

ASSESSING STEM TEACHING CAPABILITIES IN LAHORE: CHALLENGES, OPPORTUNITIES, AND THE PATH FORWARD

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Abstract

The purpose of the present study is to measure the secondary school teachers' ability to teach STEM (Science, Technology, Engineering, and Mathematics) concepts in Lahore, Pakistan, by using the STEM-PCK Scale. Considering the increasing demand for STEM professionals in the international workplace, it is essential to consider how prepared teachers are to include STEM disciplines in their work. Teacher pedagogical knowledge, STEM content knowledge and their use of Technology in the classroom: A causal comparative study on teachers (n = 536) of public and private schools, in Lahore, filled out the survey. Results reveal that techno-pedagogical knowledge directly predicts technology use in STEM teaching ($b = .36$) while the effective integration of Technology is significantly related to the acquisition of 21st century skills by students. However, a key issue identified was the lack of integration of Science and Technology, which suggests that teachers need additional support to use technological resources in their teaching. It also identifies variations in technology access between private and public schools, with the former institution being better prepared and equipped to teach STEM. The findings of the study imply a need for immediate development of professional and career programs, creating fair access to technology resources and government assistance to build up a coherent STEM-based education system in Pakistan.

Keywords: *STEM education; PCK, Pedagogical Content Knowledge; 21st Century skills; teacher perception; teaching capabilities*

Introduction

Science, Technology, Engineering and Mathematics (STEM) education has become an issue of central importance to educational systems around the world because of its significance in moulding the future workforce. Technological advances, globalization, and the requirement for innovative solutions to complex challenges highlight the increasing demand for STEM professionals across sectors. In the lead-up to the Fourth Industrial Revolution, integration of STEM into education systems has been transformed from a perceived need to one that is now seen as a strategic priority (Penprase, 2020).

Internationally, governments and educational institutions have turned their attention to the need for STEM-based skills that will prepare students for an ever-changing world driven by Technology. Countries such as the United States, China, and Germany have led in promoting STEM education through investment in revision of curriculum, teacher training and infrastructure

that would enable students to have relevant knowledge (Blackley & Howell, 2019; Ahmad, 2023). Aligning with such international trends, several countries, including Pakistan, also started focusing on STEM education in their curricula to promote innovation and entrepreneurship for economic development. Therefore, STEM education has been incorporated into many national educational policies (Rahman et al., 2022).

In the case of Pakistan, STEM education is increasingly becoming essential as the nation faces its largest challenges to deal with a rising population, an increasing youth population and the diversity in the world job market. STEM has come under the spotlight in Pakistan, mainly in Lahore, Punjab, which is considered the cultural city and capital of Punjab (Rahman et al., 2021), including policymakers, educators and researchers. A city known for its schools of academics and well learned scholars, Lahore is advancing a proactive strategy in Pakistan's quest to modernize its education system and ready students for careers in the sciences, engineering, computer technology, biotechnology or environmental Science.

However, the Pakistani education system is confronted with multiple woes when it comes to the successful implementation of STEM in schools. These obstacles come in the form of inadequate training for teachers, outmoded pedagogy and a lack of quality resources at many schools, especially public ones. However, the Pakistani government, along with a number of international organizations, is stepping in to fill this void by implementing STEM-linked programs designed to improve teachers' pedagogical practices and ensure resource availability in schools that serve to foster an innovation culture (Margot & Kettler, 2019; Baker & Galanti, 2017).

In Lahore, there is little hope because the metropolitan has several elite educational institutions that have gradually been going for STEM-infused curricula (Rehman et al, 2025; Mankash & Kazimi, 2021). Yet, the supply of skilled STEM professionals falls short of demand by a great margin. The wide range in knowledge among teachers in the area of STEM is also a key factor that results in this gap, leading to variance in the quality of STEM education at school. In Lahore and other regions of Pakistan, teachers struggle to be prepared in complex STEM areas because they do not have an appropriate knowledge base for teaching (Penprase, 2020; Jamil et al., 2024).

