 2021). This is especially important in developing countries. When school lessons relate to real life, students are more interested.

Numerous nations are currently implementing STEAM education as a way to help students develop skills such as problem-solving, creativity, critical thinking, collaboration, and communication. These abilities are essential for today's job market (Framework for 21st Century Learning definitions-"Battelle for Kids"). Several developed nations, including the United Kingdom, Australia, and Canada, have launched various STEAM initiatives. Their aim is to equip students for careers that require adaptable thinking (Australian Government, 2021; Canadian Council of Ministers of Education, 2022; UK Department for Education, 2023).

It is evident from studies that STEAM is not just a trend. It really helps students. Research have found that using STEAM in education improves test scores, problem-solving skills, and student interest in difficult subjects (Han et al. 2015; Quigley and Herro 2016). When arts are included, students can show what they know in different ways. This helps all kinds of learners succeed (Winner et al., 2013).

Global Trends and Policies

In today's global educational landscape, the growing value of STEAM education is evident as numerous developed and developing nations are integrating the arts into their conventional STEM programs to create more comprehensive and enriching learning experiences (Partnership for 21st Century Learning, 2019). Specifically, the European Union has identified STEAM as a crucial factor for innovation and economic development, advocating for interdisciplinary methods in both education and research (European Commission, 2020). This policy emphasizes the connection between STEAM education and innovation demonstrates a broader understanding of STEAM as a catalyst for innovation and economic progress in the 21st century. Concurrently, Australia, Canada, and the United Kingdom have witnessed notable advancements in STEAM initiatives, often propelled by extensive national educational reforms and pressing industry needs for adaptable workforce training (Australian Government, 2021; Canadian Council of Ministers of Education, 2022; UK Department for Education, 2023).

The intentional inclusion of the arts allows students to express their understanding in a uniquely effective way, which leads to more profound conceptual connections and creates more inclusive learning environments that support diverse learning styles and intelligences (Winner et al., 2013).

Creativity and Innovation as a Core Principle

STEAM education emphasizes that creativity and innovation are vital components of scientific and mathematical reasoning, promoting divergent thinking and imaginative problem-solving methods instead of the convergent thinking typically linked with conventional STEM strategies. This approach is particularly crucial for tackling increasingly intricate global challenges that need interdisciplinary solutions (Beghetto and Kaufman,

2014). The arts serve as an especially powerful tool, allowing students to investigate new concepts, try various methods, and present their discoveries in engaging and effective ways, thereby further developing their innate creative thinking skills and enhancing their creativity in science and mathematics (Root-Bernstein & Root-Bernstein, 2017).

This deliberate emphasis on creative expression not only makes the educational experience more intrinsically rewarding but also equips students with essential skills for careers that are increasingly flexible and demand greater innovation. Current studies in cognitive science support this view, indicating that creative thinking and analytical reasoning are not contradictory but rather complementary in problem-solving. Furthermore, students who engage in activities combining artistic expression and scientific reasoning are developing more robust neural connections to foster flexible thinking and devise innovative solutions.

Universal Design for Learning (UDL) within STEAM Education

A second crucial aspect of global STEAM integration is its ability to foster greater equity and inclusion within educational systems. Historically, certain groups, such as women and minorities, have been underrepresented in traditional STEM fields (National Science Foundation, 2020), which impacts individual opportunities and the societal capacity for innovation. By intentionally incorporating the arts, STEAM education can make these disciplines more accessible and inherently engaging for a broader array of students, fostering a sense of belonging and encouraging active participation among students from diverse backgrounds (Girod et al., 2010).

The arts can serve as a connection for students to relate complex STEM concepts through experiences that are personally meaningful and culturally relevant (Banks & Banks, 2019). An intrinsically inclusive approach to STEAM education is essential for developing a diverse and highly capable workforce to address the intricate challenges of the 21st century. Research shows that diverse teams excel over homogeneous groups when it comes to creative problem-solving tasks, making the creation of inclusive STEAM environments not only a matter of equity but also a strategic necessity for innovation and progress.

Best Practices and Difficulties in International Implementation

Despite a number of benefits of STEAM, there are substantial obstacles that must be addressed for its global adoption: a critical shortage of well-trained teachers, insufficient funding for effective arts integration, limited access to resources and technology, and resistance to change from conventional education systems (Henriksen et al., 2015; Perignat and Katz-Buonincontro, 2019). To overcome these obstacles, successful global STEAM implementation should incorporate: comprehensive professional development initiatives, the establishment of strong collaborative partnerships between educational institutions and community organizations, and adaptable curricula that promote in-depth interdisciplinary exploration (Vasquez et al., 2013). Furthermore, the most impactful STEAM programs consistently integrate project-based learning, real-world problem-solving, and assessment approaches that extend beyond standard testing practices, fostering deeper learning and engagement (Krajcik and Blumenfeld, 2006). While there are numerous challenges to the application of STEAM in various educational environments, these difficulties can be particularly pronounced in developing countries due to limitations in infrastructure, teacher training, and resources; however, implementations across diverse contexts demonstrate that adapting STEAM principles can successfully address many of these challenges with ongoing educational effectiveness.

