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Blending STEM Teaching and Technology-Enhanced Learning: Exploring Educator Beliefs and Practices at the University Level in Pakistan

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Abstract

This qualitative research study explored how Pakistani university teachers adopt and believe in Technology-Enhanced Learning (TEL) implementation in STEM education contexts. The researchers used purposive sampling within phenomenology to interview 18 STEM faculty members at various universities until the data reached the saturation point. Four core themes were explored using thematic analysis: Perceived Value of TEL, Barriers to TEL Integration, Digital Competence and Self-Initiated Learning, and Attitudinal Shifts and Resistance to Change. TEL gained appreciation from participants who recognized its power to engage students and offer flexible instruction. However, they emphasized technical difficulties, the absence of institutional guidelines, insufficient training, and the lack of promotion mechanisms for teaching advancement. Educational professionals displayed excellent adaptive capabilities with self-directed learning as an obstacle primarily during the COVID-19 pandemic. Efficient implementation of TEL requires institutions to provide complete assistance alongside structured training on digital teaching methods and technical infrastructure upgrades while endorsing teaching innovation policies. Educational institutions should consider building teaching and learning centers, implementing modular training programs, and developing national TEL standards to close digital gaps so that students can have equal access to opportunities in Pakistani higher education.

Keywords: Technology-Enhanced Learning, STEM Education, Digital Pedagogy, Higher Education Pakistan, Faculty Development

Introduction

In recent years, the integration of Science, Technology, Engineering, and Mathematics (STEM) education with Technology-Enhanced Learning (TEL) has become a noteworthy focus in higher education. Like other developing countries, Pakistan has also been listed in this focus. The urgency to renovate teaching methods is driven by the global shift toward digital classrooms and the demand for 21st-century teaching skills (Asad et al., 2021; Al-Ghurbani et al., 2022).

Despite this, Pakistani universities and higher education institutions face unique challenges, such as limited digital literacy, inadequate technological infrastructure, and inconsistent institutional support (Sain & Anggarini, 2023; Ghani et al., 2024). These practices and numerous challenges hinder effective TEL implementation in STEM education in general. A fundamental barrier is the adequacy of technological infrastructure. Many universities lack sufficient bandwidth, hardware,

and technical support to reliably run online components. Internet access in Pakistan remains limited—only approximately 35% of the population has Internet access, and the country ranks in the bottom quartile of the Inclusive Internet Index. Until recently, only a few campuses (outside top private institutions) provided campus-wide connectivity or devices for students. The digital divide is especially stark between urban and rural areas: students from remote regions often struggle with poor or non-existent internet connections and power outages, which disrupt online learning. During the pivot to online teaching in 2020, these issues became more apparent. One university teacher noted that only 40% of his students could join Zoom classes because of connectivity issues, with the rest unable to participate in the online sessions. Even in technology-related programs, such as computer science, students have reported "restricted access to the LMS" and online materials, indicating the patchy implementation of e-learning systems (Asad et al., 2021; Bajwa et al., 2024).

Another major challenge is the lack of institutional readiness and support for blended learning programs. Research has widely observed that Pakistani higher education institutions did not have robust e-learning policies or contingency plans before the COVID-19 pandemic (Jamil & Muschert, 2024). In a survey by Mahmood (2024), 98% of students reported that their university had no clear guidelines or policies to facilitate the blended learning process. This absence of a formal framework means that instructors often improvise using technology without pedagogical guidance, resulting in inconsistent experiences for students. Related to this is the scarcity of technical support: 87% of students in the same survey felt that insufficient technical support was available to help them fully utilize online learning platforms. Many STEM faculty members also lack instructional design support for developing digital content (Chikaji et al., 2024).

Despite these challenges, there have been success stories and gradual progress. Many students and teachers have discovered the benefits of blended learning: improved flexibility, more resources at their fingertips, and the ability to review recorded lectures, among others. In a study of three public universities found that students widely acknowledged the benefits of blended learning, such as a better understanding of content and a more engaging, "captivating" learning experience when online elements were effectively used. This favourable feedback has encouraged some departments to continue blended models post-pandemic as well. Moving forward, the key is to systematically address implementation barriers. Researchers recommend a multi-pronged strategy, including investment in campus IT infrastructure (reliable high-speed Internet, electricity backup), dedicated technical support teams for e-learning, and ongoing training for faculty to develop quality digital course materials (Alotaibi, 2022).

