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Challenges in the Implementation of STEM in Islamabad

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Abstract

It is critical to prepare students to cater for the problems of twenty first century challenges through integration of Science, Technology, Engineering, and Mathematics (STEM) education. While policy initiatives in Pakistan have increasingly emphasized STEM, many institutions are trying hard to implement STEM effectively but the effective implementation in Islamabad schools remains uneven. The main purpose of this study was to explore the challenges of implementing STEM education in the locale of Islamabad. It was a qualitative study in which phenomenology design was used to learn about the lived experiences of participants. Data was collected through semi structured interviews. The participants of the study were science teachers with experience of five years of teaching in Islamabad Capital territory. Ten science teachers from Islamabad Capital Territory institutions and ten from private institutions were purposefully selected for interviews. Data was analyzed through thematic analysis. The themes that evolved through interviews were necessary infrastructure, teacher training, curriculum and assessment design, and policy-practice gaps. Key challenges include moderate teacher content and pedagogical knowledge, limited resources (labs, ICT), rigid, exam-oriented curricula, and insufficient policy support and monitoring. Keeping in view the key findings, it was recommended for effective STEM education implementation in Islamabad schools can be done through teachers training in STEM education, improvement in infrastructure, curriculum reforms, public involvement and policy framework development and implementation.

Keywords: Science, Technology, Engineering, Mathematics, Implementation, Challenges

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Introduction

STEM (Science, technology, Engineering and Mathematics) is a term that is an emerging field in education. This is important to cope with the challenges of 21st century and for the advancement of science and technology. It is used as an important strategy by teachers for creativity and innovation in science and technology. Pakistan Ministry for planning, development and reforms has conducted a survey in which it was observed that teachers of our country are competent, but they don't show their full potential due to low salaries and lack of motivation. The government of Pakistan has recognized the need for and importance of STEM education and now they are trying to include this in the formal curriculum (Hali et al., 2021).

There is worldwide emphasis on STEM education, but developing countries are still trying to experience how their education system should be updated so that it can meet the standard of 21st-century education and produce a skilled workforce. Existing studies mostly focus on the performance of students and policy alignment regarding STEM education, but there is a gap regarding teacher preparedness, infrastructure challenges, and policy framework regarding STEM education in developing countries like Pakistan. Developed countries like the USA, China and Europe are investing high in STEM education to enhance the critical thinking and problem-solving skills of students (Rehman et al., 2025).

STEM education has gained prominence globally to foster innovation, problem-solving, critical thinking, and adaptability (Schweingruber et al.,2014). International research has emphasized that teachers' training, availability of resources and curriculum reforms are highly needed for effective implementation of STEM projects. There is a mismatch in the goals of the national curriculum and pedagogical practices in Pakistan. Research has shown that people have a positive attitude towards STEM, but there is no effective implementation. Moreover, our education system is still relying on rote memorization, ignoring the provision of problem-solving and critical thinking skills (Aslam et al., 2023).

In Pakistan, including in Islamabad, government policies such as the National Education Policy and programs led by the Pakistan Science Foundation aim to promote STEM teaching and learning. There are a lot of challenges regarding the successful implementation of STEM in Pakistan. There is a big issue in our country that we are still facing gender disparities in our education system. Girls are not encouraged to get an education in tribal areas and South Punjab. For this reason, we are not successful in

meeting the standard in STEM education. Recent initiatives include STEM teacher workshops under the PSDP ("Launching of STEM in Pakistan, Phase-I") and the establishment of STEM FabLabs to provide hands-on learning environments (Aziz et al., 2024).

However, several studies show persistent challenges in STEM implementation across Pakistan. For example, research on teacher trainers and trainees in Islamabad shows they have only moderate knowledge in STEM content, especially mathematics and engineering domains, though attitudes are positive. Similar studies in Punjab and South Punjab reveal infrastructural constraints, lack of professional development, and curriculum limitations.

Islamabad, being our capital, is a valuable case study because it contains a mix of well-resourced private schools and public schools that may lack in comparison, so the disparities are more visible. There are a variety of institutions and a lot of opportunities available to students.So the aim of this study was to explore the challenges of implementing STEM education in the locale of Islamabad.

Rationale of the Study

While there is growing literature on STEM in Pakistan, much of the research is national or provincial in scale; fewer studies focus in depth on Islamabad with direct data from teachers, administrators, and schools. Moreover, many of the existing studies point out challenges but do not comprehensively map their interactions (e.g. how teacher training, infrastructure, curriculum design, and policy environment together constrain implementation). Understanding these challenges in Islamabad will be helpful for policy makers, educational institutions, and teacher training bodies to design targeted interventions.