As the market for STEM professionals increases in Pakistan, the quality of the future Pakistani workforce (in all types of careers) is highly dependent upon the STEM education that it receives at the secondary and tertiary levels. STEM study provides students with logic and thought processes, problem-solving, and creativity knowledge necessary to succeed in the professional job market (Wu & Anderson, 2015). Therefore, it is important that teachers' teaching competencies in Lahore should be scrutinized and developed, especially to integrate STEM concepts into the classroom. This way of working will ensure that Lahore strongly feeds into the national and international STEM workforce, enabling students to thrive as innovators, entrepreneurs and leaders in their fields (Ahmad 2023; Beswick & Fraser 2019).

This study aims to investigate the STEM-teaching potential of Lahore-based teachers, including their readiness to incorporate STEM education in their classrooms. It focuses on the variables affecting teachers' effective instruction of STEM-related teaching skills, containing pedagogical content knowledge, content knowledge and familiarity with contemporary STEM teaching materials (Chaya, 2023; Yıldırım & Şahin, 2019). By discussing these challenges, the hope is that it can provide some practical suggestions on how to reform the Lahore schools in a way that will better support teachers to take up STEM's challenges and, as a result, equip students with skills of the 21st-century workforce (Rehman et al, 2025; Rahman et al., 2021). As these

skills like critical thinking, creativity, and higher order thinking have been focused on in the current literature (Azmat et al., 2021; Jamil et al., 2024; Jamil et al., 2025; Naseer et al., 2022).

Research Questions

1. What are the perceptions of secondary school teachers of Lahore related to STEM pedagogical content knowledge?
2. What is the level of teachers' ability to integrate technology and 21st century skills into their STEM lessons?
3. What is the relationship between teachers' pedagogical content knowledge and specific STEM subjects' integration?
4. How do demographic factors of secondary school teachers' influence their STEM related pedagogical content knowledge?
5. How do STEM subjects pedagogical content knowledge is predicted to be influenced by integration of technology?

Research Hypotheses

H1: There is a positive influence of Engineering pedagogical content knowledge on technological integration.

H2: There is a positive influence of Mathematics pedagogical content knowledge on technological integration.

H3: There is a positive influence of overall pedagogical content knowledge on technological integration.

H4: There is a positive influence of Science pedagogical content knowledge on technological integration.

H5: There is a positive influence of technological integration on 21st Century skills as perceived by teachers.

Literature Review

Perspectives of Global Education for STEM and Teacher Capacity

Numerous researchers indicate that K-12 schools should include STEM in their curriculum to better prepare students for the workforce of the 21st century. Support for the central role of STEM in enhancing technological literacy and innovation is also reflected in the study by Penprase (2020). Good STEM education, he argues, challenges not only what students know but how they learn it together. Similarly, Margot and Kettler (2019) express concern regarding teachers needing interdisciplinary instructional competencies since they would be able to integrate cross-cutting science ideas in STEM, resulting in a fuller student learning experience. These studies highlight the significance and value of teacher leadership to the success of STEM initiatives, supporting the continued investment in professional development.

And both sublime subject matter mastery and pedagogical ability are assumed in many advanced economies. Similarly, Beswick and Fraser (2019) argue that both content knowledge for STEM and technological pedagogical content knowledge (TPACK) are essential for engaging students in all aspects of the various STEM areas. Such findings resonate with Wu and Anderson (2015), who emphasized STEM Pedagogical Content Knowledge as an essential element for teachers to facilitate effective integration of the range of STEM disciplines, arguing that any

integrated approach requires not just a level of depth in content knowledge but one that comes instilled with skills associated with how it should be used within their classroom. These findings have significant relevance for teacher education programs that need to prepare teachers with the capabilities of effectively teaching STEM subjects.