Specifically, implementing TEL within STEM disciplines poses additional difficulties. STEM courses often require practical labs, hands-on experimentation, and complex problem-solving sessions that do not easily translate into online formats. Developing virtual labs or simulations requires resources and expertise that most Pakistani universities lack.

Research Objectives

1. To explore university teachers' beliefs, attitudes, and perceptions regarding integrating TEL into STEM teaching practices in Pakistan.
2. To identify the current practices, enabling factors, and challenges influencing the effective implementation of blended STEM teaching using technology in Pakistani higher education institutions.

Research Questions

1. What are university-level teachers' beliefs and perceptions regarding integrating Technology-Enhanced Learning into STEM teaching in Pakistan?

2. What are the existing practices, facilitating factors, and challenges influencing the implementation of blended STEM teaching in Pakistani higher education institutions?

Literature Review

Integrating Science education with Technology-Enhanced Learning is globally recognized as a way to improve educational outputs. To enhance engagement and develop future-ready skills through STEM. However, this type of integration remains limited in the higher education sector. The Pakistani context has changed because of infrastructural, pedagogical, and attitudinal barriers (Asad et al., 2020). Key themes include faculty attitudes and digital competencies, current blended learning practices and obstacles, institutional and policy factors, student perspectives, and comparisons with similar developing countries. The goal was to provide a comprehensive overview of the findings and insights obtained.

Technology-Enhanced Learning has increasingly become a successful method of modern pedagogical reform and change strategies in higher education. In Science, Technology, Engineering, and Mathematics education, TEL aptitudes increase access, enhance instructional delivery, and support student engagement in learning. In Pakistan, integrating TEL into university-level and STEM education grants both significant opportunities and persistent challenges for teachers and learners. This study synthesizes key themes and findings from recent literature, focusing on the Pakistani university context.

Numerous studies have emphasized the transformation of potential TEL to improve educational delivery and accessibility at the university level. TEL platforms, such as Learning Management Systems, simulation tools, and virtual labs, have been shown to enhance conceptual understanding in STEM disciplines (Chikaji et al., 2024). Personalized learning experiences. These improvements are the result of interactive tools, particularly in the remote regions of Pakistan, which have helped bridge learning gaps. Furthermore, new initiatives, such as the STEM-5 program in Lahore, have successfully piloted outreach and coding camps to engage youth in STEM. Digital platforms have made this possible (Ghani et al., 2024). These initiatives demonstrate the scalability of the TEL system in engaging both teachers and learners, highlighting the positive reception of face-to-face, blended, and online formats (Alotaibi, 2022).

In previous studies, several barriers prevented extensive TEL adoption in Pakistan, especially in higher education departments. The most frequently cited limitations in the literature are unreliable internet access, infrastructural deficits, power outages, and inadequate institutional support (Sain & Anggarini, 2023; Ghani et al., 2024). Teachers and faculty members also reported this. However, they were aware of TEL's benefits but lacked structured training and incentives to utilize digital tools in their pedagogical teaching practices (Asad et al., 2021). Research conducted in Punjab medical colleges found that institutional readiness was inconsistent. Conversely, some studies have reported that faculty members lack the technical skills and departmental provisions required for practical use and implementation (Bajwa et al., 2024; Asad et al., 2021). In conclusion, studies summarize that TEL adoption often depends on self-effort and motivation. With minimal formal policies guiding TEL, integration can still succeed (Jamil & Muschert, 2024; Luo et al., 2020).

Faculty attitudes toward teaching and learning are key factors influencing TEL success. Teachers' positive perceptions alone are insufficient until they are backed by confidence in using digital tools and incentives to innovate the system and STEM teaching. A nationwide research review revealed a lack of systematic TEL training programs and a gap in instructional teaching design skills among STEM educators (Kim, 2021). Furthermore, Shah et al. (2012) reported five levels of engagement with technology among Pakistani teachers, from basic multimedia use to conceptualizations of

TEL as supreme. These five levels highlight the varied digital readiness of teachers among faculty and the need for differentiated learning strategies (Shah et al., 2012), as cited in Khan (2023).

