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Teacher Awareness and Classroom Implementation of STEM and STEAM Teaching Strategies in Pakistani Secondary Schools

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Abstract

This study examines current teaching strategies for STEM and STEAM education in Pakistani secondary schools, focusing specifically on the gap between teacher awareness and classroom implementation. A quantitative descriptive survey was conducted with 341 STEM/STEAM-engaged teachers (EST Science and SST Science) across Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan. A validated structured questionnaire measured awareness and implementation of twelve teaching strategies using a three-point dual rating scale. Data were analyzed using descriptive statistics, paired t-tests, one-way ANOVA, and independent t-tests. Traditional teacher-centered strategies (lecture, textbook, question-answer) were fully implemented ($M > 2.50$), while innovative STEM/STEAM strategies showed critically low implementation: inquiry-based learning ($M = 1.68$), project-based learning ($M = 1.59$), technology integration ($M = 1.76$), and arts integration ($M = 1.45$). Paired t-tests revealed statistically significant awareness-implementation gaps for all twelve strategies ($p < .001$), with largest gaps for collaborative learning ($\Delta M = 0.53$, $d = 0.67$) and hands-on laboratory work ($\Delta M = 0.53$, $d = 0.65$). Significant provincial disparities placed Baluchistan behind Punjab, and SST teachers outperformed EST teachers on innovative strategies. This is the first four-province empirical study to systematically measure the awareness-implementation gap in STEM/STEAM teaching strategies in Pakistan, providing evidence that policy awareness has not translated into classroom practice and identifying specific leverage points for reform.

Keywords: STEM Education, STEAM Education, Teaching Strategies, Teacher Awareness, Implementation Gap, Secondary School, Pakistan

Introduction

The teaching and learning of STEM and STEAM are crucial in today's education to push students beyond memorisation to the realm of practical thinking. STEM is the integration of the fields of Science, Technology, Engineering and Mathematics and STEAM incorporates Arts for creativity, design thinking, communication and innovation (Dare et al., 2021; Yakman & Lee, 2012). These are all significant because today's students require more than just knowledge of the books. They must be able to ask questions, problem solve, collaborate in teams, utilize technology and apply classroom concepts to real world situations (Freeman et al., 2019). The significant value of STEM and STEAM education at secondary school level is that it is from this stage that students start to make the decision on whether they would like to pursue a career in science, maths, technology, engineering, medical or technical (Khattak, 2012).

At the national level, there are initiatives that have been taken up in Pakistan that have caught the attention of STEM and STEAM education, including the STEM education project and the STEAM Pakistan programme. The activities are designed to enhance science and mathematics teaching and learning by means of activity-based learning, inquiry learning, experiments, STEAM club, teacher support and classroom activities (STEAM Pakistan, 2023). By October–November 2023, 1,416 government schools, 79 districts, 122,310 students, 670 STEAM clubs, and 5,716 teachers across Pakistan had engaged in the programme (STEAM Pakistan, 2023). These figures indicate that Pakistan has begun to take steps towards embedding STEM and STEAM education into the

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institutional fabric. But the question is: Do these ideas actually get used in secondary schools appropriately?

The introduction of STEM and STEAM education has been made, however, many secondary schools in Pakistan continue to rely on traditional methods of instruction. Lecture teaching, classroom explanation of books, board writing and question-and-answer sessions are often used in the classroom. Although these are common and familiar, they are not completely conducive to inquiry, creativity, project work, experiments and problem-solving (Aslam et al., 2022; Sahito, 2024). The other major problems of the many schools are inadequate laboratories, shortage of science books, lack of adequate internet and science equipments, large classes, hurry to complete the syllabus, examination system that emphasizes memorization of answers (Saleem, 2025). Recognizing these issues, teachers might know about STEM and STEAM strategies, but may not be able to effectively implement them in the classroom.

A key challenge in STEM and STEAM education is the disconnect between teacher awareness and classroom practice. Awareness is when teachers are aware of a teaching strategy and implementation is when they actually apply this strategy in their classroom practice. These are pedagogical strategies that a teacher may be familiar with, but does not necessarily employ regularly, such as inquiry-based learning, project-based learning, collaborative learning, technology-integrated lessons, hands-on laboratory work, formative assessment, and arts integration (Rogers, 2003; Shulman, 1986). This is significant because, if teacher training and teacher awareness are not translated into actual classroom practice, they will have no impact on learning. It is important to consider both teacher knowledge and teacher action in the content area.

While there are several studies on STEM and STEAM education in Pakistan, these studies have been mainly on policy issues, teacher preparedness, resource issues, gender issues and awareness. Very little research has, however, focused specifically on what secondary school teachers are currently doing for STEM and STEAM education. More importantly,

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studies to date have failed to clearly examine the discrepancies between teachers' knowledge of STEM/STEAM strategies and their actual use in the classroom. Hence, this study is aimed at filling this gap by analyzing the awareness–implementation gap of secondary schools in Pakistan regarding the awareness of teachers about the strategies and their utilization of the strategies, and location of the gap between the two.

The incorporation of STEM and STEAM education in Pakistan is a step towards enhancing the science and mathematics education by adopting a problem-solving, inquiry-based, activity-based, and technology-integrated pedagogical approach. But the classrooms of secondary education are still mainly based on the traditional teaching methods of lecturing, explaining the textbooks and learning in the exam style. This presents an important challenge: teachers may have learned about STEM and STEAM strategies in training or in the programme, but they may not be effectively applying STEM and STEAM strategies when teaching in a classroom. This issue is important because in secondary school students develop their interest in science, mathematics, technology, engineering, and future professions. If STEM and STEAM strategies are not being used correctly in this case, students could just memorize instead of getting creative, thinking through problems, working collaboratively, and learning to use tools. Thus, actual teaching strategy used should be identified and gap between awareness – implementation should be analyzed. This study is justified because of a need for evidence-based improvement. If there is no information about current practice, then policy makers, teacher trainers and school leaders will be unable to create effective training or implementation plans. This research is important because it gives practical information for the strategies commonly used in STEM/STEAM, the strategies that are not being used as well as where teachers need support. Thus, the study can influence the policy level awareness of the reform in STEM and STEAM in the real classroom in Pakistan.

The purpose of this study is to explore the present teaching methods adopted in the secondary school education in the field of STEM and STEAM education with a particular focus on the awareness and classroom implementation of teachers. The implications of the study are the opportunity to determine if teachers are merely exposed to STEM/STEAM concepts or are using them in practice in their classroom through inquiry-based learning, project-based learning, technology integration, laboratory experiences, collaborative learning, formative assessment, and arts integration. The study is significant for the policy makers, teacher trainers, school leaders, and curriculum developers as it provides evidence to show the actual training and awareness–practice gap. A novelty of the study is that it does not merely talk about STEM/STEAM education at policy or awareness level but specifically investigates the gap between awareness and implementation for secondary school teachers in Pakistan that can help move the reform of STEM/STEAM from general promotion to implementation in the classroom.

