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Implementation of 5Cs in the Classroom Practices of Trained Science Teachers to Maintain Quality of STEAM Education: A Study of Schools of Sindh Education Foundation of Larkana Division

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ABSTRACT
The 21st-century education discourse increasingly emphasizes competency-based learning frameworks, with the 5Cs, comprising critical thinking, creativity, collaboration, communication, and citizenship, identified as foundational skills for preparing learners capable of addressing complex real-world challenges. While STEAM (Science, Technology, Engineering, Arts, and Mathematics) education has been recognized globally as an effective vehicle for developing these competencies, empirical evidence on their implementation in classroom practice, particularly in under-resourced and rural contexts in Pakistan, remains scarce. This study examined the extent to which trained science teachers in STEAM-based schools of Larkana Division, Sindh, successfully apply the 5Cs in their classroom practices, and identified which competencies are most dominant in their instructional behavior. A quantitative descriptive cross-sectional design was employed, with data collected from 100 purposively sampled trained science teachers using a structured, expert-validated, Likert-scale questionnaire. Data were analyzed through descriptive statistics including means, standard deviations, and competency rankings. Findings revealed that all five competencies were implemented at a high level, with each recording a mean score above 4.00 on a five-point scale. Citizenship (M = 4.0677) emerged as the most dominant competency, followed by collaboration (M = 4.0578), critical thinking (M = 4.0244), creativity (M = 4.0114), and communication (M = 4.0016). The findings suggest that STEAM-based professional training has meaningfully translated into classroom practices that reflect all five competencies, with teachers demonstrating stronger instructional capacity in the social, ethical, and analytical dimensions of the 5Cs than in the creative and communicative dimensions. The study concludes with implications for teacher professional development, curriculum design, and education policy in Sindh, and recommends longitudinal and qualitative follow-up research to deepen understanding of 5Cs implementation in under-resourced educational contexts.

Keywords: 5Cs, STEAM education, classroom practices, science teachers, competency-based learning, Larkana Division, Sindh, Pakistan

1. Introduction

Global educational reforms have progressively shifted from content-focused, rote-based learning toward competency-based approaches that equip learners with skills essential for navigating the complexities of the 21st century. Among the most widely recognized frameworks for this shift are the 5Cs: critical thinking, creativity, collaboration,

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communication, and citizenship. These competencies are identified across international curricula as foundational to preparing learners who can assess information critically, address real-world problems, engage meaningfully with others, and participate as responsible members of society (Voogt & Roblin, 2012). Science, Technology, Engineering, Arts, and Mathematics (STEAM) education has emerged globally as a powerful vehicle for developing these competencies through authentic, interdisciplinary learning experiences. Research consistently reports that STEAM-based and project-based pedagogies improve conceptual understanding, creative reasoning, critical thinking, and collaborative and communicative capacities through inquiry-driven and hands-on engagement (Henriksen, 2014; Yakman & Lee, 2012). A systematic review by Suryaningsih et al. (2024) further confirms that STEAM pedagogies promote higher-order thinking, interdisciplinary knowledge integration, and meaningful peer interaction. Comparative international evidence also indicates that countries integrating STEAM into national curricula demonstrate higher levels of student resilience, self-directed learning, and collaborative competency (Voogt & Roblin, 2012), reinforcing the broader educational value of the STEAM framework.

In Pakistan, the adoption of 21st-century competency frameworks and STEAM-aligned pedagogies has gained formal policy recognition; however, consistent classroom-level implementation remains elusive. Research indicates that although many teachers acknowledge the importance of inquiry-based and student-centered instruction, actual practices remain predominantly teacher-centered, constrained by resource limitations, examination pressures, and inadequate professional development (Rehman et al., 2025). Azeem and Rasool (2024) found that STEM-based learning had a significant positive effect on the critical thinking of elementary students in Faisalabad, though implementation challenges persisted. Similarly, Kasim et al. (2025) reported through a systematic literature review that integrated STEM approaches improve critical thinking in secondary school students but demand stronger teacher preparation. In Sindh specifically, studies have indicated that teachers frequently lack the structured training needed to integrate creativity, communication, and collaboration effectively into science instruction (Rehman et al., 2025).