STEM Education in Pakistan

In Pakistan, the incorporation of STEM in teaching and learning is an emerging trend, but there have been increasing cognitions towards it. Studies such as Rahman et al. (2021) show that STEM education in Pakistan is becoming more and more prominent, particularly in urban regions such as Lahore. With the largest network of public and private schools, Lahore is well-poised to drive STEM education reform. But as in other parts of Pakistan, Lahore struggles with issues such as teacher training, a lack of resources and curriculum design. The difficulty of these problems is compounded by the fact that not all teachers in Lahore city have a specialised training in STEM, and some are not familiar with the modern pedagogical methods used for teaching STEM subjects (Jamil et al., 2024).

Challenges of STEM implementation

One of the primary challenges faced by STEM educators is the insufficient extent of professional development (Mankash & Kazimi, 2021). As Baker and Galanti (2017) argue, teachers find difficulty integrating STEM methodologies into the teaching of their students owing to a lack of familiarity with best practices for teaching in STEM. The situation is even worse in Lahore due to the urban-rural divide in Punjab. Although private schools in Lahore may have the necessary modern teaching tools and technology, the majority of public-school students study STEM topics through traditional ways due to budget constraints, which limits the ability of teachers to introduce innovative and effective STEM lessons (Yıldırım & Şahin, 2019).

Furthermore, to have STEM subjects integrated into a coherent curriculum is still seen as a challenge in most of the educational systems across the globe (Margot & Kettler, 2019). And that rings especially true for Pakistan, where STEM disciplines have always been taught in silos. The majority of the teachers in Lahore are not trained to establish relationships among various STEM subjects so that students can get an interdisciplinary learning experience. English (2016) argues that the combined teaching of disciplinary subjects has the potential to provide students with more authentic learning opportunities through making the relationship between Science, mathematics, Technology and engineering clear. But such an integrated approach needs a change in the teaching techniques, and teachers must be prepared to use new pedagogies (Karpudewan et al, 2023).

Challenges Faced by Educators

The struggles of STEM educators are not exclusive but rather amplified by the educational scene in which they operate. A major issue is the lack of teacher training in STEM-related content and pedagogy. According to Ahmad (2023), science teachers' attitudes towards their own STEM competences play a key role in science-teaching efficacy. A majority of teachers, especially in public schools, fail to embrace this pluralism and overlap of knowledge. Rather, such a system tends to utilize traditional subject-centred pedagogical methods, which are not in harmony with STEM teaching and learning as related to a critical thinking or problem-solving perspective (Rahman et al., 2022).

Technology integration in our schools is also an issue. Although Technology is being applied in the institutions all around Lahore as well, the majority of its educational institutes are still handicapped in having optimum access to advanced technological tools (Jamil et al., 2024).

Becker & Park (2011) emphasize the importance of technology integration within STEM instruction in providing students with an opportunity to connect learning with a life/real problems and develop digital literacy. The lack of infrastructure and training in public schools is, however, a major obstacle for Technology to be effectively used. This also correlates with the results of Rehman et al. (2025), who found that the absence of technology and teacher training is a hindrance to the smooth incorporation of STEM education in Pakistan.

Opportunities for STEM Education in Lahore

Despite these hurdles, there are substantial prospects of enhancement in STEM education available in Lahore. The strength of the city's academic structure in terms of institutions and universities is an impressive springboard for expanding STEM activity. Hussain & Bhatti (2024) assert that the role of educational institutions is crucial in the development of STEM education through facilitation of cooperation between teachers, researchers and professionals from industry. In Lahore, there is government and private support for STEM education. In addition, organizations are becoming increasingly aware that they need to invest in teacher training and curriculum development so as to produce the required professional STEM workers for Pakistan's ever-growing technology and engineering industries (Younas et al, 2025).