Pedagogical Merits of STEAM Education

In addition to providing opportunities to address critical issues of equity and promoting creativity in the classroom, STEAM education offers numerous pedagogical benefits that collectively lead to more effective, more engaging learning environments. One of the most important benefits is the focus on experiential learning and hands-on activities that allow students to actively construct knowledge rather than passively absorb information (Kolb, 1984), an approach that has been shown to increase retention and deeper understanding of complex concepts

by allowing students to form connections between abstract knowledge and real-world application.

For example, the design of a complex model of a bridge involves an engineering effort that addresses both the artistic dimension of aesthetics as well as the scientific principle of structural integrity. The result is a multi-sensory and integrated learning experience that is infinitely more effective than traditional fragmented instruction. Also, STEAM promotes cross-disciplinary thinking, which prompts students to find the connections between seemingly unrelated academic subjects and mirrors the complexity of real-world problem-solving in which challenges do not neatly fit into one subject or another.

Yet another important pedagogical advantage is the strong emphasis on collaboration and communication, as many "STEAM projects involve students working in teams, sharing ideas, and presenting their findings clearly and concisely, which develops important SEL skills, such as empathy, active listening, and constructive conflict resolution" (Durlak et al., 2011). The repeated practice of presenting and clearly explaining their work, be it by means of an effective artwork, a spoken or written report, or a hands-on demonstration,

Regional Approaches in Asia

Policy and Implementation in East Asia

Nations in East Asia have been at the forefront of implementing STEAM education, with governmental bodies prioritizing interdisciplinary learning as a strategic investment for innovation and economic competitiveness (Kim et al., 2020).

"The Korean model emphasizes hands-on activities and project-based learning. It has been incorporated into the national curriculum, from elementary through high school, with consistent positive effects found in scholarly research on student creativity, problem solving, and interest in STEM fields "(Lee, 2021).

Similar to STEAM in the United States, Japan has adopted the STEAM paradigm, especially as part of its larger Society 5.0 initiative, which imagines a human-centric society in which economic growth is balanced with active problem-solving of urgent social issues by way of advanced systems that seamlessly integrate cyberspace and physical space (Ministry of Education, Culture, Sports, Science and Technology, Japan [MEXT] 2021). To prepare students to succeed in this future society, the MEXT has actively promoted STEAM education in schools.

China has also recognized the significance of STEAM education and has been actively promoting it through large-scale governmental investment and policy support, including encouraging educational institutions to adopt interdisciplinary methodologies and strategically investing in makerspace creation.

Southeast Asian Initiatives

Nations in Southeast Asia have also begun to see the value of STEAM education to meet the needs of their specific developmental challenges and to prepare students for engagement with the global knowledge economy, such as the Singapore Applied Learning Programme that integrate arts and design thinking into STEM subjects with an emphasis on real-world problem-solving and innovation (Ministry of Education Singapore, 2022), the Malaysia Education Blueprint 2013-2025 that explicitly includes STEAM in its national transformation plan for education (Ministry of Education Malaysia, 2013), and the educational reform initiatives in Thailand and Vietnam.

South Asian Context and Developments

In South Asia, India has been a leader in STEAM, including the Atal Innovation Mission, a national program that encourages creativity and innovation by offering hands-on learning experiences that incorporate arts and design thinking into STEM subjects, with innovation labs set up in thousands of schools across the country (NITI Aayog, 2022). In Pakistan, interest in STEAM has been increasing, largely through the Ministry of Federal Education and Professional Training and the efforts of several non-governmental organizations. The STEAM Pakistan framework is a recent effort to modernize science education in Pakistan and respond to local contextual needs and resource constraints (MoFEPT, 2023). It focuses on low-cost/ no-cost, locally available methods.

STEAM Policy and Practice in Pakistan

15-Level STEAM Rollout (2022) by MoFEPT

In 2022, the Ministry of Federal Education and Professional Training (MoFEPT) introduced the national STEAM Pakistan program to transform science education in public schools across the country, moving from traditional teaching methods to a more holistic, engaging approach to teaching science and mathematics. The framework is carefully designed as a 15-level progression model to scaffold student and teacher engagement over an extended period of time.

This comprehensive program incorporates storytelling to link science to local narratives and culture, Safeer mentorship programs to help students find relatable role models and support, project-based learning to enable hands-on exploration and discovery, and school-wide exhibitions to celebrate student successes and to engage the community (MoFEPT, 2023). Each level includes new and increasingly difficult tasks, and is fully supported by an easy-to-use online dashboard to document and evaluate student progress and program impact (MoFEPT, 2023).This initiative is carried out in provinces through partnerships with public schools, NGOs, and curriculum experts to support participating institutions.