Literature Review

1. Theoretical Framework

The STEM and STEAM approach to education demanded teachers to tap into more than just subject knowledge. Shulman's Pedagogical Content Knowledge (PCK) channeled that understanding of an effective teacher who must not only have knowledge of science, mathematics, technological content, but also have to know how to teach it with appropriate methods, examples, activities, assessment and student-centered approaches. In STEM/STEAM, this meant inquiry-based learning, project-based learning, hands-on laboratory work, technology integration, collaborative learning, formative assessment and arts integration. Dare et al., (2021), Freeman et al. (2019), Portillo-Blanco et al. (2024), and Yakman and Lee (2012) demonstrated that effective STEM/STEAM teaching enhanced problem solving, creativity, practical learning and application to real life. These studies, however, were international in nature and failed to provide a comprehensive understanding of the implementation of these strategies in Pakistani secondary schools. In the same way, twenty-first century skills, formative assessment and interdisciplinary learning were highlighted by Cebrero (2025), Clawson (2025), and Andrei (2026), but the

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findings needed to be validated locally as Pakistani classrooms had various realities like examination pressure, limited resources, and traditional teaching culture.

A previous study in Pakistan revealed that there are serious concerns when it comes to STEM and STEAM education. The study by Aslam et al. (2022), Sahito (2024), Rehman et al. (2025), and Khan et al. (2024) found weak policy implementation, inadequate teacher preparation, insufficient resources, and inadequate implementation of the policy in classrooms. Abdullah (2025) and Saleem (2025) revealed low awareness about STEM and low learning outcomes in Quetta, whereas Ali et al. (2023), Kalim and Bibi (2024), and Telaumbanua et al. (2025) suggested enhancement of teachers' competence and continuous professional development. The other studies also identified contextual barriers, such as gender disparities in STEM participation (Mumtaz & Nasreen, 2025), a lack of integration in the arts (Batool & Lodhi, 2024), and regional/structural barriers in education reform (Amalia et al., 2025; Ali et al., 2025; Shah, 2024). These studies found that the creation of awareness and training were not sufficient unless teachers put the STEM/STEAM strategies into practice in classrooms. Thus, using Rogers' Diffusion of Innovation Theory, the present study explored the reasons why teachers might be aware of innovative strategies for teaching but not do so because of their perceived complexity, lack of resources, low support and low compatibility with the present examination system. This led to the identification of the following research gap: there were a number of studies that considered the STEM/STEAM problem in general but few studies measured the specific gap between teacher awareness and the use of STEM/STEAM teaching strategies in Pakistani secondary schools.

2. Effective STEM and STEAM Teaching Strategies: International Perspective

According to international studies, there were a number of teaching practices that could help to make STEM and STEAM education more relevant, creative, and student-centered. Freeman et al. (2019) and DeCoito et al. (2024) explained that integrated curriculum, real-world problem solving, innovative pedagogy and teacher support were important factors

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in strong STEM education. Razi and Zhou (2022) studied the evolution of STEM, iSTEM, and STEAM education and found that STEM education has taken a shift from integration of subjects and expanded to STEAM education: Science, Technology, Engineering, Arts, and Design, and Social relevance. Similarly, Talib et al. (2019) conducted semi-structured interviews with secondary school teachers and discovered that model-based inquiry was found to be suitable for STEAM teaching and teachers required training in the method and the teachers required some examples of classroom model to be able to apply it effectively. These studies revealed that when students were learning through inquiry, STEM/STEAM projects, teamwork, models, technology and real-life tasks, as opposed to lectures and textbooks, this approach proved to be both effective and successful.

Moreover, studies revealed that STEAM was more robust when technology, creativity, sustainability and social issues were introduced into the teaching. Although their study was conducted in Vietnam, Nguyen et al. (2020) reviewed STEM secondary school teaching and analyzed teachers' STEM projects, and concluded that STEM could contribute to sustainable development, but the teachers' projects were designed for practical learning tasks. Harris and De Bruin (2018) did a global research in Australia, USA, Canada and Singapore and reported on the results that the understanding of creativity by teachers in STEAM was related to their classroom practice of creativity. Mang et al. (2021) designed a socio-scientific issue based STEAM model and found that when science is related to real social issues, there is an improvement in science literacy, which also requires time consideration in the teacher's planning. A systematic review by Leavy et al. (2023) revealed that with the advent of emerging technologies, the use of these tools in the STEAM education sector has become more prevalent, yet access, teacher competence and pedagogical design were still considered significant limitations. Spyropoulou and Kameas (2023/2024) created the STEAM educator competence framework, demonstrating that there were several teacher competences needed for effective STEAM teaching, such as Pedagogy, Collaboration, Creativity, and Community Connection. The findings were

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pertinent in the context of the current study because if Pakistani secondary teachers know about modern strategies for STEM/STEAM it is necessary to train them, provide resources to them and get them support for implementing the strategies at the classroom level.

Table 1: Effective STEM/STEAM Teaching Strategies

Strategy Category	Specific Strategy	Main Idea	Key Finding	Application to Present Study	Key Source
Inquiry-based learning	Model-based inquiry	Students learned through questions and investigation.	Inquiry improved learning when teachers had clear examples.	Used to check teachers' use of inquiry-based teaching.	Talib et al. (2019)
Technology-supported learning	Digital tools and personalization	Technology was used to support flexible learning.	Digital tools improved learning when teachers were trained.	Used to examine technology-integrated lessons.	Glushkova et al. (2022)
Global STEM pedagogy	Integrated curriculum	STEM teaching used real-world and active learning.	Effective STEM needed curriculum, teacher support, and resources.	Helped compare Pakistani practice with international standards.	DeCoito et al. (2024)
Sustainable STEM learning	STEM projects	Students solved real-life and sustainability problems.	Projects improved practical understanding.	Supported project-based and problem-based learning.	Nguyen et al. (2020)
Teacher competence	STEAM educator skills	Teachers needed skills for creativity, pedagogy, and teamwork.	STEAM worked better when teachers had clear competences.	Supported the awareness–implementation gap analysis.	Spyropoulou & Kameas (2023/2024)
Creativity-based STEAM	Creative classroom practice	Teachers used creativity in science and learning tasks.	Creativity improved student engagement.	Supported arts integration in STEM/STEAM teaching.	Harris & De Bruin (2018)