1.1 Problem Statement

The situation is particularly challenging in Larkana Division, where schools regularly face inadequate laboratory facilities, overcrowded classrooms, outdated instructional resources, and inconsistent teacher training support, all of which limit the practical applicability of the 5Cs within STEAM education (UNESCO, 2023; Government of Sindh Education Reports, 2022). Inequities in funding and curricular provision, compounded by limited digital connectivity, widen the gap between educational intent and actual classroom practice. Even where teachers have been exposed to modern pedagogies through professional training programs, a persistent discrepancy exists between training content and classroom application, particularly in rural and low-resource settings. Although STEAM approaches and 5C competencies are included in teacher professional development programs in Pakistan, empirical research on how these translate into actual classroom practices, specifically in Larkana Division, Sindh, remains scarce (Government of Sindh Education Reports, 2022). It is therefore not yet understood which elements of the 5Cs trained science teachers successfully implement, which competencies are most prominent in their instructional behavior, and how these patterns relate to the overall quality of STEAM teaching. This study addresses that gap.

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1.2 Research Objectives

1. To examine which elements of the 5Cs are successfully applied in the STEAM-based classroom practices of trained science teachers in Larkana Division, Sindh.
2. To identify which elements of the 5Cs are most dominant in the classroom practices of trained science teachers.

1.3 Research Questions

1. What elements of the 5Cs are being successfully applied by trained science teachers in their classroom practices to sustain the quality of STEAM education?
2. Which specific elements of the 5Cs emerge as dominant in the classroom practices of trained science teachers, as reflected in frequency and level of application?

2. Literature Review

The 5Cs framework, comprising critical thinking, creativity, collaboration, communication, and citizenship, serves as the theoretical lens guiding this study. Originating from global movements toward competency-based education, the 5Cs represent a set of interrelated skills considered essential for preparing learners to function effectively in complex, knowledge-driven societies (Voogt & Roblin, 2012). Within the context of STEAM education, these competencies are not treated as discrete skills but as interconnected capacities that are simultaneously developed through authentic, interdisciplinary, and inquiry-based learning experiences (Henriksen, 2014; Mishra & Henriksen, 2018). The following sub-sections review existing literature on each of the five competencies, moving from global evidence to the Pakistani context, with particular attention to Sindh and the challenges specific to under-resourced educational settings.

2.1 Critical Thinking

Critical thinking is widely recognized as a foundational competency of 21st-century education, enabling learners not merely to receive knowledge but to process, evaluate, and apply it meaningfully. In Pakistan, policy documents and academic scholarship consistently emphasize the importance of cultivating critical thinking to prepare students who can solve problems, make informed decisions, and engage in lifelong learning (Rehman et al., 2025). STEAM approaches, project-based learning, and interactive pedagogies have been proposed as effective means of developing critical thinking because they require students to engage actively with content, think analytically, and address real-life problems (Kasim et al., 2025). Nevertheless, consistent application of such pedagogies in Pakistani classrooms, particularly in under-resourced or rural settings, remains limited (National Curriculum Review, 2020).

Empirical evidence from within Pakistan demonstrates the effectiveness of these approaches in developing critical thinking. A study conducted in Faisalabad using a Solomon Four-Group experimental design found that students taught through STEM-based approaches significantly outperformed those taught through conventional methods on both post-test and retention test scores (Azeem & Rasool, 2024). Similarly, Kimani (2024) demonstrated that project-based learning meaningfully enhanced critical thinking and complex problem-solving among secondary school students. Additionally, a meta-analysis covering studies from 2008 to 2023 found that gamification in STEM classrooms enhances student motivation, engagement, and critical thinking, suggesting that interactive learning environments can meaningfully contribute to the development of analytical skills (Zeng et al., 2024).

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Despite this promising evidence, classroom realities significantly constrain the development of critical thinking in practice. Research indicates that although many educators recognize its importance, factors such as large class sizes, examination-focused curricula, insufficient instructional resources, and institutional pressure limit effective implementation (Rehman et al., 2025). Techniques such as inquiry-based learning, collaborative problem-solving, Socratic questioning, and argument mapping can support the integration of critical thinking, but their use varies considerably and depends largely on individual teacher motivation and capacity (Kasim et al., 2025).

Several gaps persist in the literature on critical thinking in Pakistan. The majority of empirical studies are conducted in urban or well-resourced schools, leaving rural and under-resourced areas substantially underrepresented. Studies tend to focus on individual subjects or specific grade levels, and longitudinal investigations tracking the development of critical thinking over time remain scarce. Systemic constraints including inadequate teacher training, limited instructional resources, and the dominance of rote learning continue to hinder progress (Azeem & Rasool, 2024; Rehman et al., 2025). The present study addresses some of these gaps by examining the classroom practices of trained science teachers in the Larkana Division, a context that is both under-researched and resource-constrained.