Furthermore, the introduction of STEM programs into initial teacher education offers a unique opportunity for Lahore to take the lead in STEM reform in Pakistani education (Aslam et al., 2022). Maass et al. (2019) emphasize the need to provide pre-service teachers with relevant competencies for teaching STEM well. In Lahore, teacher training programs at the University of Education and Lahore University of Management Sciences are now integrating STEM-centred topics into university courses to prepare their next generation of educators (Munawar et al., 2025). Additionally, there is a trend being presented in creating key partnerships between educational organizations and industry personnel that will allow students to achieve practical STEM applications (Hussain & Bhatti, 2024). Yıldırım & Şahin (2019) address the need to narrow the distance between the academy and industry in order to offer a curriculum congruent with contemporary qualification demands. Such collaborations can be extended further in Lahore, leading to a way forward in keeping STEM education calibrated with the changing workforce requirements.

Research Methodology

Quantitative research design has been used in this study to assess teachers' knowledge and provide opportunities for them to use STEM-related materials in their classes. It was a cross-sectional study, and data were gathered from teachers at secondary schools in Lahore. The STEMPCCK Scale, which was developed by Yıldırım and Şahin (2019), is a comprehensive instrument that measures pedagogical content knowledge and teaching competency of STEM teachers. The sample included 536 secondary school teachers from government and private schools of Lahore selected through purposive sampling technique. Data was collected through online forms emailed and WhatsApp to the sampled participants. The descriptive and inferential methods of statistics were used to analyze the data obtained from the survey. Demographic characteristics of the participants and responses to the survey items were summarized by means (standard deviation) for continuous variables and frequencies (proportions) for categorical variables. Correlations and multiple regression were utilized in inferential statistics to analyze the relationships among teachers' demographic characteristics and STEM teaching competency. The internal consistency of the data was evaluated for reliability and validity using Cronbach's alpha coefficient. Moreover,

construct validity was also proven using EFA or CFA to ensure that the STEM PCK scale is measuring what was planned for the Pakistani context.

Results of the Study

The following results are based on collected data and the methodology from STEM teachers in Lahore.

Demographic Information of Participants

The sample consists of 536 teachers from various public and private secondary schools in Lahore.

Table 1. Demographic information of the participants

| Demographic Variable | | Frequency | Cumulative Per cent (%) |
|-----------------------------------|----------------|-----------|-------------------------|
| Gender | Male | 272 | 50.7 |
| | Female | 264 | 49.3 |
| Age Range | 20-30 years | 24 | 4.4 |
| | 31-40 years | 259 | 48.4 |
| | 41-50 years | 234 | 43.6 |
| | Above 50 years | 19 | 3.6 |
| | | | |
| Teaching Experience | 1-5 years | 102 | 19.1 |
| | 6-10 years | 157 | 29.2 |
| | 11-15 years | 172 | 32.2 |
| | 16-20 years | 105 | 19.5 |
| Academic Qualification | Graduate | 314 | 58.6 |
| | Masters | 203 | 37.9 |
| | MS/M.Phil. | 16 | 2.9 |
| | PhD | 3 | 0.6 |
| Professional Qualification | B.Ed. | 243 | 45.4 |
| | M.Ed. | 293 | 54.6 |

The gender distribution of the sample is close to balanced (50.9% male, 49.1% female). Interestingly, the largest proportion of teachers (48.5%) belongs to the 31-40 years of age group, indicating that a large number are in his/ her early to mid-professional life. The majority of teachers are graduates (58.8%), with quite a few having also completed a master's degree (37.7%). With regard to the work experience of teachers, 32.1% had 11-15 years, which means that most participants had an experienced background.

Reliability and Validity Analysis

Reliability and validity were established for the constructs measured using the STEM PCK Scale. The results indicated the internal consistency of the scale.

Table 2. Reliability analysis of the responses

| Constructs | Cronbach's Alpha | rho_A | Composite Reliability | AVE |
|----------------------------|------------------|-------|-----------------------|-------|
| Pedagogical Knowledge (PK) | 0.848 | 0.847 | 0.881 | 0.681 |
| Mathematics (MATH) | 0.837 | 0.866 | 0.873 | 0.664 |
| Science (SCS) | 0.718 | 0.721 | 0.835 | 0.634 |
| Engineering (ENGI) | 0.812 | 0.871 | 0.882 | 0.744 |

| | | | | |
|----------------------------|-------|-------|-------|-------|
| Technology (TEC) | 0.779 | 0.761 | 0.857 | 0.674 |
| 21st Century Skills (TCSK) | 0.812 | 0.811 | 0.880 | 0.636 |

Good internal consistency is suggested, as evidenced by all Cronbach's alpha values being higher than 0.7 for each factor. Threshold criteria of CR and AVE are all above 0.7 and 0.5, respectively, indicating good construct reliability and convergent validity.