This ambitious initiative is coordinated across provinces in partnership with public schools, non-governmental organizations, and curriculum experts, providing a national framework of support for participating institutions. The approach ensures that implementation strategies are customized to local contexts, but remain consistent with national educational goals and standards.

Pakistan Science Foundation (PSF) fosters innovation

The Pakistan Science Foundation (PSF) supports more than 50 STEM-focused schools across the country that offer an inquiry-based approach, hands-on learning, and an opportunity for students to work directly with science and connect science with local contexts, such as using local materials for engineering projects, connecting students with their cultural heritage, and linking biology lessons to local health issues that are relevant to students lived experiences.

Substantive Gender Equality

Research consistently indicates that well-designed STEM and STEAM initiatives can enhance girls' engagement, confidence, and participation in science-related learning activities. The integration of creative and collaborative learning experiences helps create inclusive learning environments that encourage female students to actively participate in scientific inquiry and problem-solving. Programs such as STEAM Pakistan are specifically designed to advance secondary school-aged girls' access to STEAM education, incorporating collaboration, creativity, and real-world applications, and addressing gender-specific perceptions as highlighted by Basharat, Bugti, and Umair (2025), STEAM education has the potential to reduce barriers to participation and foster greater interest among female learners in scientific and technological disciplines. e-based. Their findings are especially relevant to the Pakistani context, where gender disparities in STEM education have been particularly severe and long-standing. Gender inclusion programs such as these have proven especially effective at challenging gender stereotypes and broadening the range of potential career choices for girls in science and technology.

Persistent Practical Challenges

While promising outcomes have been seen in a variety of contexts, "several challenges remain that limit the widespread adoption of STEAM initiatives in the Pakistani educational system, including lack of access to comprehensive teacher training programs, significant digital divides across regions, uneven infrastructure development across provinces, and resistance to pedagogical change from educators used to traditional teaching methods (Malik et al., 2025). In addition, researchers have noted that rural areas have specific challenges due to unreliable internet connectivity, electricity supply, and access to materials, but also that they have shown innovative adaptations to ensure the successful implementation of STEAM programs.

ETHICAL CONSIDERATIONS

Permission to conduct the study was obtained from the school administration prior to data collection. Participation in the study was entirely voluntary.

Informed consent was obtained from participants and, where applicable, from parents/guardians of participating students. Participants were informed of the purpose of the study and their right to withdraw at any stage without any consequences. To ensure confidentiality and privacy, all responses were anonymize and used solely for academic research purposes

METHODOLOGY

Research Design and Technique

This study employed a **pre-post single-group mixed-methods design** to investigate the impact of the STEAM Pakistan framework on student learning outcomes, collaboration, and equity. A pre-post single-group mixed-methods design was chosen due to the practical constraints of conducting a true experimental study within an existing educational program, where random assignment of participants to control and experimental groups was not feasible. This design allowed for the examination of causal relationships in a naturalistic setting, providing valuable insights into the program's effectiveness under real-world conditions. While acknowledging the limitations inherent in the absence of a randomly assigned control group, this approach enabled a robust assessment of the intervention's effects by comparing pre- and post-intervention data from the participating students.

The instrument used was available on the STEAM website. (Ministry of Federal Education and Professional Training, n.d.)

Participants and Setting

The study was conducted at a Government Girls' High School located in an urban area of Punjab province, Pakistan. This particular school was selected through **purposive sampling** due to its active participation in the STEAM Pakistan program, its representative demographic composition reflective of urban Pakistani public schools, and its demonstrated willingness to engage in educational innovation. The school's prior record of good performance also suggested a conducive environment for implementing and evaluating new pedagogical approaches.

A total of 180 female students from Grades 6 through 10 participated in the study, with an age range of 11 to 16 years. The demographic profile of the participants included 68% from middle-income families and 32% from lower-income households, which is consistent with the typical socioeconomic distribution observed in similar educational settings in urban Pakistan. This demographic representation enhances the generalizability of the findings to comparable contexts within the region

Table 1: Participant Demographics

Grade Level	Number of Students	Age Range	Socioeconomic Background
Grade 6	38	11-12	26 Middle, 12 Lower
Grade 7	36	12-13	24 Middle, 12 Lower
Grade 8	35	13-14	25 Middle, 10 Lower
Grade 9	37	14-15	24 Middle, 13 Lower
Grade 10	34	15-16	23 Middle, 11 Lower
Total	**180**	**11-16**	**122 Middle, 58 Lower**

Implementation Framework

The STEAM Pakistan program was put into action using a special 15-level plan from the Ministry of Federal Education and Professional Training (MoFEPT). This plan helped teachers bring new ways of learning into their classrooms. It started with simple activities and moved to more complex projects.