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Socio-scientific learning	Real social issues	Students studied science through social problems.	Social issues made science learning more meaningful.	Supported real-world problem-solving strategies.	Mang et al. (2021)
Motivation and learning	STEAM courses	STEAM activities were linked with motivation.	STEAM improved student interest and engagement.	Supported the need to check classroom implementation.	Hsiao & Su (2021)
Programme context	STEAM Pakistan	Schools, teachers, clubs, and students were engaged.	Programme showed national-level STEAM activity.	Helped define the Pakistani context of the study.	STEAM Pakistan Report (2023)

3 STEM and STEAM Education in Pakistan: Policy Context

Recent surveys revealed that there is a need for more policy support, teacher training and classroom implementation of STEM and STEAM education in Pakistan. Rafiq-uz-Zaman and Malik (2025) analyzed the situation between Pakistan and India, revealing a demand for more systematic STEAM planning and classroom support in Pakistan. Rafiq-Uz-Zaman (2026) concluded that there was a need to expose children to STEAM in Grades 6 – 8 before their entry into Secondary education. Rehman et al. (2025) found that there are significant challenges in the STEM field and teacher preparedness in Pakistan. The study conducted by Aslam and Shah revealed that elementary teachers in Sukkur were having positive views on STEAM but they were not trained, provided with materials, and supported by administration for its implementation in the classrooms. Bibi & Zafar (2026) explored the STEM curriculum in secondary level and demonstrated that students' motor and learning development was facilitated through practical STEM activities. Arce and Güler (2026) investigated the relationship between STEAM education and environmental ethics and argued that STEAM education is a way to foster value-based and culturally relevant learning. Habib (2026) focused on design-based STEAM learning and pointed out the importance of incorporating creativity and innovation into instructional practice. Amjad et al. (2026) investigated the relationship between teacher-student interaction and the help-seeking in the context of Society 5.0 and STEM and concluded that the teacher-student interaction had an impact on the students' engagement in STEM learning. Madar et al. (2026) conducted a review of the integration of STEM in schools and suggested that the implementation of STEM in schools should be done with a good curriculum planning, competent teachers and institutional support. Overall, these studies provided evidence that Pakistan's STEM/STEAM policy trajectory was building but the key challenge was the disconnect between teacher awareness and implementation in the classroom.

Methodology

1. Research Design

The present study used a quantitative descriptive survey design. This design was suitable as the study was aimed at finding out the present teaching methods adopted in STEM/STEAM education in the secondary school level in Pakistan and the gap between teachers awareness and real practices in the classrooms. The numerical data was obtained using a descriptive survey design, which facilitated the researcher to systematically describe the classroom practices as they exist among a large number of teachers. Taking into account that there was no intervention/experimental treatment provided in the study, the survey design was suitable for examining the teachers' reported level of awareness, level of implementation and differences between the provinces and the teacher categories. It was also consistent with the purpose of the study, which was to identify the current STEM/STEAM teaching practices instead of testing a new teaching model.

2. Population of the Study

The target population of the study included science related teachers from government secondary schools in the four provinces of Pakistan (Punjab, Sindh, KPK and Balochistan). This population comprised teachers who had direct and/or indirect involvement with secondary school STEM/STEAM teaching or activities. The specific teachers in the study

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were EST Science teachers and SST Science teachers who teach the science related subjects (general science, mathematics, biology, chemistry, physics and related STEM subjects).

The study was conducted on government secondary schools as STEM and STEAM has primarily been promoted in public-sector school programmes and through official education department frameworks in Pakistan. The STEAM Pakistan Bi-Monthly Progress Report for October/November 2023 identified 1,416 government schools, 79 districts, 122,310 students, 670 STEAM clubs, and 5,716 teachers engaged in the programme in Pakistan. In this present study, the number of partner schools in the province has been used to estimate the population in the four provinces. Based on this, accessible population was estimated as 1,158 STEAM partner schools and 4,682 STEM/STEAM engaged teachers at the four provinces (Punjab, Sindh, KP, and Balochistan).

To note that the available official report gave aggregate teacher-engagement data and that there were no official counts of the number of teachers that were engaged, teaching, or inactive in EST Science and SST Science in each province. Thus, the population in this study consisted of the STEM/STEAM engaged science-related teachers which include EST Science teachers, SST Science teachers, focal persons, and relevant science-related teachers in the school level involved in STEM/STEAM related activities.

3.3 Sampling Technique and Sample Size

In this study, stratified random sampling technique was used. This was the most suitable method for the target population which was spread, among four provinces, with various categories of teachers. Stratification ensured that teachers from each province were represented in line with their proportion of the total estimated population. The main strata were province and respondents were chosen proportionately from Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan. This approach minimised sampling bias and enhanced the representativeness of the sample.

The sample size was calculated using Yamane's formula (1967), which is commonly used when the population size is known:

$$n = \frac{N}{1 + N(e)^2}$$

Where:
n = required sample size
N = total population size
e = margin of error
For this study:
N = 4,682
e = 0.05

$$n = \frac{4682}{1 + 4682(0.05)2}$$
$$n = \frac{4682}{1 + 11.705}$$
$$n = \frac{4682}{12.705}$$
$$n = 368.52 \approx 369$$

Therefore, the required sample size was **369 teachers**. The sample was distributed proportionately across provinces according to the estimated number of STEM/STEAM-engaged teachers.

Table 2: Province-wise Population and Sample Distribution

Province	STEAM Partner Schools	STEM/STEAM-Engaged Teachers (N)	Sample Size (n)
Punjab	531	2,149	169
Sindh	579	2,337	184
Khyber Pakhtunkhwa	40	162	13
Balochistan	8	34	3
Total	**1,158**	**4,682**	**369**

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4. Research Instrument

The research instrument used was a structured questionnaire. The questionnaire designed to assess teachers' awareness and application of STEM and STEAM teaching methods in the classroom. It contained a total of 12 major teaching strategies that were picked from the literature and consistent with the purpose of the study. The strategies adopted were lecture, textbook explanation, question and answer, lab work, co-operation/group work, formative assessment, technology integrated lesson, inquiry-based learning, project-based learning, problem-based learning, integration of STEAM/arts, and design thinking.

The questionnaire was rated on dual three-point scale. The two measures used for each teaching strategy were:Each teaching strategy was evaluated on two measures: To begin with, teachers' levels of awareness were rated. Second, they rated their level of implementation. This dual scale was relevant because the research project sought to not only measure teacher knowledge of STEM/STEAM strategies, but also teacher implementation of these strategies in classrooms.