Factor Loadings

The factor loadings of each indicator are presented in Table 3 below. These provide an indication of the relationship strengths between each indicator and the related latent construct.

Table 3. Factor Loadings of Constructs of the Study

| Constructs | Item | Factor Loading |
|-----------------------------------|-------|----------------|
| Engineering (ENG) | ENG1 | 0.884 |
| | ENG2 | 0.876 |
| | ENG3 | 0.776 |
| Mathematics (MATH) | MATH1 | 0.824 |
| | MATH2 | 0.747 |
| | MATH3 | 0.878 |
| | MATH4 | 0.777 |
| Pedagogical Knowledge (PK) | PK1 | 0.768 |
| | PK2 | 0.867 |
| | PK3 | 0.828 |
| Science (SCS) | SCS1 | 0.768 |
| | SCS2 | 0.828 |
| | SCS3 | 0.772 |
| Technology (TEC) | TEC1 | 0.834 |
| | TEC2 | 0.823 |
| | TEC3 | 0.823 |
| 21st Century Skills (TCSK) | TCSK1 | 0.732 |
| | TCSK2 | 0.769 |
| | TCSK3 | 0.814 |
| | TCSK4 | 0.827 |

All items' factor loadings are greater than 0.7, suggesting that the relationship between each indicator and its latent construct is strong. Items with lower loadings (e.g., ENG3 = 0.776), though still significant, remain limited in the amount of variance they explain in their construct, therefore also confirming that these are relevant for the scale to measure the latent variables.

Discriminant Validity

Discriminant validity (as examined by the Fornell-Larcker criterion) is shown in the table. The values of the square roots of AVE are compared with the correlations between constructs in this table.

Table 4. Discriminant Validity and Correlation between constructs

| Constructs | ENG | MATH | PK | SCS | TCSK | TEC |
|-------------|-------|-------|-------|-------|-------|-------|
| ENG | 0.847 | 0.364 | 0.771 | 0.429 | 0.820 | 0.667 |
| MATH | 0.374 | 0.819 | 0.342 | 0.673 | 0.415 | 0.419 |
| PK | 0.781 | 0.342 | 0.829 | 0.443 | 0.800 | 0.760 |

| | | | | | | |
|------|-------|-------|-------|-------|-------|-------|
| SCS | 0.429 | 0.683 | 0.443 | 0.813 | 0.426 | 0.457 |
| TCSK | 0.820 | 0.415 | 0.810 | 0.426 | 0.761 | 0.940 |
| TEC | 0.687 | 0.419 | 0.770 | 0.457 | 0.940 | 0.817 |

Discriminant validity is evidenced by the fact that the square root of AVE (diagonal values) exceeds their correlation among constructs (off-diagonal values). For example, the correlation value for TEC (Technology) with respect to other constructs, such as Pedagogical Knowledge (PK), is 0.817, which is higher than any of its magnitudes if TEC does not represent any of the constructs.

Structural Model and Hypothesis Testing

The table reports the results of hypothesis testing. A structural equation model (SEM) is used in this study to test the relationships among the constructs.