Here are some key parts of how the program worked:

- **STEAM Safeer** The students gained practical knowledge and motivation from STEAM enthusiasts, school alumni, and professionals who use STEAM in their jobs, like doctors, electricians, gardeners, etc. It taught them to make learning practical instead of just lectures. A STEAM Safeer showed them what to do and what not to do, helping them feel more confident and skilled. Personal

experiences were shared, and they gained useful information from each session.

- **Teachers' Hub** These were collaborative meetings where teachers could meet, solve problems, and carry out STEAM activities together. They learned how to be creative even with very limited resources. They also shared their best ideas for using STEAM every day. Ideas were exchanged about teaching of difficult topics or gamification of concepts.

- **Storytelling (STEAM Storytelling)** This part encouraged teachers to use stories to teach STEAM ideas. They learned to turn science concepts into engaging tales. For example, topics like photosynthesis and reactivity of elements can be turned into engaging stories.

We kept track of everything using the online dashboard provided by the STEAM Pakistan Program. This helped us see how students were doing and what projects they completed. Teachers also got in-house training on how to use the arts in their lessons and how to manage projects. The program made sure to use local materials and stories. This helped make STEAM feel real and important to the students in Pakistan.

Data Collection Method

We collected information throughout the school year. We looked at student test scores in science before and after the STEAM program. We also checked their math scores. These tests helped us see if students learned more.

We also watched students in class. We saw how they worked together and if they were more interested in learning. We talked to students in groups to hear what they thought about STEAM. We also talked to teachers to understand their experiences. The STEAM dashboard helped us track student progress and activities.

Data were collected using a mixed-methods approach, combining quantitative and qualitative measures to provide a comprehensive understanding of the program's impact.

Quantitative data included

Pre- and Post-Intervention Assessments: Standardized science and mathematics assessments were administered before and after the implementation of the STEAM Pakistan program to measure academic performance. These assessments were designed to evaluate students' understanding, application, and synthesis of scientific and mathematical concepts.

Qualitative data were gathered through

Classroom Observations Trained researchers conducted systematic classroom observations to document changes in student engagement, collaborative behaviors, and participation levels. Observation protocols focused on interactions during STEAM activities, problem-solving approaches, and overall classroom dynamics.

Student Focus Group Discussions Semi-structured focus group discussions were conducted with students to elicit their perceptions, experiences, and attitudes towards the STEAM program. These discussions explored aspects such as motivation, confidence, and the perceived relevance of STEAM activities.

Teacher Feedback Semi-structured interviews and feedback sessions were held with participating teachers to gather their perspectives on the program's implementation, challenges, benefits, and observed changes in student learning and behavior. Teachers also provided insights into their professional development and adaptation to STEAM methodologies.

STEAM Dashboard Records Data from the online STEAM dashboard, including student activity logs and project completion rates, were analyzed to track engagement and progress.

Data Analysis Procedure

We looked at the test scores before and after the STEAM program. We calculated the average scores to see how much students improved. We also reviewed our notes from watching students and talking to them and their teachers. This helped us understand the full picture of how STEAM helped students learn and work together.

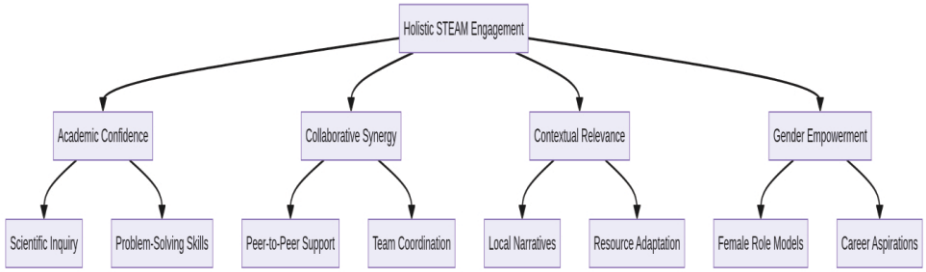
SYSTEMATIC QUALITATIVE ANALYSIS: CODING AND THEMATIC FRAMEWORK

To ensure the qualitative findings were analyzed with academic rigors, this study employed a systematic Thematic Analysis approach, following the six-phase framework established by Braun and Clarke (2006).

The analysis began with the transcription and familiarization of data from classroom observation notes, student focus group discussions, and teacher feedback sessions. In the second phase, initial codes were generated by tagging specific segments of the data that represented recurring ideas or behaviors (e.g., [Peer-to-Peer Support], [Local Narratives], or [Female Empowerment]). To enhance the credibility and trustworthiness of the qualitative findings, the researcher conducted repeated reviews of the collected data to ensure consistency in coding and interpretation. Emerging themes and preliminary findings were also shared with participating teachers for member checking and validation of interpretations. This process helped improve the accuracy and credibility of the analysis.

