04-44-AESSR-6302-1156

Academy of
Education and Social Sciences Review
Vol. 5 No. 4 | November, 2025 | 513 - 526
ISSN (p): 2790-8348 | ISSN (e): 2789-6781
DOI: https://doi.org/10.5281/zenodo.17768233

Exploring Science and Maths Teachers' Perceptions of STEM Education in Hunza, Gilgit-Baltistan

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Published online: 30 November 2025

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How to Cite:

Murtaza, B., & Qutoshi, S. B. (2025). Exploring Science and Maths Teachers' Perceptions of STEM Education in Hunza, Gilgit Baltistan. *Academy of Education and Social Sciences Review, 5*(4). https://doi.org/10.5281/zenodo.17768233

Publisher's Note:

International Research and Publishing Academy (*i*RAPA) stands neutral with regard to jurisdictional claims in the published maps and institutional affiliations.

Abstract

This qualitative case study explores the perceptions of secondary school science and mathematics teachers regarding STEM education in the context of Hunza. Data was collected from 10 teachers via a multi-method approach, including semi-structured interviews, personal meaning mapping, photo elicitation, and document analysis of lesson plans. Thematic analysis of the data revealed three overarching themes. First, teachers hold multiple, nuanced definitions of STEM education, primarily conceptualising it as integrated learning, technology-based instruction, a student-centred pedagogical approach, and, in one instance, specifically as robotics. Second, teachers perceived significant multifaceted benefits for students, including heightened motivation and active engagement, the development of robust problem-solving and critical thinking skills, early awareness of STEM career pathways, and a marked increase in student confidence. Third, teachers faced substantial systemic and operational challenges in implementation, such as profound difficulties in forming integrated STEM instruction due to a lack of cross-disciplinary content knowledge, lack of specialised in-service training, overwhelming time constraints within a rigid curriculum, and a pervasive lack of administrative and resource support. The study finds a significant gap between acknowledging STEM's importance and effectively implementing it. Thus, it recommends a comprehensive strategy that includes creating a clear, localised definition of STEM through collaboration, providing ongoing teacher training, reforming the curriculum for flexibility, and increasing administrative support and funding.

Keywords

Integrated learning

Professional development

STEM education

Teachers' perceptions of STEM

Teaching approach

INTRODUCTION

The relentless pace of global economic and technological change necessitates a fundamental transformation in educational paradigms. To get students ready for the challenges of the digital age, we need to move away from traditional, isolated teaching methods and towards a more interesting, hands-on, and cross-disciplinary approach. The global focus on Science, Technology, Engineering, and Mathematics (STEM) education is a good example of this change (Gonzalez, & Kuenzi, 2012). These skills include being able to solve problems in new ways, think critically and analytically, be creative, come up with new ideas, work well with others, and use technology (Mustam & Adnan, 2019; Perales & Aróstegui, 2024). The significance of STEM education lies in its unique ability to equip students with the necessary skills and knowledge to meet the demands and capitalize on the opportunities presented by a contemporary global economy primarily fuelled by technological advancements and innovation (Hallinen, 2024). It facilitates a culture of inquisitiveness and continuous learning, empowering students to investigate, interrogate, and uncover the phenomena of both the natural and artificial world.

Furthermore, STEM education has been shown to facilitate a more comprehensive and significant comprehension of fundamental concepts and principles across its constituent disciplines, highlighting their interrelatedness and practical implications (Perales & Aróstegui, 2024; Hallinen, 2024). Beyond academic achievement, it can foster a sense of identity and belonging among students within a society that increasingly esteems and promotes STEM fields, potentially increasing their inclination to pursue STEM careers and contribute to socio-economic welfare (Hallinen, 2024). However, despite its proclaimed potential, STEM education implementation encounters several universal challenges and limitations, including insufficient awareness, inadequate resources, issues of diversity and inclusion, and misalignment with existing curricula and standardized assessment regimes (Hallinen, 2024; Perales & Aguilera, 2024). These challenges are often exacerbated in developing nations.