The awareness scale was:
1 = Not at all aware
2 = Partially aware
3 = Fully aware

The implementation scale was:
1 = Not implemented
2 = Partially implemented
3 = Fully implemented

This was the structure that allowed a calculation of the gap between what was perceived to be being done and what was actually being done for each teaching strategy. For instance, if a teacher knew all about PBL but failed to apply it, this meant that there was an awareness-implementation gap for that teacher. This directly contributed to the primary objective of the study.

5. Validity and Reliability of the Instrument

The questionnaire was pretested with experts and pretested with a trial run. To ensure content validity, the instrument was checked by five education specialists who have expertise in science education, STEM/STEAM education, teacher education and research

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methodology. The experts analyzed the items of the questionnaire for clarity, relevance, and appropriateness of measuring STEM/STEAM teaching strategies at the secondary school level. The feedback was employed for revising item wording, eliminating ambiguity, and consistency with the research objective.

A pilot test was then carried out with 30 teachers who were not part of the final sample.A pilot test was then conducted with 30 teachers not part of the final sample, which were expert validated. The object of conducting a pilot test was to examine clarity, response time, understanding of items and internal consistency of the questionnaire. Cronbach's alpha was used to check reliability. Cronbach's alpha for awareness scale was **α**= 0.89 and that of the implementation scale was

α =0.91.

These values suggested high internal consistency as well as reliability of the instrument in data collection

6. Data Collection Procedure

The data collection period was from February to April 2025. To reach teachers in different school settings, two modes of data collection were used. In urban schools where teachers had access to the internet, the questionnaire was distributed via online Google Form. Printed questionnaires were sent and received by trained research assistants for teachers in rural or low connectivity settings.

Before data collection, respondents were informed about the purpose of the study. They were told that they were volunteering for the study and that their answers would only be used for academic research. The questionnaire did not ask for any personal identifying details. A total of 341 teachers completed the questionnaires and they were used in the final analysis from the planned sample of 369 teachers. This yielded a response rate of 92.3%, deemed adequate for analysis based on surveys.

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7. Data Analysis

Coding and analysis of the collected data were done by SPSS Version 26. The teachers' STEM/STEAM teaching strategy awareness and implementation were summarized using descriptive statistics for 12 STEM/STEAM teaching strategies. The data were described using frequencies and percentages, and means and standard deviations were used to interpret the awareness and implementation scores.

Paired samples t tests were used to explore the difference between awareness and implementation. This test was appropriate because the same respondents rated two related ratings for each strategy: Awareness, and Implementation. A paired t-test was used to help determine if the difference between awareness and implementation was statistically significant.

One way ANOVA was applied to explore the differences between the provinces with regards to implementation. This test was used to compare the implementation score across the four provinces of Punjab, Sindh, KPK and Balochistan. Independent samples t-tests were used to compare the differences between the teacher categories; that is, between EST and SST Science teachers. A level of statistical significance of $p < 0.05$ was used.

8. Ethical Considerations

The research in the study was conducted in accordance with the ethical principles of educational research. The study was voluntary and participants were briefed on the academic objectives before answering the questionnaire. Confidentiality and anonymity of the participants were preserved throughout the process of conducting the research. These collected data was not shared with any unauthorized person, and were used exclusively for research purposes. Participants could refuse to answer any question or abstain from answering a particular question if they felt uncomfortable.

9. Methodological Limitation

One of the methodological constraints of the study was that the official STEAM Pakistan data did not include province-wise figures for the teachers of STEAM Science, but instead

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gave the engagement figures only as aggregate. The study, therefore, relied on the actual data on teacher engagement in the programme as estimated from available official programme data. Another constraint was that the study was self-reported; the questionnaires were completed by subjects. Awareness and implementation by the teacher might have been over-reported because of social desirability. To minimise this, the questionnaire was anonymous and participants were asked to respond to it truthfully.

Results

The results of the quantitative descriptive survey are presented in this chapter. The collected data was analysed using SPSS Version 26 from 341 secondary school teachers who were involved in STEM/STEAM. The results are arranged in order of the research questions: (1) teacher awareness of STEM/STEAM implementation strategies; (2) implementation of STEM/STEAM implementation strategies in the classroom; (3) the magnitude and significance of the awareness–implementation gap; and (4) differences by province and teacher category. Paired samples t-test, one-way ANOVA, and independent samples t-test are used to look at differences and relationships, with descriptive statistics used to summarize central tendencies. To determine practical significance, effect sizes (Cohen's d) are also presented with p values.

1. Demographic Profile of Respondents

After discarding the questionnaires that were incomplete, 341 completed questionnaires were used for analysis, with a response rate of 92.3%.

Table 3, summarizes the demographic and professional characteristics of the respondents.

Table 3: *Demographic Profile of Respondents (N = 341)*

Variable	**Category**	***n***	**%**
Gender	Male	198	58.1
	Female	143	41.9
Teacher Category	EST Science	175	51.3
	SST Science	166	48.7

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Teaching Experience	1–5 years	89	26.1
	6–10 years	112	32.8
	11–15 years	78	22.9
	16+ years	62	18.2
Province	Punjab	156	45.7
	Sindh	170	49.9
	Khyber Pakhtunkhwa	12	3.5
	Balochistan	3	0.9
Location	Urban	148	43.4
	Rural	193	56.6

The sample was mostly male (58.1%) and almost equal number of EST Science (51.3%) teachers and SST Science (48.7%) teachers. Experience was evenly distributed between all career phases with the majority in the 6-10 year range (32.8%). From a geographical standpoint, the sample had a strong representation from the provinces of Punjab (45.7%) and Sindh (49.9%) as these are the provinces where most of the STEAM Pakistan partner schools are currently operating. 3.5% (n = 12) of respondents belonged to the Khyber Pakhtunkhwa province while 0.9% (n = 3) belonged to Balochistan province. There were slightly more teachers who taught in rural schools (56.6%).

2. Teacher Awareness of STEM/STEAM Teaching Strategies

The mean scores for descriptive statistics were used to identify the self-reported awareness of the 12 teaching strategies, as revealed by the teachers. Mean scores were interpreted with respect to the 3-point scale: 1 = Not at all aware, 2 = Partially aware, 3 = Fully aware. The ranked results are shown in table 4.