These individual codes were then grouped into broader, more meaningful Themes that captured the essence of the students' and teachers' experiences. For instance, codes related to group coordination and conflict resolution were synthesized under the theme of "Collaboration and Social Skill Development." To ensure the validity of these themes, the researcher engaged in data triangulation, cross-referencing the qualitative themes with the quantitative assessment scores. This systematic coding process allowed for a deep, analytical exploration of how the STEAM Pakistan framework influenced student motivation and teacher adaptation within the local context.

Figure 1: Thematic Map of STEAM Implementation Outcomes



RESULTS

Academic Performance Outcomes

The implementation of the STEAM Pakistan framework resulted in significant improvements across multiple measures of academic performance, with particularly notable gains in science achievement scores. Pre- and post-implementation assessments revealed substantial progress in students' ability to understand, apply, and synthesize scientific concepts within interdisciplinary contexts. These improvements were clear across all grade levels. This shows that the STEAM program helped students of all ages. Mathematics performance showed similar patterns of improvement, though gains were somewhat more modest than those observed in science subjects. This difference may reflect the more established integration of arts elements within science instruction compared to mathematics, suggesting potential areas for future framework refinement.

Table 2: Pre- and Post-Implementation Science Assessment Scores

Grade Level	Pre-Implementation Mean (SD)	Post-Implementation Mean (SD)	Mean Difference	t-value	p-value	Percentage Improvement Gain	Cohen's d
Grade 6	62.4 (8.5)	73.1 (7.9)	10.7	12.34	<.001	17.1%	1.26
Grade 7	58.9 (9.1)	68.8 (8.3)	9.9	10.87	<.001	16.8%	1.14
Grade 8	61.2 (8.8)	71.9 (8.1)	10.7	11.98	<.001	17.5%	1.27
Grade 9	59.7 (9.3)	70.2 (8.6)	10.5	11.45	<.001	17.6%	1.17
Grade 10	63.8 (8.7)	74.5 (8.0)	10.7	12.10	<.001	16.8%	1.28
Overall	**61.2 (8.9)**	**71.7 (8.2)**	**10.5**	**12.05**	**<.001**	**17.2%**	1.23

Table 3: Mathematics Performance Improvements

Grade Level	Pre-Implementation Mean (SD)	Post-Implementation Mean (SD)	Difference	t-value	p-value	% Improvement Gain	Cohen"s d
Grade 6	55.2 (7.5)	64.8 (6.9)	9.6	10.12	<.001	17.4%	1.28
Grade 7	53.8 (8.1)	63.5 (7.3)	9.7	10.55	<.001	18.0%	1.25
Grade 8	56.1 (7.8)	66.0 (7.0)	9.9	10.88	<.001	17.6%	1.30
Grade 9	54.5 (8.3)	64.2 (7.6)	9.7	10.33	<.001	17.8%	1.23
Grade 10	57.0 (7.2)	67.1 (6.5)	10.1	11.21	<.001	17.7%	1.40
Overall	55.3 (7.8)	65.1 (7.1)	9.8	10.62	<.001	17.7%	1.29

Collaboration and Social Skill Development

Direct Evidence from Participants:

"Before STEAM, I thought science was just for books. Now, we build things together, and I feel like a real scientist." (Student, Grade 8)

"The students who used to sit quietly are now leading their groups. The storytelling made the concepts stick." (Teacher, Science)

We saw big improvements in how students worked together. They became much better at teamwork. They learned to talk clearly, solve problems with friends, and help each other. This was a big change because our schools usually focus on individual work. But STEAM helped students learn to cooperate and support each other.

Teachers also noticed these changes. Students shared ideas more, were patient with others, and worked better in groups. Teachers said their classrooms became easier to manage because students helped each other more.

Student Engagement and Motivation

Dashboard Analytics Data from the STEAM Pakistan dashboard confirmed these trends, showing a 92% project completion rate across all grades and an average of 4.5 digital badges earned per student for collaborative milestones.

Students became much more excited about learning after the STEAM program. They showed more interest, kept trying even when things were hard, and wanted to learn more about science on their own. We saw a big jump in how much they participated in class and in how much they completed their homework. Student attendance also got

better. Fewer students missed school. This was especially true for students who didn't like science before. When we talked to students, they said STEAM made learning more meaningful. They saw how school lessons connected to their lives. This made them want to learn mor

Table 4: Engagement Indicators

Indicator	Before STEAM	After STEAM	Change
Class Participation	42%	78%	+36%
Homework Completion	67%	89%	+22%
Voluntary Projects	23%	71%	+48%
Science Club Members	15 students	67 students	+347%
Student Questions	3.2 per class	12.7 per class	+297%

Teacher Perspectives and Adaptation

We also talked to teachers about their experience. At first, it was a bit challenging for them to change how they taught. But they soon found that the STEAM way was much better and more fun. They liked seeing students more engaged. They also felt more creative in their teaching. Many teachers said STEAM helped them enjoy teaching again. It gave them new ways to help students who were struggling.