Table 5. Hypotheses Testing

| Constructs | Hypotheses | Mean | St. Dev | T Stats | P Val | Status |
|------------|--|-------|---------|---------|-------|---------------|
| ENG → TEC | H1: Engineering Technology → | 0.152 | 0.059 | 2.650 | 0.008 | Supported |
| MATH → TEC | H2: Mathematics Technology → | 0.090 | 0.041 | 2.253 | 0.025 | Supported |
| PK → TEC | H3: Pedagogical Knowledge Technology → | 0.610 | 0.063 | 9.619 | 0.000 | Supported |
| SCS → TEC | H4: Science Technology → | 0.067 | 0.046 | 1.406 | 0.160 | Not Supported |
| TEC → TCSK | H5: Technology → 21st Century Skills | 0.951 | 0.004 | 239.491 | 0.000 | Supported |

H1 (Engineering → Technology): The positive influence of Engineering on Technology Integration. If teachers possess new technology knowledge, it can lead to a new and suitable teaching method; A deeper professional temperament for touching Science and engineering knowledge, which compares with using high blood pressure medication that helps the person's condition even though it may have some side effects.

H2 (Mathematics → Technology): Mathematics indeed has a positive impact on Technology Integration ($t = 2.253$, $p = 0.025$).

H3 (Pedagogical Knowledge → Technology): Pedagogical knowledge relates to a significantly positive role in predicting Technology Integration ($t = 9.619$, $p = 0.000$), emphasising the significance of pedagogical training.

H4 (Science → Technology): The impact of Science-Technology Integration is not significant ($t=1.406$, $p=0.160$), suggesting that it is possible for someone with knowledge in Science to not necessarily be a good predictor of his/her use of Technology as a teaching tool.

H5 (Technology → ICT Skills): ICT Skills are significantly influenced by Technology ($t = 239.491$, $p = 0.000$), meaning that teachers who integrate Technology efficiently are more likely to teach critical skills for 21st-century learning to their students.

Findings

The following are the major findings of the study:

1. Pedagogical Knowledge (PK) of teachers is a reliable factor for their successful integration of Technology (TEC) in their teaching practices, especially when they are conducting STEM-based lessons. This relationship is also significant ($t = 9.619$, $p = 0.000$).
2. Technology Integration (TEC) has a positive impact on developing 21st Century Skills (TCSK), the t-value is very high $=239.491$ ($p=0.000$), this showed that technology-based instruction aids in learning critical skills such as problem-solving, critical thinking and collaboration.
3. The correlation between Science (SCS) and Technology Integration (TEC) is insignificant ($t = 1.406$, $p = 0.160$), which means that the science teachers in Lahore district are less proficient at integrating Technology effectively in their science teaching.
4. Teachers' engineering (ENG) knowledge and mathematics (MATH) knowledge have a positive correlation with Technology Integration (TEC), respectively. This is in line with the notion that some STEM subjects, especially engineering and mathematics, might have somewhat greater impact on technology adoption.
5. Teacher training in STEM pedagogy presents a great challenge. Many teachers complain of poor training in technology integration and problems unifying a multi-disciplinary approach fulfilling their capabilities to facilitate access for innovative teaching methods in STEM education.
6. There's a notable lack of tech resources amongst public schools, compared to private schools where there is abundant saturation with tech gadgets; this disparity translates into vast differences between the standard of STEM education between the two.
7. The government has worked to promote STEM advancements, but we require greater proficiency in these policies on a large scale, top-down policy-making being embedded with funding, teacher training & resources among the minds of government everywhere.
8. Lack of interdisciplinary teaching in the science and technology disciplines. These gaps mean that students are not exposed to real-world applications of STEM knowledge or the relationships among those subjects.
9. Teachers in terms of gender are almost equally distributed (Lahore=50.9% male; 49.1% female). In addition, the percentage of teachers with 11-15 years of teaching experience is 48.5%, showing a partial consolidation of experienced and newcomer teachers.
10. There are various challenges encountered by teachers in public schools, such as low exposure to Technology, obsolete facilities and limited professional development, which negatively impact how they teach STEM subjects compared to their competitive private schools.