Table 4: Descriptive Statistics for Teacher Awareness of STEM/STEAM Teaching Strategies

Rank	Strategy	*M*	*SD*	Interpretation
1	Lecture-based instruction	2.85	0.36	Fully aware
2	Textbook-based explanation	2.82	0.41	Fully aware
3	Question-answer sessions	2.78	0.44	Fully aware

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4	Hands-on laboratory work	2.45	0.62	Partially aware
5	Collaborative/group learning	2.38	0.59	Partially aware
6	Formative assessment	2.21	0.67	Partially aware
7	Technology-integrated lessons	2.08	0.71	Partially aware
8	Inquiry-based learning	2.01	0.73	Partially aware
9	Project-based learning	1.94	0.76	Partially aware
10	Problem-based learning	1.88	0.79	Partially aware
11	STEAM (arts integration)	1.67	0.82	Partially aware
12	Design thinking	1.58	0.84	Partially aware

The information shows a significant division between teachers' awareness. There is a high level of awareness ($M > 2.75$) for all traditional teacher-centred approaches: lecture, textbook explanation and question-answer.All the traditional teacher-centred approaches – lecture, textbook explanation and question-answer – are found with a high level of awareness ($M > 2.75$) that shows they are well-established in teachers' professional cognition. Comparatively, there was a much lower awareness of innovative STEM/STEAM practices. Hands-on lab work received the highest mean for innovative strategies ($M = 2.45$), but was not yet considered "fully aware." The lowest awareness was observed in strategies that require higher pedagogical design or interdisciplinary integration such as STEAM/arts integration ($M = 1.67$) and design thinking ($M = 1.58$) which indicates that these strategies are not mainstream in the professional preparation and development of Pakistani secondary science teachers.

3. Classroom Implementation of STEM/STEAM Teaching Strategies (Research Question 2)

Table 5, reports the descriptive statistics for the implementation dimension, using the same 3-point metric (1 = Not implemented, 2 = Partially implemented, 3 = Fully implemented).

Table 5: ***Descriptive Statistics for Classroom Implementation of STEM/STEAM Teaching Strategies***

Rank	**Strategy**	***M***	***SD***	**Interpretation**
1	Textbook-based explanation	2.71	0.48	Fully implemented
2	Lecture-based instruction	2.68	0.52	Fully implemented

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3	Question-answer sessions	2.59	0.55	Fully implemented
4	Hands-on laboratory work	1.92	0.72	Partially implemented
5	Collaborative/group learning	1.85	0.74	Partially implemented
6	Formative assessment	1.79	0.76	Partially implemented
7	Technology-integrated lessons	1.76	0.78	Partially implemented
8	Inquiry-based learning	1.68	0.79	Partially implemented
9	Project-based learning	1.59	0.81	Partially implemented
10	Problem-based learning	1.54	0.82	Partially implemented
11	STEAM (arts integration)	1.45	0.85	Partially implemented
12	Design thinking	1.38	0.86	Partially implemented

There was uniformity in implementation scores lower than awareness scores for all 12 strategies. The three traditional strategies (textbook explanation, lecture, question-answer), were the only ones to score "full implementation" ($M > 2.50$). The mean scores for all innovative STEM/STEAM strategies were concentrated in the "partially implemented" category, with scores ranging from 1.38 to 1.92. Interestingly enough, despite being at the core of the pedagogical vision of the STEAM Pakistan programme, inquiry-based learning ($M = 1.68$), project-based learning ($M = 1.59$), and design thinking ($M = 1.38$) showed particularly low implementation. The present findings indicate that the national policy focus on activity-based and student-centred learning has not yet found its way into the day-to-day operations of the government secondary schools.

4. The Awareness–Implementation Gap

The observed differences between the awareness and implementation were compared using paired samples T-test for statistical significance. The mean differences, t-statistics, degrees of freedom, exact p-values, and effect sizes are reported in Table 6.

Table 6: *Paired Samples t-Test Results: Awareness versus Implementation*

Strategy	**Awareness *M***	**Implementation *M***	**Δ*M***	***t* (340)**	***p*-value**	**Cohen's *d***
Collaborative/group learning	2.38	1.85	0.53	12.45	< .001	0.67
Hands-on laboratory work	2.45	1.92	0.53	11.98	< .001	0.65

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Formative assessment	2.21	1.79	0.42	10.23	< .001	0.55
Project-based learning	1.94	1.59	0.35	9.12	< .001	0.49
Problem-based learning	1.88	1.54	0.34	8.12	< .001	0.44
Inquiry-based learning	2.01	1.68	0.33	8.45	< .001	0.46
Technology-integrated lessons	2.08	1.76	0.32	7.89	< .001	0.43
STEAM (arts integration)	1.67	1.45	0.22	5.67	< .001	0.31
Design thinking	1.58	1.38	0.20	5.12	< .001	0.28
Question-answer sessions	2.78	2.59	0.19	5.34	< .001	0.29
Lecture-based instruction	2.85	2.68	0.17	4.98	< .001	0.27
Textbook-based explanation	2.82	2.71	0.11	3.45	< .01	0.19

Note. All differences are statistically significant at $p < .001$, except textbook-based explanation ($p < .01$).

Analysis shows that for all teaching strategies, there is a statistically significant awareness–implementation gap. However, this difference is quite large in some instances. Collaborative/group learning ($\Delta M = 0.53$, $d = 0.67$) and hands-on laboratory work ($\Delta M = 0.53$, $d = 0.65$) showed moderate effect sizes and were the largest and most practically significant deficit areas. This means that teachers have moderate knowledge of these strategies, but do not make these strategies happen in the classroom due to systemic barriers. A significant difference was also found for formative assessment ($\Delta M = 0.42$, $d = 0.55$).

Note that project-based learning ($\Delta M = 0.35$, $d = 0.49$), inquiry-based learning ($\Delta M = 0.33$, $d = 0.46$), and problem-based learning ($\Delta M = 0.34$, $d = 0.44$) had moderate gaps among

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inquiry-oriented strategies. The same was true for technology-integrated lessons (ΔM = 0.32, d = 0.43)

For the traditional strategies, there were also small but significant differences, ranging from 0.19 (textbook-based explanation) to 0.29 (question-answer). The slight differences indicate that even the well-known pedagogies are not implemented completely faithfully in terms of teacher awareness.

However, the smallest but still notable gaps were for design thinking (ΔM = 0.20, d = 0.28) and STEAM/arts integration (ΔM = 0.22, d = 0.31). The small range of variation in these variables (floor effects) probably restricts the potential difference in awareness and implementation.