2.2 Creativity

Creativity is recognized globally as an essential competency that enables learners to approach challenges innovatively, generate original ideas, and apply knowledge across diverse contexts. Evidence from international scholarship indicates that creativity is not confined to the arts but is equally vital in science, technology, engineering, and mathematics, making it a central component of STEAM education, which promotes design thinking, problem-solving, and interdisciplinary application (Runco, 2014; Cropley, 2019). Within STEAM frameworks specifically, creativity and STEAM learning reinforce one another, as the integration of arts-based thinking into scientific inquiry opens pathways for imaginative problem-solving that purely technical approaches do not (Mishra & Henriksen, 2018).

In the Pakistani context, several studies have examined the role of pedagogical interventions in promoting student creativity. Fazal et al. (2024) found, through a quasi-experimental study in Pakistani public schools, that targeted creative thinking programs produced significant improvements in students' creative thinking abilities compared to control groups. Similarly, Fazal et al. (2023) identified through qualitative inquiry that teachers in Pakistani public schools recognized the importance of creative thinking but frequently lacked the practical skills and institutional support to foster it consistently. These studies together suggest that while creative thinking is valued in the Pakistani educational context, both teacher capacity and systemic support remain insufficient.

Despite these positive findings, structural barriers constrain the consistent application of creativity-focused pedagogies in Pakistan. Formal teacher training programs frequently offer limited practical guidance on strategies for promoting creativity in classroom settings (Rehman et al., 2025). Large class sizes, insufficient instructional materials, and examination-driven curricula further restrict the routine use of creative pedagogies. Longitudinal research on the retention and transfer of creative abilities across subjects and grade levels also remains limited, constraining understanding of long-term effectiveness.

Notably, the majority of existing research is concentrated in urban and well-resourced schools, leaving rural and under-resourced regions such as Larkana Division

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substantially underrepresented. Research examining the extent to which trained science teachers in such contexts have implemented creativity-oriented strategies, and the contextual factors that enable or impede those strategies, can provide valuable evidence for curriculum design, teacher training, and policy development aimed at fostering creativity across diverse and resource-limited educational environments.

2.3 Collaboration

Collaborative learning is understood as the capacity of students to organize effectively in groups, exchange ideas, negotiate solutions, and work toward shared goals. It is widely recognized as an indispensable 21st-century competency that develops interpersonal skills, communication, problem-solving, mutual respect, and shared responsibility (Dillenbourg, 2020; Johnson & Johnson, 2019). Within STEAM education, collaboration is a particularly emphasized principle because most STEAM learning activities involve joint decision-making, experimentation, and knowledge construction, preparing students not only for academic success but also for team-based work in real-world contexts (Laal & Ghodsi, 2012).

In Pakistan, empirical studies affirm the positive effects of collaborative learning in educational settings. Khan et al. (2024) found that collaborative learning meaningfully improved academic performance among students in Pakistani teacher education programs, with group-based interaction enhancing both conceptual understanding and interpersonal skills. The study confirmed findings from Laal and Ghodsi (2012) that collaborative learning produces social, psychological, and academic benefits simultaneously. Rehman et al. (2025) similarly noted that teacher preparedness for facilitating collaborative work in STEM classrooms remains a significant gap in Pakistan, particularly at the secondary level.

Teacher practices and classroom organization play a decisive role in determining whether collaborative learning is achieved effectively. Educators who provide structured group tasks, clear instructions, and opportunities for peer evaluation tend to foster more productive collaboration (Laal & Ghodsi, 2012). However, implementation is frequently hindered by large class sizes, limited resources, examination-focused curricula, and a lack of professional development support for managing collaborative work in contextually challenging conditions (Rehman et al., 2025).

As with creativity, the existing collaboration literature in Pakistan is concentrated in urban and resource-available schools, with rural and under-resourced areas such as Larkana Division remaining underrepresented. The absence of digital resources, dependence on individualistic evaluation models, and rigid curricular structures further limit opportunities for meaningful collaboration. Empirical evidence on how trained teachers apply collaborative strategies, how students respond, and what contextual factors shape collaboration in under-researched settings can meaningfully inform teacher training, curriculum design, and policy. In STEAM education particularly, where real-world problem-solving increasingly depends on teamwork and interdisciplinary thinking, strengthening collaboration-driven pedagogies has the potential to enhance both academic achievement and students' socio-emotional development.

2.4 Communication

Communication is widely regarded as one of the most critical skills in contemporary education, enabling students to convey ideas, engage in dialogue, comprehend information, and function effectively in team-based settings. Internationally, both verbal and non-verbal as well as digital communication skills are considered

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prerequisites for academic success and workplace readiness (OECD, 2018). In STEAM education specifically, effective communication is essential for sharing findings, explaining solutions, providing feedback, and collaborating on projects, and is therefore integral to authentic learning and problem-solving processes (Mishra & Henriksen, 2018).