In Pakistan, and particularly in remote regions like Gilgit-Baltistan, the integration of STEM education within the K-12 and tertiary levels is nascent and faces unique hurdles. The nation's STEM education system is often described as underprepared and unfocused, grappling with a lack of adequate regulatory measures and a low literacy rate that highlights significant gaps in educational quality (Hali et al., 2021; Aslam et al., 2022). While the necessity to enhance the "STEM pipeline" from school to the workforce is acknowledged globally (as cited in Washington et al., 2006 under National Science Board), achieving this in the Pakistani context requires a deep understanding of ground-level realities, starting with the teachers who are the primary agents of instructional reform (Bybee, 2013).

Teachers are the indispensable pedagogical leaders in their classrooms, and their role in implementing and sustaining educational innovations like STEM is paramount (Wang et al., 2011). Their attitudes, beliefs, and perceptions significantly impact their pedagogical choices and classroom practices, which in turn directly influence student learning outcomes and experiences (Margot & Kettler, 2019; Zhan et al., 2022). Teachers' views on STEM education include how they see its value, usefulness, achievability, and effectiveness, as well as how confident, skilful, and ready they are to teach in a way that combines different subjects and encourages students to ask questions. Previous studies indicate that educators frequently encounter several challenges, such as misalignment of curricula, resource scarcity, time limitations, inadequate training, and restricted collaborative possibilities (Margot & Kettler, 2019). They could also have wrong ideas or negative feelings about STEM, seeing it as a passing trend, a burden, or a threat to their professional identity (Al Murshidi et al., 2019).

There is a significant body of research on teacher perceptions in developed Western countries; however, there is a notable deficiency of studies examining how educators in socio-economically diverse contexts, such as Pakistan, particularly in its mountainous northern regions, perceive and engage with the concept of STEM education. This study seeks to address a significant need by examining the perceptions of secondary school science and mathematics educators in Hunza, Gilgit-Baltistan. It aims to comprehend how these educators delineate STEM, the obstacles they encounter in its execution, and the advantages they believe it provides to their students. The findings of this investigation are poised to provide valuable insights for curriculum developers, teacher trainers, and policymakers seeking to promote meaningful and sustainable STEM education integration in similar contexts. Thus, to carry out this study following research questions are developed.

- How do teachers perceive STEM education?
- What are the challenges that in-service secondary school teachers face in implementing STEM education in their classrooms?
- What are the opportunities for in-service secondary teachers in implementing STEM education in their classrooms?

LITERATURE REVIEW

The evolution and conceptualization of STEM education provide essential context for understanding current teacher perceptions. The acronym STEM, standing for Science, Technology, Engineering, and Mathematics, gained widespread prominence in the early 21st century, though its conceptual roots are deeper. The term is credited to the U.S. National Science Foundation, which initially used SMET before changing it to STEM for phonetic reasons. Its rise to global educational prominence can be linked to a response to international economic competitiveness and concerns about national security, notably after reports highlighted a comparative lag in the STEM competencies of U.S. students (Friedman, 2005; National Academy of Sciences, 2007). However, as Bybee (2013) extensively documents, the emphasis on science and mathematics education has earlier origins, tracing back to events like the post-Sputnik education reforms of the 1950s and 1960s, which marked a significant shift towards prioritizing these disciplines to ensure national defence and technological superiority.

A persistent and fundamental challenge in the field is the lack of a universally agreed-upon definition of STEM education. Due to the involvement of diverse interest groups—including governmental organizations, businesses, and educational institutions, each with distinct objectives—scholars have not reached a consensus on a single definition or approach (Siekmann, 2016). Academics also disagree on the nature of the relationship between the four disciplines, leading to a variety of classifications, from teaching them separately to fully integrating them (Bybee, 2013). Hasanah (2020) categorizes prevailing definitions into four broad categories: STEM as a Discipline, a Field, a Career path, and as an instructional approach. This ambiguity is reflected in the perspectives of educators themselves. A study by Radloff and Guzey (2016) found that preservice teachers' definitions fell into categories of instruction, integration, exclusion, and discipline. Likewise, Kelley and Knowles (2016) discovered that there was no standard interpretation of STEM among university staff, since perceptions were influenced by distinct academic backgrounds and mindsets.