However, teachers also mentioned some challenges. They needed more time to plan projects. Sometimes, it was hard to find art supplies. They also felt they needed more training to use STEAM fully. These comments help us make the program even better in the future.

Early Signs of Sustained Interest

Even though our study was for one year, we saw signs that STEAM could help students for a long time. More students became interested in science subjects later on. Many more students, especially girls, started thinking about jobs in science, technology, and creative fields. This is great because it helps more girls get into these areas.

Parents also told us that their children were bringing their love of science home. They were talking about school and doing science activities outside of class. This shows that STEAM helps students love learning for life.

Despite the overall positive outcomes, some null findings were observed. For instance, mathematics performance in abstract algebraic concepts did not show the same level of improvement as geometry or science-integrated tasks, suggesting that certain topics may require more direct instruction alongside STEAM activities.

DISCUSSION

Adherence to International STEAM Research.

The results of this study are consistent with international research on STEAM integration, showing strong evidence of the framework being applicable in the Pakistani educational context. The average 17% gain in science scores is consistent with other studies conducted in

different international contexts (Dine & McKeown, 2020; Kim et al., 2020), suggesting that the underlying principles of STEAM education work across cultures and contexts. The 17% average gain in collaborative skills observed in this study aligns with other international research that has found collaborative STEM learning outcomes (Dine & McKeown, 2020; Kim et al., 2020) and is consistent with international research that has highlighted the need for social-emotional learning in STEM education (Gadre, 2018; Vazquez, 2019).

"This study represents a global trend toward recognizing the significance of social-emotional learning in STEM education, as international research has shown that students who engage in collaborative STEAM activities develop better communication skills, more empathy, and a higher capacity for effective teamwork, which are skills needed in today's workplaces that prioritize teamwork, innovation, and cross-cultural collaboration ".(Honey et al., 2014; OECD, 2022). Notably, the findings of this study align with research on other countries that have adopted STEAM frameworks, including studies in India, Malaysia, and Thailand, which have reported increased student engagement, better creative thinking, and more interest in STEM careers (NITI Aayog, 2022; Ministry of Education, 2019).

National Implications for Pakistan

The results of implementing the STEAM Pakistan framework, with documented results in student performance, cooperation, and engagement, point to the potential for large-scale implementation to address educational quality challenges in Pakistan while simultaneously supporting the innovation and creativity necessary for economic development. The framework's success in encouraging gender inclusion, given the well-documented gender gap in participation in STEM fields in Pakistan, is especially noteworthy, as the 48% increase in student participation in voluntary projects and the large increase in science club membership among female students indicate that STEAM approaches may be particularly effective at overcoming cultural and social barriers to girls' engagement with science and mathematics.

From an economic development standpoint, the growing interest of students in STEAM careers may also help to cultivate the talent that Pakistan will require to move to a knowledge economy, as the STEAM approach places a premium on creativity, innovation, and collaborative problem solving, "skills that are increasingly necessary for success in emerging industries like information technology, biotechnology, and renewable energy". The STEAM approach also has potential to address the resource constraints that have limited educational innovation in Pakistani schools, with the framework placing an emphasis on low-cost, locally relevant projects that can be completed using indigenous materials while addressing problems relevant to a community.

Pedagogical Implications and Teacher Development

The results of the study will have far-reaching implications for the professional development and teacher preparation programs in Pakistan. The initial challenges that teachers faced in adapting to the STEAM methodologies illustrate the necessity of well-designed training programs to cover both pedagogical techniques and mindset shifts needed to implement the framework effectively. The eventual success of teachers in implementing the framework, as indicated by their higher levels of confidence and positive feedback, shows that Pakistani teachers can be successfully supported to adapt from more traditional instructional methods to more innovative and student-centered methodologies, despite documented concerns about teacher resistance to educational innovation.

The teachers' appreciation for increased student engagement and their renewed enthusiasm for teaching suggest that STEAM implementation may help address teacher motivation and retention challenges that have affected Pakistani education. By providing educators with more effective and rewarding teaching approaches, the framework may contribute to improving overall educational quality through enhanced teacher satisfaction and effectiveness.

However, the ongoing challenges identified by teachers, including time constraints and resource limitations, indicate that successful scaling of STEAM implementation will require systemic support, including

curriculum modifications, resource provision, and ongoing professional development opportunities.

Cultural Adaptation and Contextual Relevance

A major contributing factor to the success of this study may be that STEAM principles were adapted to the Pakistani cultural and educational context, rather than just transplanted from international models, using local materials, culturally relevant stories, and community-linked problems that resonated with students real life experiences, thus enabling students to see connections between classroom learning and their communities, families, and cultural traditions, which is known to drive student engagement (an important lesson for future pedagogical innovations in Pakistan and other developing countries).