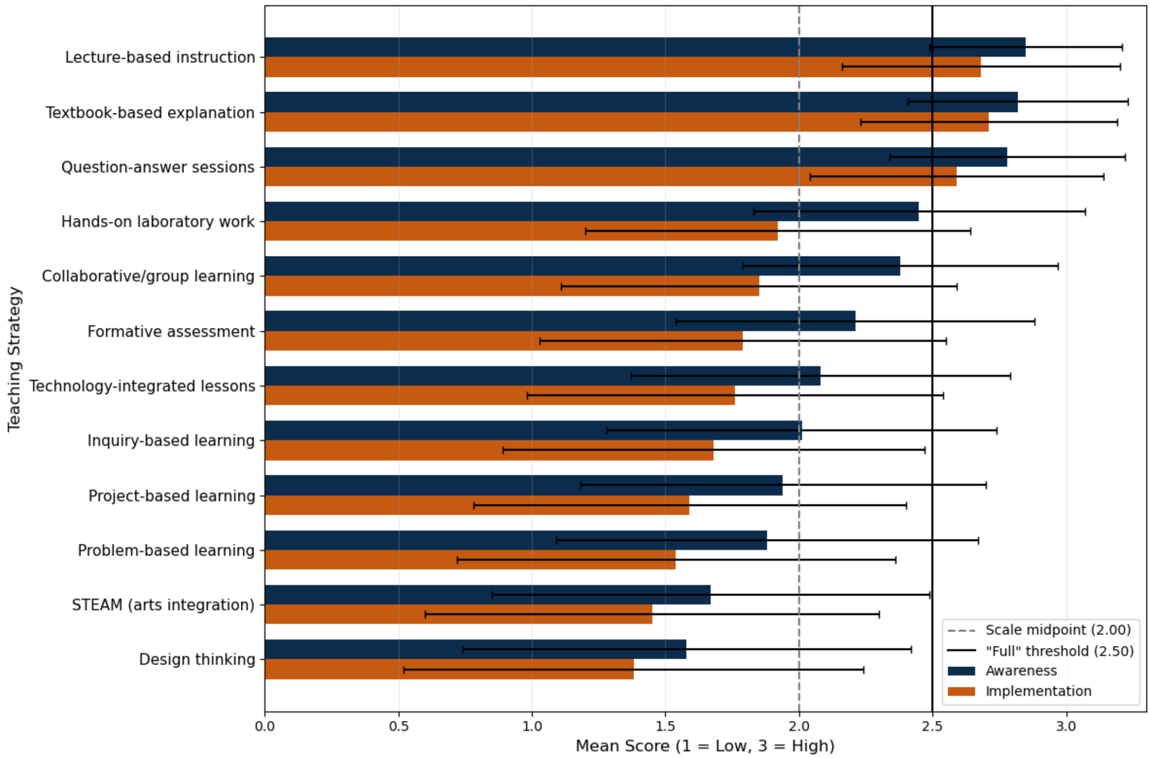

Figure 1. Mean Awareness and Implementation Scores for STEM/STEAM Teaching Strategies

As illustrated in Figure 1, teachers' awareness was greater than implementation of all STEM/STEAM teaching strategies. The awareness and implementation scores of the traditional teaching methods were high, including lecture-based instruction, textbook explanation, and question–answer activities. Innovative approaches like inquiry-based learning, project-based learning, problem-based learning, STEAM/arts integration and design thinking, demonstrated less implementation. Overall, the figure indicates a strong level of awareness–implementation gap, where teachers had awareness of a large number of STEM/STEAM strategies, but were not fully implementing those strategies in their classroom practice.

5. Comparative Analysis by Province and Teacher Category

a. Provincial Differences in Implementation

The mean implementation scores in the four provinces were compared using one-way ANOVA. Due to the hugely disproportionate sample sizes of Punjab (n = 156), Sindh (n = 170), KP (n = 12) and Balochistan (n = 3), interpretations for KP and Balochistan must be tentative and considered exploratory. Strategies that showed significant provincial variation are summarized in Table 7 in the ANOVA results.

Table 7: ***One-Way ANOVA for Implementation Differences by Province***

Strategy	Punjab *M* (*SD*)	Sindh *M* (*SD*)	KP *M* (*SD*)	Balochistan *M* (*SD*)	*F* (3, 337)	*p*	Post-hoc
STEAM/arts integration	1.49 (0.84)	1.42 (0.86)	1.33 (0.78)	1.00 (0.00)	2.89	.036*	Balochistan < Punjab
Collaborative learning	1.89 (0.73)	1.82 (0.75)	1.75 (0.75)	1.33 (0.58)	2.78	.042*	Balochistan < Punjab
Hands-on laboratory work	1.96 (0.71)	1.89 (0.73)	1.83 (0.72)	1.33 (0.58)	2.98	.032*	Balochistan < Punjab
Inquiry-based learning	1.72 (0.78)	1.65 (0.80)	1.58 (0.79)	1.33 (0.58)	2.45	.063	ns
Technology-integrated lessons	1.81 (0.76)	1.72 (0.79)	1.67 (0.78)	1.33 (0.58)	2.21	.087	ns

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**Significant at p < .05; ns = not significant.*

There were three innovative strategies where statistically significant provincial differences were found. In all of these instances, Balochistan did significantly worse than Punjab. For STEAM/arts integration, the omnibus test was significant ($F(3, 337) = 2.89$, $p = .036$), with Balochistan ($M = 1.00$) scoring lower than Punjab ($M = 1.49$). Likewise collaborative learning was also found to differ between various provinces ($F(3, 337) = 2.78$, $p = .042$), the mean value for Balochistan being 1.33 while the mean value for Punjab was 1.89. The provincial variation was also significant for hands-on laboratory work ($F(3, 337) = 2.98$, $p = .032$) with Balochistan ($M = 1.33$) significantly below Punjab ($M = 1.96$).

There were no significant differences found between Punjab and Sindh for any strategy and the mean scores were the same descending provincial gradient for inquiry-based learning ($p = .063$) and technology-integrated lessons ($p = .087$). These findings indicate that there is no uniformity in provincial implementation of STEM/STEAM in terms of a smooth linear gradient but rather a binary form of the gap between relatively resourced (Punjab, Sindh) and severely underserved (Balochistan) provinces.

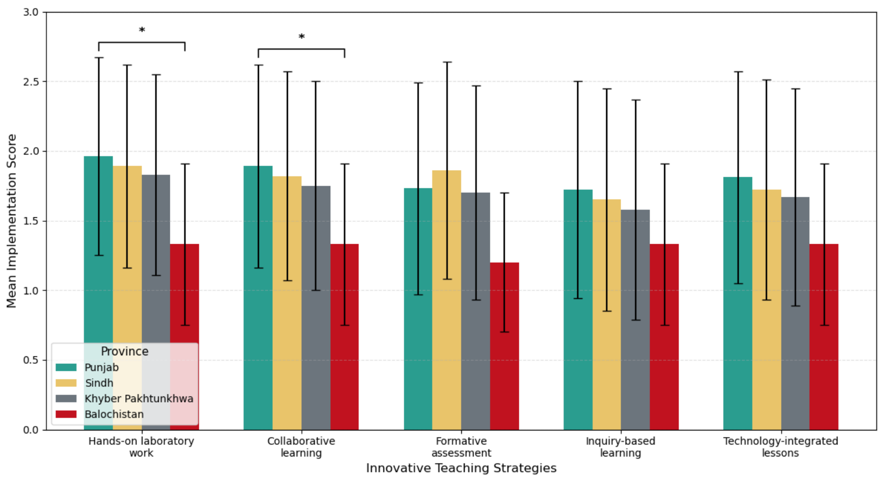

Figure 2: Provincial Differences in Implementation of Innovative STEM/STEAM Strategies