Literature Review

STEM education is a unified discipline of four academic fields that are Science, Technology, Engineering and Mathematics. It is widely used in various countries and is rapidly increasing the use of STEM disciplines. It is an interdisciplinary field that helps link independent disciplines, such as mathematics, technology, and engineering, with science to solve real-world problems. STEM education equips students with 21st-century skills necessary to address the challenges of this technological era. For this reason, STEM education is a benchmark for human resource development. It enhances the competitiveness of any country in the world. It is a key driver behind the motivation of students to learn science and technology (Kayan-Fadlelmula et al., 2022).

Now STEM has become a major trend in the contemporary education system to engage students in shaping a bright future. It has been integrated into the curriculum in different ways. This integration can be disciplinary, multidisciplinary, transdisciplinary and interdisciplinary. The most common integration of STEM is interdisciplinary because it helps to tackle real problems. For example, problems related to the environment, weather forecasting, waste management and topics of biological science, chemical science and technology (Suhirman & Prayogi, 2023).

STEM education has become a successful supporter for industrial development in several developed countries, like the USA and Russia. This is due to the latest reforms in their education system that motivate the students to participate in the modern economy (Börner et al., 2018). In developing countries, there are lot of challenges in the implementation of STEM education, as in Indonesia, there is more research is needed to learn how STEM education can be implemented successfully and effectively (Verawati et al., 2022).

STEM education is an innovative and exciting field for students to enhance their interest and to satisfy their curiosity about nature. This education improves the conceptual understanding of students because it helps to connect abstract thinking with concrete understanding. Robotics can also be used in subjects like history and literature provides the opportunity for active interaction. Different organizations have tried to make STEM education more interesting and accessible for students by using different techniques. Several challenges need to be addressed during its implementation that vary according to age, location and demand of people.

Many students have lost their interest in science and mathematics subjects during school days. The main reason is the abstraction of important concepts that must be imagined by the students. This causes ambiguity among the students, and they don't take an interest in them. For example, an atom is an abstract concept, and it is difficult to explain in front of students how different particles are present in an atom. Similarly, it is difficult to explain how information is transferred through cell phones without wires. Another problem is that teachers don't allow the students to work on real projects. There is a lot of stuff in the curriculum that is theoretical and leaves no space for practical work. There is a need to update the teaching techniques to figure out the issues properly (Qureshi& Qureshi, 2021).

STEM education provides the opportunity for playful experiences. Every child is curious from birth, and this curiosity has been enhanced with the help of playful activities and STEM provides these activities.

These activities are joyful and engaging and help to understand the concepts clearly. Availability of STEM education at an early stage for students can help them to strengthen their abstract concepts of science and mathematics. They help the students to gain meaningful learning, and they can understand what they have seen and done. These activities also provide interactive ways to learn effectively (Verawati et al., 2022).

Early education in the classroom is the best place to provide STEM education, as it works as a solid foundation for STEM. Young children are curious, and their STEM skills can be enhanced through singing, dancing, playing, reading and imitating. Different techniques used by teachers boost the confidence of students and their attitude towards science. These techniques should be effective; otherwise, students lose their interest in science and mathematics. They considered that these subjects are complex and avoid learning them. Moreover, abstract concepts of mathematics and science can be made attractive with the help of technological tools.

In Pakistan, there is an alarming situation regarding science and math. The need is to provide more facilities for schools, suitable blended learning facilities, more trained teachers and lab equipment. STEM education was introduced in 2022 in Pakistan's Single National Curriculum (SNC). Policy emphasized that there should be high-level and high-quality human resources to meet the standards at the international level. It is important to focus on the training of teachers so they can enhance their knowledge and abilities in the field of STEM education. Many efforts have been made to make reforms in science and mathematics in the field of STEM, but there are still no desired changes. Research has shown that a lack of proper infrastructure and interest of different stakeholders give poor results regarding the implementation of STEM (Soomro & Malik, 2025).

Teachers should have Pedagogical content knowledge for the successful implementation of STEM education. They can apply relevant strategies successfully and can plan the different tasks for students. Research has shown that those teachers who have strong PCK are better able to integrate STEM education. They achieved more participation of students effectively. Most teachers have a better understanding of STEM PCK, but they have fewer skills to integrate technology with scientific integration in STEM. It is a holistic discipline that requires strong technological skills and expertise to integrate with four disciplines (Ahmad, 2023).

Attitude is an important factor for the implementation of STEM education, as it is a mental state that is about a particular process. Research has shown that attitude regarding the transdisciplinary nature of

STEM helps to support the self-efficacy of teachers. It involves the efforts of teachers to integrate classroom teaching with real life context. Technology has advanced and become an integral part of every field. It is needed that 21st-century skills be inculcated among the teachers. They can apply problem-solving and critical thinking to enhance learning and teaching (Ichsan et al., 2023).