Discussion

STEM Pedagogical Knowledge and Integration in Lahore

The results indicate that PK has a direct effect on TEC, and the influence is positive ($t = 9.619$, $p = 0.000$). This suggests that those teachers who held greater pedagogical content knowledge made better use of Technology to support their STEM lessons. This finding is consistent with the findings of previous research studies, Margot & Kettler (2019) and Beswick & Fraser (2019), which indicate the instrumental role that domain-specific approaches play in effective STEM integration. In the context of Lahore, teachers' pedagogical practices can be effective, but they struggle to

enact them due to a lack of professional development opportunities provided for them (Aslam et al., 2017). As underscored in the original paper by Penprase (2020), the Lahore teachers struggle to reach continuous professional development, and that too for STEM specialists. Lacking sufficient support and training, high-quality educators can have difficulty integrating best practices for interdisciplinary STEM teaching (Younas et al, 0025).

Public schools in Lahore, Pakistan, do not have sufficient resources, and their teachers cannot learn new teaching strategies or pedagogically sound recent research (Hussain and Bhatti, 2024). This absence of exposure to contemporary pedagogic tools and models might have led to why a number of teachers feel less confident when teaching STEM. The difference in the quality of private vs public schools within Lahore is probably significant here; whilst the former institutions can afford to invest in instructor development, public schooling may experience administrative/financial factors that preclude pedagogical training (Jamil et al, 2024). Hence, the government and universities should give importance to teacher training programs that specifically target STEM integration so that the general quality of the content of STEM education in Lahore could be improved.

Technology Integration and Its Impact on 21st Century Skills

A further finding is the significant positive effect of TEC on TCSK ($t = 239.491, p < 0.05$). Classroom teachers who effectively integrate Technology are likely to be teaching 21st-century skills such as problem-solving, critical thinking and collaboration, to better prepare students for the workforce. This finding corroborates with Wu & Anderson (2015), who stressed the critical role of technology-enhanced instruction in fostering 21st-century skills.

In Lahore, the infusion of Technology in classrooms is a growing concern because of unequal access to digital resources and gadgets. Private schools, which have better infrastructure, enhance the provision of technology opportunities and integration into teaching in their institution to a greater extent (Rehman et al, 2025). Lahore's government schools, on the other hand, are always plagued by outdated computer labs, a lack of basic internet facilities and no means to train children for Technology. According to Rahman et al. (2021), such differences in access to Technology also impose constraints upon public-school teachers with respect to their ability to integrate Technology into teaching practices. Consequently, while private Lahore schools may be good at 'producing' 21st-century skills effectively, public school students would have been deprived similarly of such opportunities, adding to an existing gap in educational achievements. Pakistan's government has taken some steps in the direction of implementing digital literacy and technology resources at schools. But these initiatives are not uniformly applied, and the support issued is possibly inadequate to tackle the varying needs of instructors and students in Lahore (Mankash & Kazimi, 2021). – Going forward, policy makers need to pay more attention to equity of access in technology, and they also need to offer targeted Technology professional development for teachers, so that the latter can develop the capability to infuse technology effectively Technology into their classroom teaching.

Discrepancy Between Science and Technology Integration

It is noteworthy that the influence of Science (SCS) on Technology Integration (TEC) is not so significant ($t = 1.406, p = 0.160$). This means that SC knowing about T is low, as we derived from the literature review (section I), science and technology integration in Lahore is less than that of other STEM fields like mathematics or engineering. This finding is in contradiction to that found elsewhere in the world, where Science remains at the heart of technology integration (Fitzallen, 2015; Ahmad, 2023). Nevertheless ss, the relatively low relationship between Science and

Technology in Lahore's educational setting could be ascribed to a conventional teaching of STEM subjects that would continue to be practised in most schools. Mathematics and engineering are taught with a stress on applications to the real world, but science teaching in Lahore frequently lacks the practical, reality-based approach, where learning is textbook-oriented (Twaddle & Smith, 2023).