Pupils in Pakistani universities normally express positive attitudes towards TEL, especially regarding self-directed learning, flexibility, and resource accessibility. Disparities persist based on socioeconomic status and geography. Students in rural areas struggle with access to Internet devices and consistent connectivity, raising concerns about digital equity (Al-Ghurbani et al., 2022). Efforts have been made to design more effective and inclusive e-learning systems. This includes local language content and mobile-optimized platforms, which are essential to ensure that TEL benefits are justifiably distributed (Rahmat et al., 2022).

TEL presents a transformative opportunity for STEM education in Pakistan. Although progress is evident, particularly in urban centers and private institutions, significant gaps remain in infrastructure, policy, and professional development (Jamil & Muschert, 2024). A sincere coordinated effort and equity-focused strategy are needed to bridge these gaps and fully realize the potential of TEL in STEM education in Pakistan (Siddiqui et al., 2023). Therefore, there is a need for pedagogy to promote digital classrooms focusing on life skills and critical thinking skills, which have been emphasized in recent literature (Ahmad et al., 2024; Jamil, 2021; Jamil, Chohan, & Tabassum, 2024; Jamil, Mehmood, & Shah, 2024; Jamil, Zahra, & Fida, 2024; Naseer et al., 2022)

Research Methodology

This study employed a qualitative research design. A phenomenology research design was used to explore teachers' beliefs and practices regarding STEM teaching and integrating Technology Enhanced Learning in Pakistan. A phenomenological research design was selected from qualitative research to explore participants' lived experiences (Creswell & Poth, 2016; Anjum et al., 2021). This study was conducted at selected universities in Pakistan. These targeted university faculty members were involved in teaching STEM and TEL. The purposive sampling technique was used to select participants who had experience with or were exposed to TEL practices in their teaching as this sampling technique is used to select participants fulfilling the purpose (Iqbal et al., 2022)

Data were collected using semi-structured interviews until data saturation was achieved. Seven participants participated in the 1st phase, seven in the 2nd phase, and four were exposed to the finalized themes in the third phase of data collection. The data collection process involved recruiting participants until data saturation was reached. Data were collected through semi-structured, in-depth interviews. An interview protocol was developed to explore the participants' beliefs, motivations, institutional support, challenges, and implementation strategies regarding TEL in STEM. All interviews lasted approximately 40-60 minutes. Furthermore, these were conducted in person or online, depending on the participants' preference and location. The responses were audio-recorded and transcribed for further analysis. Thematic analysis was used for the data analysis. Data saturation was achieved after 18 interviews, ensuring comprehensive coverage of the emerging themes. Member checking was conducted by sharing excerpts and interpretations with the selected participants, affirming the credibility of the findings. Peer debriefing and audit trails enhance the transparency and confirmability of the analysis process, thereby reinforcing methodological rigor.

Findings of the Study

Theme 1: Perceived Value of TEL in STEM Education

Participants widely acknowledged the potential of TEL to enhance student engagement and improve instructional flexibility.

"Technology can simplify complex STEM concepts. When I show simulations in class, students grasp the idea faster." (Participant 3)

"Blended learning is the future, said one teacher. It gives students more control over how and when they learn." (Participant 12)

"When I uploaded my lectures online, students said they felt more confident revisiting the material before exams." (Participant 8)

Theme 2: Barriers to TEL Integration

Educators have consistently highlighted infrastructural and institutional limitations as barriers to the successful adoption of TEL.

"I want to use more tools, but the internet is so unreliable at my campus, especially in the evenings." (Participant 5)

"Our university has no clear policy. We are left to figure it out on our own, which is frustrating." (Participant 10)

"Even if I want to innovate, I do not get any recognition for it. Research gets you promoted, not teaching." (Participant 16)

Theme 3: Digital Competence and Self-Initiated Learning

Most faculty members described their digital skills as self-taught, with limited formal training available through their institutions.

"Before COVID, I had never used Zoom or Moodle. I learned everything by watching YouTube tutorials." (Participant 1)

"We had no training sessions. I had to experiment a lot—and fail—before I got things working." (Participant 7)

"Some of us are trying to stay updated, but honestly, we need proper workshops and ongoing support." (Participant 14)

Theme 4: Attitudinal Shifts and Resistance to Change

While some educators embraced TEL, others disagreed with or struggled to transition from traditional teaching methods.