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Figure 2, shows that Punjab and Sindh had higher implementation scores for innovative STEM/STEAM strategies than Khyber Pakhtunkhwa and Balochistan. The lowest scores were obtained in the province of Balochistan particularly for hands-on laboratory learning and collaborative learning. Some strategies had statistically significant differences denoted by the asterisks. Overall, the figure suggests that there is a variability in STEM/STEAM implementation across provinces with higher implementation in Punjab and Sindh, and lower implementation in the under-resourced provinces.

b. Differences by Teacher Category (EST vs. SST Science Teachers)

Independent samples *t*-tests were performed to compare EST Science (n = 175) and SST Science (n = 166) teachers on implementation scores. Table 8 presents the results.

Table 8: Independent Samples t-Test: EST Science versus SST Science Teachers

Strategy	**EST *M***	**SST *M***	**Δ*M***	***t* (339)**	***p*-value**	**Cohen's *d***
Technology-integrated lessons	1.68	1.84	0.16	–2.89	.004**	0.31
Hands-on laboratory work	1.85	2.00	0.15	–2.21	.028*	0.24
Inquiry-based learning	1.61	1.75	0.14	–2.34	.020*	0.25
STEAM/arts integration	1.38	1.52	0.14	–2.12	.035*	0.23
Project-based learning	1.53	1.66	0.13	–2.01	.045*	0.22
Formative assessment	1.73	1.86	0.13	–1.98	.048*	0.21

*$p < .05$; **$p < .01$.

There was statistically significant higher implementation across all six innovative strategies with SST Science teachers compared to EST Science teachers. The largest difference was found for technology integrated lessons (M difference = 0.16, t(339) = –2.89, p = .004, d = 0.31), which was small to moderate. Significant differences were also found for hands-on laboratory work (p = .028, d = 0.24), inquiry-based learning (p = .020, d = 0.25), STEAM/arts integration (p = .035, d = 0.23), project-based learning (p = .045, d = 0.22), and formative assessment (p = .048, d = 0.21)

There were no significant differences among the three traditional strategies (lecture, textbook explanation, question-answer); this suggests that the two groups of teachers use

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traditional strategies at about the same level. The differences lie solely in pedagogies that are pedagogically innovative and student oriented. This pattern points to the fact that the expertise that SST teachers possess, generally in their content area, combined with their advanced academic qualifications, may be conducive to the use of advanced STEM/STEAM strategies, while EST teachers, who often teach general science in multiple domains, may not have the depth or expertise needed to implement these strategies.

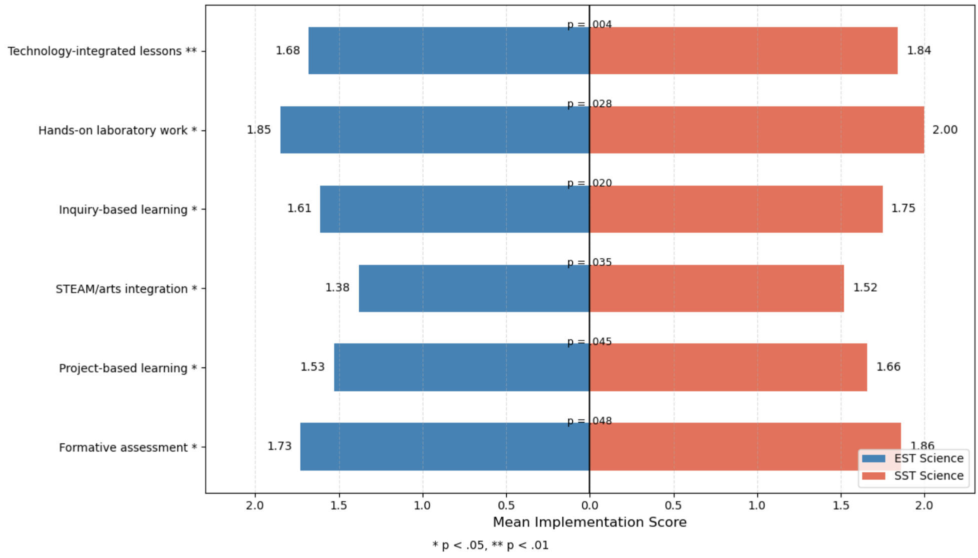

Figure 3: Differences in Implementation by Teacher Category (EST vs. SST)

Figure 3, shows that SST Science teachers implemented innovative STEM/STEAM strategies There were no significant differences among the three traditional strategies (lecture, textbook explanation, question-answer); this suggests that the two groups of teachers use traditional strategies at about the same level. The differences lie solely in pedagogies that are pedagogically innovative and student oriented. This pattern points to the fact that the expertise that SST teachers possess, generally in their content area, combined with their advanced academic qualifications, may be conducive to the use of advanced STEM/STEAM strategies, while EST teachers, who often teach general science

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in multiple domains, may not have the depth or expertise needed to implement these strategies.

6. Discussion

Our statistics show a startling fact: traditional teaching is still prevalent in classrooms of secondary schools despite the efforts of the national policies on STEM and STEAM. Teachers use a lot of lecture-based teaching ($M = 2.68$), textbook explanation ($M = 2.71$), and question-answer sessions ($M = 2.59$); but they barely use innovative strategies. Inquiry-based learning is at $M = 1.68$, project-based learning at $M = 1.59$, and arts integration at $M = 1.45$, all of which fall below the mid-point of the scale. This is not just an imbalance; it's a systemic failure of policy into practice.

The novelty of this study is that the previous studies conducted in Pakistan only measured the teacher's attitude towards/liking STEM and/or availability of the resources in schools. Abdullah (2025) conducted studies in Quetta and Rehman et al. (2025) did studies at the national level, but their studies focused only on attitudes and policy descriptions. Our research is the first four-province empirical study to use a dual-rating instrument, proving that for all 12 strategies, implementation is significantly lower than awareness ($p < .001$). The gaps are not abstract but real, substantial, and significant. There was a 0.53-point difference between collaborative learning and hands-on laboratory work with moderate effect sizes, $d = 0.67$ and 0.65, respectively, which indicates that teachers are likely to be familiar with these methods but may not be using them. This disconnect has been hypothesized in past studies but was not statistically documented by our data.