Research demonstrates the effectiveness of communication-oriented pedagogies in promoting student engagement and collaborative capacity. Kasim et al. (2025) noted that structured peer discussions and collaborative presentations in secondary science settings helped students articulate their thinking more clearly and develop stronger communication competencies. Rehman et al. (2025) identified communication skill development as one of the key areas where Pakistani STEM teachers remain underprepared, particularly in lower-resourced schools. Structured communication activities including student-led presentations, peer feedback, and scientific debate have been found to build both verbal confidence and the capacity to explain reasoning coherently.

Teacher practices play a significant role in developing students' communication competencies. When teachers create structured opportunities for presentation, debate, role-play, and peer feedback, students develop more effective communication skills (Laal & Ghodsi, 2012). Nonetheless, the size of classes, the absence of adequate instructional materials, and curricula oriented toward rote learning remain persistent barriers to the consistent application of communication-enhancing strategies (Rehman et al., 2025).

As with other competencies in this review, most research on communication in Pakistani classrooms is conducted in urban settings, and rural and under-resourced regions such as Larkana Division are substantially underrepresented. Structural barriers including limited classroom resources, the absence of digital tools, and examination-focused evaluation reduce authentic communication opportunities for students. Research examining how trained science teachers implement communication-oriented strategies, and what contextual factors shape those practices, can provide evidence to support curriculum design, teacher education, and policy decisions aimed at strengthening communication as a core competency within STEAM classrooms.

2.5 Citizenship

Citizenship education addresses the development of social responsibility, moral reasoning, civic awareness, and community engagement, and is recognized internationally as a critical component of 21st-century learning (Banks, 2020). Citizenship competencies equip students to understand democratic values, contribute to social cohesion, and exercise responsible judgment. Within STEAM education, problem-solving involving societal challenges, collaborative community-oriented projects, and ethical reasoning naturally intersect with citizenship development, making it a competency that is both embedded in and reinforced by STEAM approaches (Mishra & Henriksen, 2018).

In the Pakistani context, studies demonstrate that citizenship education in schools carries particular importance given the social, civic, and ethical challenges facing Pakistani youth. Iqbal et al. (2023) found through curriculum analysis that Pakistan Studies secondary curricula lack sufficient emphasis on civic skills such as problem-solving, decision-making, and active participation, suggesting that teachers must supplement formal curricula with citizenship-oriented activities. Munir and Zaidi (2023) similarly argued that institutionalizing civic engagement through skilled civic education requires both curriculum reform and enhanced teacher capacity in Pakistan. Hayat et al. (2024) demonstrated through a qualitative study that innovative pedagogical approaches, including classroom-based deliberation on real social issues, significantly strengthened civic awareness and responsibility among Pakistani students.

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Recent scholarship further proposes that engaging students in authentic social problem-solving, rather than passive content learning, makes citizenship education more meaningful and lasting (Hayat et al., 2024). When students participate in activities such as environmental stewardship, health awareness campaigns, or community dialogue, they begin to perceive themselves as catalysts for positive social change. STEAM pedagogies that incorporate social concerns such as sustainability, equity, and technology ethics can further deepen civic awareness and responsibility among learners.

Despite these positive findings, structural barriers limit the consistent integration of citizenship-oriented pedagogies. Curriculum limitations, oversized classes, resource scarcity, and inadequate professional development constrain the systematic use of citizenship-focused approaches (Rehman et al., 2025). As with the other competencies reviewed, the majority of existing research is concentrated in urban settings, with rural areas such as Larkana Division remaining substantially underrepresented. Empirical research on how trained science teachers integrate citizenship within the 5Cs framework in under-researched and resource-constrained contexts can generate valuable evidence for curriculum development, teacher training, and policy.

2.6 Cross-cutting Observations

Across all five competencies reviewed, a set of common themes emerges that is important to acknowledge before proceeding to the methodology. First, the urban-rural resource gap consistently appears as a barrier across critical thinking, creativity, collaboration, communication, and citizenship, with the majority of empirical research concentrated in well-resourced urban schools and rural regions such as Larkana Division remaining substantially underrepresented in the literature. Second, examination-focused curricula and the persistence of rote learning function as systemic constraints that limit the integration of all five competencies regardless of teacher awareness or motivation. Third, teacher training programs across Pakistan, while improving, frequently do not provide sufficient practical guidance on implementing competency-based strategies in real classroom conditions (Rehman et al., 2025). Finally, longitudinal studies tracking the development and transfer of 5C competencies over time and across subjects are scarce across all five areas, representing a significant gap in the field. The present study responds to these intersecting gaps by focusing specifically on the classroom practices of trained science teachers in Larkana Division.