"I still believe face-to-face teaching is more effective, especially in subjects like mathematics." (Participant 2)

"There is resistance from older colleagues. They say online learning cannot replace real classroom experience." (Participant 11)

"It is not that we are against technology—it is just unfamiliar territory for many of us." (Participant 9)

Discussion

This study explores university teachers' beliefs and practices regarding the integration of Technology-Enhanced Learning in STEM teaching in Pakistan. The results provide a nuanced understanding of how institutional contexts, personal agency, and infrastructural realities shape the TEL and STEM theories.

By keeping the lens of comparison, past research and findings, and participants' responses in this study expressed a general recognition of TEL's potential to enhance STEM teaching effectiveness, student engagement, and teachers' role in STEM courses (Sain & Anggarini, 2023). Asad et al. (2020) concluded that positive attitudes were rooted in teachers' perceived benefits, such as flexibility, accessibility of digital content, teachers' involvement, and multimedia engagement (Rehman et al., 2025).

The results and key findings of this study are ambivalent for many educators. This contradiction reflects the broader patterns detected in the literature. There were also witnessed that teachers' beliefs span a continuum from enthusiastic acceptance to deep skepticism. Some participants were frightened by the loss of pedagogical or teaching control and expressed doubts about the quality of online STEM teaching and TEL learning (Cox et al., 2010).

Many teachers had to train themselves during the COVID-19 pandemic and lacked structured online pedagogical development, echoing findings in Pakistani and global contexts. Despite the growing interest, the lack of structured professional development remains a prominent barrier to effective TEL integration (Rehman et al., 2025).

Teachers have called for more training to bridge the gap between technical use and pedagogical innovation. Tools such as Moodle and LMS portals were used. Nevertheless, many teachers struggle to align them with learner-centered designs. However, infrastructure remains a persistent challenge. Participants in this study described unreliable Internet, outdated devices, and limited access to digital tools as barriers widely documented and published in the literature (Rashid et al., 2018). These constraints are especially severe in rural and public-sector universities.

Another key issue is the lack of institutional incentive. As reported in the literature, innovative teaching with technology is undervalued in Pakistan's promotion and evaluation systems (Sain & Anggarini, 2023). TEL adoption relies heavily on individual teacher initiatives, rather than systemic support.

However, the policy frameworks remain underdeveloped. National efforts in this field, such as Vision 2025 and Digital Pakistan, have received operational support at the institutional level (Rehman et al., 2025). Future researchers are slowly moving toward blended models, such as flipped classrooms, discussions, and recorded lectures, using implementations that vary in context. STEM instructors reported using video content, simulations, and messaging platforms such as WhatsApp to supplement teaching.

Conclusion

Educators in Pakistan's higher education system piloted TEL implementation. Infrastructure hurdles, such as power supply instability and low bandwidth, are common in developing contexts. In many African and South Asian countries, universities must cope with electricity outages that disrupt online classes and server uptime. Pakistan's intermittent power supply was noted earlier and is a shared challenge for nations from Nigeria to Bangladesh. Alternative arrangements, such as solar power backups for ICT labs or offline content access, have been tested to mitigate this issue. In addition, language and local content availability are challenging. Much of the open courseware is in English, which is a second language in Pakistan and many other countries. Localization of the content and interface is needed to make TEL inclusive.

Recommendations

Based on the findings, the following recommendations are proposed to enhance the effective integration of Technology-Enhanced Learning into STEM education:

1. Professional development may extend beyond technical skill. This includes digital pedagogical competencies tailored to STEM disciplines.

2. Universities might integrate TEL into their strategic and academic policies.
3. To bridge the digital divide and support equitable TEL access, Internet connectivity, power supply, and hardware in universities, especially in rural and public institutions, might be upgraded.
4. There may be peer learning among educators to enhances their confidence and adoption rates
5. At the macro level, Pakistan's educational authorities might provide directions through developing a national TEL framework with quality standards, faculty training benchmarks, and minimum infrastructure guidelines.

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