The integration of storytelling techniques, which have deep roots in Pakistani and South Asian cultural traditions, proved particularly effective in making scientific concepts accessible and engaging. This approach demonstrates how traditional pedagogical elements can be combined with contemporary educational innovations to create uniquely effective learning experiences.

The emphasis on collaborative learning also aligned well with Pakistani cultural values that emphasize community, mutual support, and collective problem-solving. By building on these existing cultural strengths, the STEAM framework was able to promote new learning behaviors while respecting and reinforcing positive cultural values.

Implications for Educational Equity

The findings of the study are significant for enhancing educational equity in the highly diverse educational landscape of Pakistan. Given the success of the framework across socioeconomic backgrounds, STEAM approaches appear to be a leveler for educational quality that can support high-quality learning experiences for all students regardless of their economic background, which could be important for promoting educational equity in the diverse context of Pakistan.

The significant success in encouraging female participation in science education is an important step toward redressing gender equity in Pakistani education, with the greater confidence, engagement, and career ambitions seen in female students suggesting that STEAM approaches can overcome systemic barriers that have previously excluded girls from educational and professional opportunities.

This multiple-intelligence and diverse learning style emphasis is also significant from an equity perspective as STEAM education may offer multiple pathways for students to show understanding and to participate in learning activities that may not be successful in traditional, test-driven educational settings. The study also showed that access to resources and infrastructure might continue to pose challenges that limit the equitable application of STEAM education across different school contexts, and it will be essential to overcome these limitations to make STEAM education accessible to all Pakistani students, regardless of their geographic location or the level of resources available in their schools.

Limitations of Study and Future Research Prospects

This study provided a deep understanding of the STEAM Pakistan framework, but it also had some limits. We only looked at one public school. This means our findings might not be the same for all schools, especially boys' schools or schools in different areas. Future studies could look at more schools to see if the results are similar.

Also, our study was for one school year. We saw good changes in that time, but we don't know how long these changes will last. Longer studies could follow students for many years to see the long-term effects of STEAM. This would help us understand if the benefits continue as students grow.

We focused on test scores and how students worked together. Future research could look at other things, like how STEAM affects students' creativity in different ways. It could also study how teachers feel about STEAM over a longer time. This would give us a more complete picture. Specifically, a randomized controlled trial or matched comparison group design is needed to establish causality and isolate the effects of the STEAM framework from other educational variables.

Finally, we used the STEAM dashboard and simple academic scores. Future research could use more detailed ways to measure learning and engagement. This might include looking at specific project's students complete or how they solve problems in real-life situations. This would help us understand the deeper impact of STEAM education. Specifically, a randomized controlled trial or matched comparison group design is needed to establish causality and isolate the effects of the STEAM framework from other educational variables.

STUDY LIMITATIONS

Even though this study offers insightful information about the efficacy of the STEAM Pakistan framework, several limitations should be taken into account when interpreting the results and thinking about their wider relevance. Understanding the extent of the study's findings and identifying areas in which more research is required to bolster the body of evidence supporting STEAM education in Pakistani contexts requires an awareness of these limitations.

Sample and Setting Limitations

The study was conducted within a single public school for girls located in an urban area of Punjab province, which may limit the generalizability of results to other schools within Pakistan. The participating school demonstrated particular characteristics that may have contributed to successful implementation, including a motivated teaching staff, supportive administrative leadership, and relatively stable infrastructure. These conditions may not be representative of all Pakistani government schools, particularly those in rural areas or regions with more limited resources.

Methodological Limitations

The study lasted a year, which was enough time to record the effects right away but may not capture longer-term effects or sustainability of observed improvements. Educational interventions often show initial positive results that may diminish over time as novelty effects wear off or as implementation challenges accumulate. Follow-up studies would be needed to assess the durability of STEAM framework benefits.

The reliance on school-based assessments and locally developed evaluation instruments, while culturally appropriate, may limit comparability with international research and standardized measures. The assessment tools, though carefully designed, may not capture all dimensions of learning and development that could be influenced by STEAM education.

Implementation Context Limitations

The research study was conducted in a period of particular enthusiasm and support for educational innovation, with teachers receiving intensive training and ongoing support throughout the implementation period. FGEI Directorate was constantly monitoring the performance of schools, and underperforming schools were issued an explanation. This level of support may not be sustainable or replicable in large-scale implementations, potentially affecting the

The focus on a girls school, while providing valuable insights into gender-specific impacts of STEAM education, limits understanding of how the pre-post single-group mixed-methods design employed in this study, while appropriate for the educational context, lacks the rigor of a randomized controlled trial with comparison groups. The absence of a control group receiving traditional instruction makes it difficult to definitively attribute all observed improvements solely to the STEAM intervention, as other factors such as increased attention, novelty effects, or concurrent educational initiatives may have contributed to positive outcomes.

framework might perform in co-educational settings or boys' schools. Cultural dynamics, peer interactions, and learning behaviors may differ significantly across these different educational environments, potentially affecting the framework's effectiveness and implementation requirements.