3. Methodology

This study adopted a quantitative descriptive research design to examine the extent to which the 5Cs of STEAM education are reflected in the classroom practices of trained science teachers in Larkana Division, Sindh. The focus of the study was on quantifying reported instructional practices rather than manipulating variables or establishing experimental conditions, which is consistent with the purpose of descriptive research in educational inquiry (Creswell, 2014).

3.1 Research Design

The study employed a cross-sectional descriptive research design. Descriptive design was selected because it allows the researcher to systematically describe and record the prevailing state of classroom practices without intervention, control groups, or treatment conditions (Creswell, 2014). The cross-sectional approach means that data were collected at a single point in time rather than over multiple time periods. This design was appropriate for determining the level of implementation of the 5Cs across trained science

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teachers and for identifying which competencies are most prevalent in their instructional practices, thereby providing a snapshot of current teaching behavior in STEAM-based schools within the division.

3.2 Sampling and Participants

Purposive sampling was used to select study participants. This approach was chosen because the research required participants who had undergone professional training specifically related to STEAM education and who were actively teaching science in STEAM-designated schools, ensuring that respondents possessed direct and relevant experience with the pedagogical framework under investigation. The study was conducted in STEAM schools within Larkana Division, Sindh, and participants included both elementary and secondary school science teachers who were applying STEAM-based approaches in their classrooms at the time of data collection. A total of 100 science teachers participated in the study (N = 100). While purposive sampling enabled the selection of an information-rich and relevant sample, it is acknowledged that findings cannot be generalized beyond the sampled population, as the sample is not randomly drawn from a wider population.

3.3 Data Collection Instrument

The primary data collection instrument was a structured questionnaire developed on the basis of the 5Cs framework. The questionnaire consisted of Likert-scale items designed to assess the frequency and level of classroom practices corresponding to each of the five competencies: critical thinking, creativity, collaboration, communication, and citizenship. Each item was rated on a five-point scale ranging from 1 (never) to 5 (always), with higher scores indicating more frequent implementation of the respective competency. The questionnaire was administered through Google Forms to allow online accessibility for respondents and to facilitate efficient data collection across multiple schools within the division.

To establish content validity, the instrument was reviewed by subject matter experts in STEAM education prior to administration. Experts evaluated the items for clarity, relevance, and alignment with the 5Cs framework, and revisions were made based on their feedback. To assess internal consistency reliability, Cronbach's alpha was calculated for each of the five sub-scales. The resulting coefficients were as follows: critical thinking ($a = 0.81$), creativity ($a = 0.79$), collaboration ($a = 0.83$), communication ($a = 0.80$), and citizenship ($a = 0.82$). All values exceeded the commonly accepted threshold of 0.70 (Cohen et al., 2018), confirming that the instrument demonstrated satisfactory reliability for use in this study.

3.4 Data Analysis Procedure

Data collected through the structured questionnaire were coded and analyzed using IBM SPSS Software (version 27). Descriptive statistics including frequencies, percentages, means, and standard deviations were computed for each of the five 5C sub-scales to determine the level of implementation of each competency across the sample of trained science teachers. Mean scores for each competency were then ranked to identify which components were most dominant in the classroom practices of the participants. For the purpose of this study, a mean score of 4.00 or above on the five-point scale was considered indicative of a high level of successful implementation, providing a quantitative threshold against which research question one was answered. Demographic data were also examined to provide contextual background for the interpretation of findings.

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3.5 Demographic Profile of Respondents

The demographic profile of respondents provides contextual background for understanding the conditions under which the 5Cs were being applied. Participants were science teachers employed in STEAM-designated schools within Larkana Division, Sindh, at both elementary and secondary levels. All participants had previously undergone professional training related to STEAM education, which was a prerequisite for inclusion in the study. Demographic variables collected included gender, level of teaching (elementary or secondary), years of teaching experience, and prior STEAM-related training.

3.6 Ethical Considerations

This study was conducted in full accordance with established ethical standards for educational research, with the rights, dignity, and privacy of all participants upheld throughout the process. Participation was entirely voluntary, and only those teachers who willingly consented to take part were included in the study. Prior to completing the questionnaire, all participants were informed of the purpose of the research, the nature of data collection, and how the data would be used. Informed consent was obtained from each participant before data collection commenced. No personally identifying information was collected at any stage; names, school identities, and contact details were not recorded, ensuring complete confidentiality and anonymity for all respondents. All data were used exclusively for academic research purposes and were stored securely to prevent unauthorized access. Participants were explicitly informed that withdrawal from the study at any point carried no consequences, and they were free to discontinue participation without obligation.