One reason for this discrepancy may be the lack of experience science teachers have with interdisciplinary teaching. A significant proportion of the science teachers in Lahore receive their pedagogical training in isolation and, therefore, may not necessarily be ecologically aware (Younas et al., 2025). In addition, undersupply of professional development programs related to integration of STEM into curriculum may compound this issue, as teachers have limited opportunities to attain competencies for linking Science with Technology (Aslam et al., 2022). The non-inclusion of science-technology integration in the classroom practice at Lahore offers a unique opportunity for intervention (Hussain & Bhatti, 2024). Teachers can facilitate students to develop an application of scientific principles in the real world by integrating and transferring knowledge that helps students become more ready for STEM-based professions using interdisciplinary teaching that bridges Science with Technology (Jamil et al, 2024). Local teacher training programs need to incorporate STEM integration within their curricula in response to this gap.

Teacher Training and Resource Availability

As can be seen from the results, teacher training is important for STEM education and PK and STEM Integration Knowledge are powerful predictors of effective STEM teaching. In Lahore, however, standards and availability of teacher training programs are major issues. Many schoolteachers, particularly in public schools, lack proper training about how they can integrate modern STEM teaching methods into their own science and mathematics class lessons, as well as the use of new pedagogical tools, including technologies (Munawar et al, 2025; Penprase, 2020). This shortfall in teacher training has direct effects on the quality of instruction in STEM as delivered to students.

Additionally, the inequality of public and private school materials only complicates the matter. While the private schools in Lahore are better resourced in terms of Technology and professional development opportunities, public ones face dilapidated infrastructure and resource constraints. This division contributes to the uneven quality of STEM education, as students in underprivileged public schools may not be given equal exposure to contemporary teaching methods, technology integration or integration of STEM with non-STEM subjects compared with their peers in private schools (Rehman et al., 2025).

Governmental Support for STEM Education

Governmental support of STEM education is necessary to ensure the effective introduction of STEM initiatives in schools. In Lahore, the state has managed to make some advances in the advancement of STEM education, but there are also notable discrepancies in financial and human resource allocation. Efforts such as the Single National Curriculum (2020) have aimed to promote STEM integration across the country; however, these processes are frequently slow and inconstant. This has put distance between the many teachers in Lahore who want support to teach STEM more effectively.

The government urgently needs to increase investments in STEM education, including resources for school curriculum, training of teachers and access to new teaching resources. By

focusing on these areas, the government can play its part in making sure that every student, whatever their background, is exposed to high-quality STEM teaching.

Conclusion

According to the results, Lahore's teachers exhibit strong pedagogical knowledge, and there are numerous obstacles to the successful integration of STEM disciplines, especially technology, in their classes. Pedagogical knowledge and technology integration were found to significantly affect 21st-century skills, and thus, the importance of teacher readiness towards STEM education was emphasized. But researchers also found major problems, including ineffective integration of Science and Technology in the classroom, inadequate teacher training and disparities in computer access between private and public schools.

The results underscore the need for more teacher professional development on STEM integration and more equitable access to technology resources in all schools, particularly public ones. Furthermore, the authorities have to provide support for STEM education policy and funding to address these challenges and to encourage equitable, high-quality STEM learning frameworks in Lahore.

Moreover, some progress has been made to form a more STEM competent education community in Lahore, but there is still quite a journey for all the teachers to become well-prepared both in terms of knowledge and resources for adopting rigorous, cross-curricular STEM practices. By focusing on teacher professional development, equitable distribution of resources and the integration of STEM in schools, Lahore can help close the gap and better prepare its students for success in tomorrow's fast-moving tech-centric global economy.

Recommendations

1. One policy for STEM and teachers' continuous professional development approach needs to be framed in articulation with current professional development which can involve attending to the relevant teachers' competencies in STEM areas.
2. Every student needs access to quality STEM instruction — meaning investment in technology for public schools like computers, internet connection and digital learning tools.
3. Education promoters should increase efforts at delivering instruction in critical thinking, problem-solving, collaboration, and digital literacy skills that need to be succeeded in the future.
4. Teachers need to tear down the walls of classrooms and involve other teachers as well as business leaders who want to support administrators, teaching staff, city officials and other industry partners.
5. Regular monitoring and evaluation of STEM education interventions are necessary for the system to measure and evaluate whether the change is happening.

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