The reasons are not only motivational but structural as well. It is a fact that in Pakistan examination system still emphasizes on memorization of answers and not questioning or creative thinking (Khattak, 2012), teachers rationally stick to textbooks and lectures. The rest of the story is explained by Rogers' Diffusion of Innovation: awareness is the first step of adoption. To implement, teachers require compatibility, manageability, and safe practice. They don't receive any of those. There are usually more than 50 students in a

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class, no lab or lab is broken, and the internet connection is unreliable. This starkly shows in the provincial data: Punjab has 531 partner STEAM schools, while Balochistan has only 8. Arts integration ($p = .036$), collaborative learning ($p = .042$), and hands-on work ($p = .032$) all reveal that Balochistan scores significantly lower than Punjab. SST teachers, however, continue to outperform EST teachers as they have specialized master's degrees and subject depth necessary to create inquiry tasks, supporting Shulman's (1986) argument that changes in the classroom call for the convergence of content knowledge and pedagogical skill.

Most importantly, this is not a programme of education reform, but an awareness campaign for the STEAM Pakistan programme. Reached 5,716 teachers and 1,416 schools, but classroom remains the same. Familiarity is established during training workshops, but it fades at the classroom door if exams don't match, functional labs are not set up, low-cost STEM kits are not available, and there is no continuous coaching. It is significant that awareness-implementation gaps were also identified in some of the more traditional methods, indicating that the awareness gaps are small but even exists across the board, meaning that external pressures such as demands for syllabus coverage, testing, and administrative compliance are affecting the teaching of the syllabus as a whole.

It is important to be forthright about the study's limitations, however. The data are self-reported, which means that the implementation scores may be more optimistic than they could be; teachers might be biased in their reporting. In reality, the amount of numbers are probably not enough to show what the situation in the classroom is like. The sample size ($n = 12$) in KP and $n = 3$ in Balochistan is too small to draw generalizable conclusions from; in addition, we only surveyed STEAM partner schools, so there is likely to be even weaker innovation in non-participating government schools. The cross-sectional design also does not permit us to infer any changes over time. However, the statistics speak for themselves, awareness without an implementing infrastructure is an empty policy indicator

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and Pakistan's STEM/STEAM reform will stay a paper exercise until the 'classroom' is rebuilt.

Conclusion

The study focussed on the methods used to impart STEM and STEAM education in government secondary schools in Pakistan, with a focus on the teacher's awareness and implementation in the classrooms for four provinces. The findings are based on the data from 341 EST and SST Science teachers and have confirmed that traditional pedagies that are fully implemented (such as lecture, textbook explanation, and question-answer) continue to be the only pedagogies used at critically high levels, while innovative pedagogies such as inquiry-based learning ($M = 1.68$), project-based learning ($M = 1.59$), technology integration ($M = 1.76$), and arts integration ($M = 1.45$) are practiced at critically low levels. The paired-samples t-tests found that there were statistically significant differences between awareness and implementation for all 12 strategies, with the greatest gaps found for collaborative learning ($\Delta M = 0.53$, $d = 0.67$), hands on laboratory work ($\Delta M = 0.53$, $d = 0.65$), and formative assessment ($\Delta M = 0.42$, $d = 0.55$). Besides, there were also differences across provinces which resulted in Balochistan being lagging behind Punjab in various strategies, while SST teachers excelled in terms of innovative strategies, as compared to EST teachers who were not. Finally, the study finds that the STEAM Pakistan programme has created some policy-level awareness but hasn't yet reached the core of the secondary school curriculum; if the exams are not aligned with STEAM, classroom teachers are not provided with materials, and there is no prolonged, embedded professional development, then STEM and STEAM reform is not a reality, but an administrative dream for Pakistan.

1. Recommendations

For Policymakers and the Ministry of Federal Education: Make the STEAM Pakistan initiative more than just a workshop to promote awareness and make it accessible through support for implementation, such as coaching in the classroom, distributing low-cost

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STEM kits to every secondary school, and introducing changes in the examination system that encourage inquiry, hands-on work and problem-solving over rote memorization. There needs to be a specific allocation of the resources that should cater for the equity gaps, with a focus on the under-served provinces, especially Balochistan.

In Teacher Professional Development: Replace 1 day training with semester-long school-based teacher professional development programmes which incorporate peer observation, lesson study and mentoring. Separate training for EST teachers, which are more focused on the general STEM/STEAM pedagogical principles, from SST teachers, who focus on the teacher's specific domain for integration.

For School Leadership: Require at least 1 hands-on or collaborative STEAM activity per week across every class; record the use of simple logs; focus on narrowing the biggest gaps in the class (collaborative learning and lab work) by conducting focused improvement cycles in the school.

2. Directions for Future Research

Future studies should focus on longitudinal designs to find if implementation gets better with time as the STEAM Pakistan programme progresses, structured classroom observation studies to validate the self-reported data and capture qualitative texture of what is happening in the actual classrooms, and in-depth case studies of the schools that are being successfully implemented to enquire about the contextual factors that are enabling. Additionally, the direct link between specific STEM/STEAM teaching approaches and students' learning outcomes should be explored, as should be comparative studies between the STEAM partner schools and non-participating schools for exploring the actual impact of programme engagement.

3. Final Thought

Pakistan has already adopted the language of STEM and STEAM, now it needs the rules of the language of the classroom. Knowledge is the first step towards reform; but its measure is implementation. The country's secondary schools are expected to yield a crop

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of canvassers who can perform inquiry, creativity, and problem solving; teachers trained are not the point of interest; it is changed classrooms that are in question.

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Appendix A: Questionnaire Items for Objective 1

Instruction: For each teaching strategy, please rate your (a) awareness and (b) implementation using the scales below.

Awareness Scale: 1 = Not at all aware, 2 = Partially aware, 3 = Fully aware

Implementation Scale: 1 = Not implemented, 2 = Partially implemented, 3 = Fully implemented

S. No.	Teaching Strategy	Awareness (1–3)	Implementation (1–3)
1	Lecture-based instruction		
2	Textbook-based explanation		
3	Question-answer sessions		
4	Hands-on laboratory work		
5	Collaborative/group learning		
6	Formative assessment		
7	Technology-integrated lessons		
8	Inquiry-based learning		
9	Project-based learning		
10	Problem-based learning		
11	STEAM (arts integration)		
12	Design thinking		

Appendix B: Ethical Approval Statement

This study was conducted in accordance with ethical research standards. Informed consent was obtained from all participants. Participation was voluntary, and anonymity was guaranteed. Data were stored securely and used only for research purposes.