4. Findings

This section presents the results of the descriptive statistical analysis conducted on data collected from 100 trained science teachers in STEAM-based schools across Larkana Division, Sindh. The findings are organized to directly address the two research questions of the study. First, the descriptive statistics for each of the five competencies are presented. Second, the competencies are ranked by mean score to identify which elements of the 5Cs are most dominant in the classroom practices of the participating teachers. A mean score of 4.00 or above on the five-point Likert scale was used as the threshold for successful implementation, as established in the methodology.

4.1 Descriptive Statistics of the 5Cs

Table 1 presents the descriptive statistics for each of the five competencies across the sample of 100 trained science teachers.

Table 1. Descriptive Statistics of the 5Cs in Classroom Practices of Trained Science Teachers (N = 100)

Competency	N	Minimum	Maximum	Mean	Std. Deviation
Critical Thinking	100	3.05	5.00	4.0244	**.35596**
Creativity	100	2.74	5.00	4.0114	**.41375**
Collaboration	100	2.90	5.00	4.0578	**.41297**
Communication	100	3.00	5.00	4.0016	**.47982**
Citizenship	100	2.73	5.00	4.0677	**.47845**
Valid N (listwise)	100				

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Note. Scores based on a five-point Likert scale (1 = never to 5 = always). N = 100 trained science teachers in STEAM-based schools, Larkana Division, Sindh.

As shown in Table 1, all five competencies recorded mean scores above the threshold of 4.00, indicating that each of the 5Cs was implemented at a high level by trained science teachers across the sampled schools. The mean scores ranged from a low of 4.0016 for communication to a high of 4.0677 for citizenship, reflecting consistently strong but differentiated patterns of implementation across the five competencies.

4.2 Ranking of the 5Cs by Mean Score

To address Research Question 2, the five competencies were ranked in descending order of their mean scores to identify which elements are most dominant in the classroom practices of trained science teachers. Table 2 presents this ranking.

Table 2. Ranking of 5Cs by Mean Score

Rank	Competency	Mean	Std. Deviation
1	Citizenship	4.0677	**.47845**
2	Collaboration	4.0578	**.41297**
3	Critical Thinking	4.0244	**.35596**
4	Creativity	4.0114	**.41375**
5	Communication	4.0016	**.47982**

As shown in Table 2, citizenship ranked first among the five competencies with the highest mean score of 4.0677, followed by collaboration (M = 4.0578), critical thinking (M = 4.0244), creativity (M = 4.0114), and communication (M = 4.0016). While all five competencies exceeded the 4.00 threshold, citizenship, collaboration, and critical thinking were the three most prominently implemented competencies, whereas creativity and communication, though still implemented at a high level, ranked comparatively lower among the five.

4.3 Summary of Findings in Relation to Research Questions

Research Question 1

What elements of the 5Cs are being successfully applied by trained science teachers in their classroom practices to sustain the quality of STEAM education? The findings indicate that all five elements of the 5Cs were successfully applied by trained science teachers, as each competency recorded a mean score above the defined threshold of 4.00. This confirms that STEAM-based professional training has translated into classroom practices that reflect all five competencies at a measurable and consistent level. Citizenship (M = 4.0677), collaboration (M = 4.0578), and critical thinking (M = 4.0244) were the three most strongly implemented competencies, with creativity (M = 4.0114) and communication (M = 4.0016) also meeting the threshold but with comparatively lower mean scores.

Research Question 2

Which specific elements of the 5Cs emerge as dominant in the classroom practices of trained science teachers? The findings clearly indicate that citizenship is the most dominant competency in the classroom practices of trained science teachers in Larkana Division, followed by collaboration and critical thinking. These three competencies consistently recorded the highest mean scores among the five, suggesting that teachers prioritize ethical, social, and analytical dimensions of learning more prominently than creative and communicative ones. Creativity and communication, while successfully

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implemented, represent the relatively least emphasized competencies and may benefit from more structured and intentional instructional attention.

5. Discussion

This section interprets the findings presented in Section 4 in relation to the existing literature reviewed in Section 2. Each key finding is discussed with reference to prior studies, agreements and disagreements with existing evidence are noted, and implications are identified.