It is reported in the literature that STEM education helps to enhance 21st-century skills among students for science learning. It can encourage the students to learn, and this motivation leads to achieving student learning outcomes. It also improves the attitude of students toward learning, and they can integrate their learning with real-world problems (Verawati et al., 2022). Science students must have learnt skills like critical thinking, problem solving, collaboration and creativity and it is only possible by integrating four fields like STEM education. Different tools can be used like educational robots that are used for technology integration like STEM. In many institutions, the science and mathematics portion of STEM education is more focused, and the engineering and technology portions are ignored. Students are not prepared for the digital world. Robotics provides this opportunity that the technological part of STEM can also be nourished to prepare the students for 21st century (Latip et al., 2022).

Purpose Statement

The purpose of this study is to explore and analyse the key challenges in implementing STEM education in Islamabad, particularly in relation to teacher readiness, infrastructural and resource constraints, curriculum and assessment practices, and the policy-practice gap.

Research Questions

1. What is the level of teacher content knowledge and pedagogical readiness for STEM education in Islamabad?
2. What infrastructural and resource-based barriers exist in schools in Islamabad for STEM implementation?
3. In what ways does the current curriculum and assessment design hinder or facilitate STEM practice?
4. How do policy frameworks, administrative support, and monitoring influence the actual implementation of STEM in Islamabad schools?

Research Methodology

It was qualitative research in which a phenomenology design was used to learn about the lived experiences of participants about a

particular phenomenon. It helps to reveal the essence and uncover the meanings of the experiences of participants in their perception.

Population & Sample

Only twenty teachers were selected through purposive sampling. Ten teachers were from the Public sector and ten teachers were from private schools from Islamabad Capital Territory (ICT).

Data Collection

Interviews/focus groups about challenges, resource availability, curriculum/assessment issues, policy and administrative support. Document review of policy documents, curricular frameworks, recent government projects (e.g. PSDP, STEM projects) in Islamabad.

Data Analysis

Qualitative data collected through semi-structured interviews. The data were analyzed through thematic analysis to extract major themes related to challenges and enablers. Method used for thematic analysis introduced by Clark and Braun (2013). It was a six-step process that included transcription, coding, and categorization. Research applied open coding firstly to highlight repeated statements in the interview. These codes were refined through axial coding. It helps to identify a relationship across teachers' readiness, curriculum reforms, policy framework and its implementation and resources. At the end, selective coding was done to ensure the consistency of broader themes with research questions.

To ensure credibility, triangulation was employed by comparing teacher perspectives with national policy documents (e.g., STEM Phase-I PSDP project) and existing curriculum frameworks. The following themes emerged.

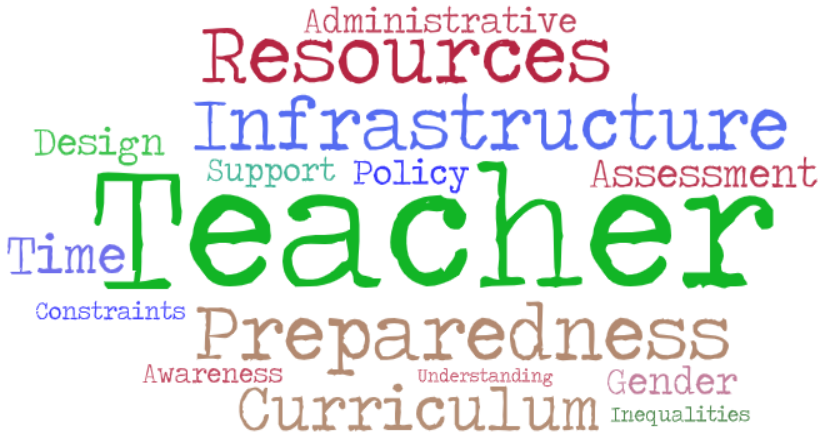
Validity / Reliability

Researcher used validated instruments where possible (e.g. STEM content / pedagogical knowledge scales), and pilot testing.

Triangulation was done across data sources (survey, interviews, documents) to confirm findings.

Results

Based on similar studies in Islamabad / Pakistan, the following are commonly observed findings. Different themes had emerged.



Teacher Preparedness

Moderate content knowledge in STEM across teachers and trainers, with weaker performance particularly in mathematics and engineering domains.

Positive attitudes toward STEM, but insufficient pedagogical content knowledge (how to teach STEM in integrative, project-based ways).

Infrastructure & Resources

Many public schools in Islamabad lack well-equipped science laboratories, ICT facilities, robotics or project-based learning spaces.

Resource constraints also include lack of materials, shortage of computers, intermittent internet, etc.

Curriculum and Assessment Design

Rigid curriculum design oriented toward examinations following rote learning rather than inquiry, experimentation, or cross-disciplinary integration.

Assessment practices are largely summative, and do not adequately assess 21st-century skills like collaboration, problem-solving, creativity.