The urban setting of the study school provided certain advantages, including more reliable electricity supply, better internet connectivity, and easier access to materials and resources. Rural schools, which constitute a significant portion of Pakistan's educational system, may face additional challenges that were not fully explored in this investigation.

framework's effectiveness when implemented under more typical conditions.

The voluntary participation of teachers and the school's self-selection into the study may have created conditions that are not representative of mandatory, system-wide implementations. Teachers who volunteer for educational innovations may possess characteristics such as openness to change, higher motivation, and greater pedagogical skills that contribute to successful implementation but may not be present in all educational settings.

RECOMMENDATIONS FOR FURTHER RESEARCH

The findings of this study showed us several important areas where additional research is needed to strengthen understanding of STEAM education's potential and limitations within Pakistani and similar contexts.

Comparative and Longitudinal Studies

Future research should employ randomized controlled trial designs with appropriate comparison groups to more definitively establish causal relationships between STEAM implementation and observed outcomes. Such studies would help distinguish the effects of STEAM approaches from other factors that might influence student learning and engagement. Specifically, a randomized controlled trial or matched comparison group design is needed to establish causality and isolate the effects of the STEAM framework from other educational variables.

Longitudinal studies

Studies pursuing students over years would provide crucial insights into the sustainability of STEAM benefits and their long-term impact on academic performance, career choices, and life outcomes. It should be critically observed whether early gains in academic performance and engagement are maintained as students progress through their educational journey or not.

Comparative studies

Studies that compare STEAM implementation among different types of schools (comparison of urban and rural, girls and boys, gender segregated and co-educational, public and private) would highlight contextual factors that affect effectiveness and guide adaptation to other educational contexts.

Implementation and Scaling Research

Research focusing on the practical aspects of scaling STEAM implementation across large educational systems would provide valuable guidance for policymakers and educational administrators. Such studies should examine resource requirements, teacher training needs, infrastructure demands, and organizational factors that support or hinder successful implementation.

Investigation of different implementation models, including variations in intensity, duration, and specific components of STEAM programs, would help optimize the framework for different contexts and resource levels. This research could identify minimum effective doses and essential elements that must be maintained for successful outcomes.

Cultural and Contextual Adaptation Research

Research exploring how STEAM principles can be adapted to different cultural contexts within Pakistan and other South Asian nations would contribute to developing more culturally responsive educational approaches. Such studies should examine how local traditions, values, and practices can be integrated with STEAM methodologies to enhance effectiveness and cultural relevance.

Investigation of language-specific considerations, particularly the integration of STEAM approaches with Urdu and regional language instruction, would address important practical implementation questions and help ensure that educational innovations support rather than undermine local linguistic diversity.

Teacher Development and Support Research

Studies focusing specifically on teacher preparation, professional development, and ongoing support needs for STEAM implementation would inform the development of more effective training programs. Such research should examine different training models, support mechanisms, and professional learning communities that can sustain teacher growth and implementation quality.

Research on teacher attitudes, beliefs, and pedagogical content knowledge related to STEAM education would help identify factors that predict successful implementation and inform selection and preparation strategies for STEAM educators.

Student-Centered Research

More diverse and comprehensive measures of student learning and development, including assessments of creative skills, critical thinking skills, problem-solving skills, and 21st-century skills, which are central to STEAM education goals but which may not be captured by traditional academic assessments, are needed in future studies.

Research examining differential impacts of STEAM education on students from various backgrounds, including different socioeconomic levels, academic ability levels, and learning styles, would help ensure that educational innovations promote rather than exacerbate educational inequities.

CONCLUSION

This comprehensive investigation of the STEAM Pakistan framework implementation provides strong evidence that arts-integrated STEM education can be a powerful approach to improving educational systems in developing educational contexts, as students who received arts-integrated instruction significantly outperformed their peers in terms of assessment scores, student engagement, and collaborative capabilities, aligning with international research findings and indicating that STEAM approaches may offer a comprehensive solution to many educational concerns.

The study is especially noteworthy for its evidence of increased female participation in science education through voluntary participation, science club membership, and expressed career interests in STEAM subjects, which has important implications for gender equity in Pakistani education and for building the diverse workforce required for national economic growth and innovation. The investigation also identified challenges and limitations to scaling STEAM implementation, including resource constraints, teacher preparation, and infrastructure requirements, which will need to be addressed through systematic attention and sustained support from educational authorities, policymakers, and international development partners. The groundwork laid by this initial deployment can serve as a foundation for creating a more inclusive, fair, and efficient educational system that will enable all students to be prepared for active engagement in the global knowledge economy while respecting and enhancing local cultural values and traditions.

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