5.1 Dominant Competencies: Citizenship, Collaboration, and Critical Thinking

Citizenship emerged as the most dominant competency among trained science teachers in Larkana Division, recording the highest mean score of 4.0677. This finding indicates that teachers consistently incorporated activities promoting ethical conduct, social responsibility, environmental awareness, and respectful participation into their STEAM-based classrooms. This result aligns with the broader argument in the literature that STEAM education, when effectively implemented, extends beyond technical and academic skill development to encompass civic values and moral accountability (Mishra & Henriksen, 2018). The prominence of citizenship in these classrooms also resonates with Hayat et al. (2024), who found that innovative classroom activities centered on real social issues produced stronger civic awareness and community responsibility among Pakistani students. Similarly, Iqbal et al. (2023) noted that supplementing formal curricula with citizenship-oriented pedagogies is particularly important in Pakistan given gaps in the national curriculum. The high implementation of citizenship in the present study suggests that STEAM-trained teachers in Larkana Division have internalized the understanding that education must produce not only academically capable learners but also socially aware and ethically responsible individuals.

Collaboration ranked second among the five competencies with a mean score of 4.0578, indicating that teachers regularly engaged students in group work, team-based problem-solving, peer mentoring, and collaborative projects. This finding is consistent with Khan et al. (2024), who reported that collaborative learning in Pakistani teacher education programs produced measurable gains in academic performance and interpersonal skills. The theoretical benefits of collaboration documented by Laal and Ghodsi (2012), including social, psychological, and academic gains, appear to be reflected in the classroom practices observed in this study. The strong emphasis on collaboration suggests that trained teachers understand cooperative skills as foundational to STEAM education, where innovation and problem-solving are characteristically team-based processes (Dillenbourg, 2020; Johnson & Johnson, 2019). In a resource-constrained context such as Larkana Division, the prominence of collaboration is particularly noteworthy because it suggests that teachers are leveraging peer interaction and group learning as a pedagogical resource even where material and technological resources may be limited.

Critical thinking ranked third among the five competencies with a mean score of 4.0244, reflecting a consistent pattern of teachers engaging students in analytical reasoning, investigative questioning, evidence-based argumentation, and real-life problem-solving. This result is consistent with Azeem and Rasool (2024), who demonstrated that STEM-based instruction produced significant improvements in critical thinking among elementary students in Faisalabad, and with Kasim et al. (2025), whose systematic review confirmed that integrated STEM approaches enhance critical thinking in secondary school students. The emphasis on critical thinking among STEAM-trained

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teachers in Larkana Division suggests that professional development programs have been effective in equipping teachers with analytical pedagogical strategies. This is an encouraging finding given the well-documented dominance of rote learning and examination-focused instruction in Pakistani classrooms (Rehman et al., 2025; National Curriculum Review, 2020).

5.2 Relatively Lower Implementation: Creativity and Communication

Creativity ranked fourth among the five competencies with a mean score of 4.0114. While this score still exceeds the threshold of 4.00 and indicates successful implementation, the comparatively lower ranking relative to citizenship, collaboration, and critical thinking suggests that creativity receives less structured and systematic instructional attention. This pattern is consistent with findings from the Pakistani literature. Fazal et al. (2023) noted through qualitative inquiry that teachers in Pakistani public schools recognize the importance of creativity but frequently lack the practical skills and institutional support to foster it consistently. Rehman et al. (2025) similarly identified teacher preparedness for creativity-focused instruction as a significant gap in STEM education in Pakistan. In the context of Larkana Division, where large class sizes, limited instructional materials, and examination-oriented curricula impose additional constraints, the relatively lower emphasis on creativity is understandable but nonetheless represents an area where targeted improvement is needed. Strengthening creativity in STEAM classrooms may require more deliberate incorporation of design thinking tasks, interdisciplinary projects, and open-ended problem-solving activities (Runco, 2014; Cropley, 2019).

Communication recorded the lowest mean score among the five competencies at 4.0016, though it remained above the threshold for successful implementation. This finding suggests that while teachers do provide opportunities for verbal expression, presentations, and peer discussion, communication is the least systematically developed of the five competencies in these classrooms. Rehman et al. (2025) identified communication skill development as one of the key areas where Pakistani STEM teachers remain underprepared, particularly in lower-resourced schools. Kasim et al. (2025) found that structured peer discussions and student-led presentations significantly improved verbal articulation and questioning skills, suggesting that intentional communication-focused strategies can be effective when consistently applied. The relatively lower implementation of communication in the present study points to an opportunity for professional development programs to place greater emphasis on structured communication activities such as student presentations, scientific debates, peer feedback exercises, and collaborative reporting, all of which are well-suited to the STEAM learning context (Mishra & Henriksen, 2018).

5.3 Overall Pattern and Implications

Taken together, the findings reveal a coherent pattern in which the social and ethical dimensions of the 5Cs, represented by citizenship and collaboration, are most prominently implemented, followed by the analytical dimension represented by critical thinking, and then the expressive and innovative dimensions represented by creativity and communication. This pattern suggests that STEAM-trained teachers in Larkana Division have developed stronger instructional capacity in areas that emphasize group interaction, values, and reasoning than in areas that require structured creative production and intentional communicative development. This is an important observation because

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balanced integration of all five competencies is necessary for STEAM education to fulfill its full developmental potential (Henriksen, 2014; Suryaningsih et al., 2024).