Policy / Administrative Support

While there are policy initiatives (e.g., PSDP projects, teacher training workshops) in Islamabad and federal level, implementation is uneven. Some schools do not receive follow-up, resources, or support.

Monitoring and accountability mechanisms are weak; policies are sometimes more ceremonial than effectively enforced.

Other Challenges

Gender inequalities: Female students and teachers may face extra cultural or social barriers (Abbas et al., 2023).
Time constraints: The Syllabus in our schools is heavy and teachers are bound to finish it in a limited and prescribed time. It is a time-consuming process to plan STEM activities and implement them alongside heavy syllabi.
Awareness/understanding: Some teachers and students have limited exposure to what STEM pedagogy entails beyond textbook teaching. They are bound on their current knowledge and don't try to enhance it or learn something new.
Concern of students: Active engagement of students also becomes a serious concern for teachers in STEM education. It hinders the learning and interest of students in STEM. Sometimes it is due to the behavior of teachers as they underestimate the abilities of students and students become demotivated.

Discussion

These findings reflect and extend what prior research in Pakistan has shown. For instance, the study by Soomro & Malik (2025) in Islamabad showed moderate knowledge among teacher trainers/trainees but noted deficits in specific STEM domains and pedagogical integration. The readiness paradigm in Punjab's public schools similarly underscored that teacher competencies and innovation pathways are stifled by lack of institutional backing and resources (Younas et al., 2025).

In Islamabad, despite being the capital with relatively more resources and policy attention, many of these barriers persist, especially in government / low-resourced schools. The gap between policy existence and classroom practice is evident: workshops and policies are launched, but many teachers do not feel sufficiently equipped, and infrastructural constraints hinder application (Saifuddin et al., 2024).

Curriculum and assessment are major impediments: when examinations reward memorization and when test designs are misaligned with hands-on or inquiry-based learning, teachers are less motivated to adopt STEM practices, even if aware of their benefits (Abbas et al., 2023).

Teacher training shows promise, but projects are recent and often episodic (e.g., short workshops). For real impact, continuous professional development and follow-up support are needed. The setting up of STEM FABLABs is a positive step (Azeem et al., 2024).

Conclusions

The challenges to implementing STEM in Islamabad are multifaceted: teacher knowledge and pedagogical skills, infrastructure/resources, curriculum and assessment design, and policy / administrative follow-through.

Even where there is positive attitude and policy intent, structural barriers limit full implementation. Without addressing all these elements in an integrated manner, efforts to improve STEM education may not produce desired outcomes (e.g., enhanced critical thinking, innovation, problem solving).

Recommendations

Based on the findings, the following actionable recommendations are suggested:

Sustained Teacher Professional Development

We should create long-term training and mentorship programs rather than one-off workshops. Training should be sustained to continue the professional development of teachers. Emphasis on pedagogical content knowledge, project-based and inquiry-based STEM teaching, and mathematics and engineering domains.

Infrastructure & Resource Investment

A major challenge in the poor implementation of STEM is the weak infrastructure of schools. The need is to equip schools (especially public ones) with science labs, ICT tools, internet access, project-based learning spaces, and necessary teaching materials.

Curriculum & Assessment Reform

Revise curricula to integrate cross-disciplinary STEM projects, allow flexibility, and encourage experimentation. Reform assessments to include hands-on, problem-solving, performance tasks, formative assessment, not just rote memorization.

Policy Implementation & Monitoring

There are a lot of policies formed in Pakistan but failed to be implemented practically. Strengthen oversight of STEM initiatives: ensure that when workshops or policies are introduced, there is follow-up support, assessment of uptake, and resources allocated. Develop clear guidelines for schools, inspection bodies, and education departments to

standardize expectations for STEM implementation.

Address Gender and Equity Issues

We should remove gender disparities among people to promote equity. Especially in remote areas, there is very little participation among females in STEM activities. We should promote female participation by removing cultural/social barriers, ensuring safe and supportive environments. Allocate more resources to less advantaged schools to reduce disparities. We should give equal representation of urban and rural areas.

Community and Stakeholder Involvement

Community involvement plays a very important role in the successful implementation of any program. We should engage parents, industry, universities, and NGOs in supporting STEM education (donations, mentoring, and field realities).

Implications

For Policy Makers: The study shows that policy directives alone are insufficient: planning must include budget, infrastructure, teacher capacity, monitoring, and equity to be effective. There should be strict monitoring for the practical implementation of policies.
For Teacher Training Institutions: Must design programmes that are contextual, continuous, and focus on both content and pedagogy; support in mathematics and engineering may need particular emphasis.
For Schools and Administrators: Should prioritize resource allocation for STEM, support teacher innovation, collaboration among teachers, and sharing of best practices.
For Future Research: More empirical studies focused on Islamabad with large sample sizes; longitudinal studies to see change over time; evaluation of interventions (e.g. FABLABS, mentorship programmes) to see what is effective.

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