The findings also carry meaningful implications for teacher professional development. Training programs should move beyond general awareness of the 5Cs framework and incorporate practical, classroom-ready strategies for promoting creativity and communication specifically, including modeled lesson demonstrations, peer coaching, and access to supplementary instructional materials suited to low-resource environments. School administrators and education policymakers in Sindh should consider designing continuing professional development structures that allow trained teachers to iteratively refine their practice across all five competencies rather than receiving one-time training interventions.

5.4 Limitations of the Study

Several limitations of this study must be acknowledged. First, the data are entirely self-reported, meaning that responses reflect teachers' own perceptions of their instructional practices rather than independently observed classroom behavior. Social desirability bias may have led some respondents to rate their practices more favorably than actual classroom implementation would indicate. Second, purposive sampling was used to select participants, which means the findings are not statistically generalizable beyond the sample of trained science teachers in STEAM schools in Larkana Division. Third, the study is cross-sectional in design, capturing practices at a single point in time and therefore unable to track changes in the implementation of the 5Cs over time. Fourth, the geographic scope is limited to Larkana Division, and patterns observed here may differ from those in other divisions of Sindh or in other provinces of Pakistan. Fifth, the study did not include student outcome data or classroom observation data, both of which would provide stronger evidence of the actual impact of 5Cs implementation on learning. Future research should address these limitations through complementary qualitative and longitudinal approaches.

6. Conclusion

6.1 Summary of Findings

This study examined the implementation of the 5Cs framework, comprising critical thinking, creativity, collaboration, communication, and citizenship, in the classroom practices of trained science teachers in STEAM-based schools of Larkana Division, Sindh. Using a quantitative descriptive design and a structured Likert-scale questionnaire administered to 100 trained science teachers, the study found that all five competencies were implemented at a high level, with each recording a mean score above the defined threshold of 4.00. Citizenship was the most dominant competency (M = 4.0677), followed by collaboration (M = 4.0578), critical thinking (M = 4.0244), creativity (M = 4.0114), and communication (M = 4.0016). These findings confirm that STEAM-based professional training has meaningfully influenced the instructional practices of science teachers in this under-researched and resource-constrained educational context. At the same time, the comparatively lower scores for creativity and communication indicate that these two competencies, while successfully implemented, receive less structured and intentional instructional attention than the other three.

6.2 Implications for Practice and Policy

At the classroom level, teachers are encouraged to design more deliberate and structured learning activities that specifically target creativity and communication. This may include incorporating regular open-ended design tasks, scientific debate activities,

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student-led presentations, peer feedback exercises, and interdisciplinary projects that simultaneously engage multiple competencies. Such activities do not necessarily require additional material resources and can be implemented within the constraints of the existing school environment.

At the professional development level, STEAM training programs should move beyond initial orientation workshops and toward sustained, iterative, and practically grounded professional development. Specific modules addressing the promotion of creativity and communication in low-resource science classrooms would address the gap identified in this study. Mentoring structures, peer coaching networks among trained teachers, and school-based lesson study groups could support the continued refinement of practice across all five competencies.

At the policy level, the findings affirm the value of STEAM-based teacher training as a mechanism for improving instructional quality in under-resourced and underrepresented regions. Education policymakers and school administrators in Sindh, including those overseeing Sindh Education Foundation schools, should sustain and expand investment in STEAM teacher training, ensure equitable access to instructional resources in rural divisions such as Larkana, and establish accountability structures that monitor the balanced integration of all five competencies in STEAM classrooms.

6.3 Recommendations for Future Research

The present study opens several directions for future research. First, a longitudinal study tracking changes in the implementation of the 5Cs among the same group of teachers over multiple academic years would provide stronger evidence of the sustained impact of STEAM training on instructional practice. Second, a qualitative follow-up study involving classroom observations and in-depth teacher interviews would help explain why creativity and communication are comparatively less emphasized. Third, a cross-provincial comparative study examining 5Cs implementation across different divisions of Sindh or across provinces would provide a broader picture of how contextual factors influence competency-based teaching. Fourth, future research should incorporate student outcome data, including assessments of actual student competency development, to examine whether higher levels of teacher implementation of the 5Cs translate into measurable gains in student learning. Fifth, replication of this study in non-STEAM schools or with untrained teachers would allow for a comparative analysis that isolates the contribution of STEAM-specific professional training to 5Cs implementation.

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