Even if definitions differ, a common theme in modern literature is the focus on integration and application. Gonzalez and Kuenzi (2012) offer a comprehensive definition, characterising it as teaching and learning in the domains of science, technology, engineering, and mathematics at all educational levels and in both formal and informal contexts. Wang et al. (2011) define STEM as "an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons," which is more in line with the integrative view. They assert that instead of segregating the disciplines, STEM education ought to embody their interrelatedness in the actual world through problem-based learning. The notion of "STEM literacy" expands this idea – the capacity to recognise and utilise concepts from STEM fields to comprehend and tackle intricate, real-world issues that cannot be resolved through a singular disciplinary perspective (McDonald, 2016; Zollman, 2012).

Teachers' perspectives are a crucial factor in the efficacy of any educational innovation, including STEM. Studies show that teachers generally have a good opinion of the goals of STEM education. Research conducted with pre-service and in-service teachers from diverse nations, such as Indonesia, Saudi Arabia, and the UAE, indicates that educators acknowledge the significance of STEM for students' academic growth and future career opportunities, advocating for its incorporation into educational curricula (Al Murshidi et al., 2019). They agree that STEM applications link what children learn in class to what they do every day, help them learn how to solve problems, and can even affect their career choices. Primary school teachers also have favourable attitudes, but they frequently identify more significant challenges regarding use of STEM (Samara & Kotsis, 2023).

The evidence indicates that the perceived advantages of STEM education are diverse. For students, they include getting them ready for the global job market where STEM skills are in great demand, helping them think critically (Winarni & Rahman, 2025), and encouraging creativity and new ideas (Mok & Ren, 2021). Experiences in STEM can boost students' motivation, engagement, and self-efficacy (Chittum et al., 2017), as well as help them learn about and be interested in STEM jobs early on (Cohen et al., 2013).

Nonetheless, these prospective advantages are frequently mitigated by considerable obstacles encountered by educators throughout the implementation phase. A substantial corpus of research elucidates prevalent obstacles. One of the biggest problems is that there aren't enough trained teachers that know a lot about different subjects (El-Deghaidy & Mansour, 2015). This is exacerbated by a significant deficiency in sufficient pre-service and in-service professional development aimed at integrated STEM instructional approaches (Shernoff et al., 2017; Altan & Ercan, 2016). Teachers repeatedly express a lack of time for preparing and executing resource-intensive, project-based STEM classes amid a congested curriculum (Srikoom & Faikhamta, 2018). Other big problems are not enough support from administrators, not enough money, not enough lab supplies and tech tools, and occasionally students not being ready or motivated (Margot & Kettler, 2019). In underdeveloped nations such as Pakistan, these problems exist within a broader educational framework characterised by limited resources and a conventional examination-centric culture, rendering the integration of STEM extremely intricate (Aslam et al., 2022; Hali et al., 2021). This study aims to examine the manifestation of global themes within the specific, under-researched environment of public secondary schools in Gilgit-Baltistan.

METHODOLOGY

Study Design and Rationale

This study utilised a qualitative case study methodology. The decision to utilise a qualitative approach was motivated by the research purpose to examine the intricate and nuanced perspectives of teachers in depth, rather than to quantify or generalise these perceptions. Qualitative research is defined by its capacity to explore intricate relationships and contextual nuances, facilitating a comprehensive knowledge of a phenomenon within its actual environment (Creswell & Creswell, 2017). A case study approach was considered most suitable as it entails a comprehensive, multi-dimensional examination of a singular instance (the perceptions of instructors at one school) inside its naturalistic setting, employing several kinds of evidence to achieve a complete understanding (Starman, 2013). This method corresponds with the interpretive paradigm, which prioritises comprehending the significance and context of human experiences using qualitative data and thematic analysis.

Researchers Role

In qualitative research, the researcher(s) serve as the principal instrument for data collection and analysis, with their background and beliefs potentially impacting the study process. The researchers in this study have ten years of expertise teaching science and mathematics in Hunza and demonstrates a profound commitment to STEM education. Recognising that this passion can lead to bias, the researchers utilised reflexivity throughout the investigation. This necessitated ongoing self-reflection and a critical awareness of how their personal experiences and preconceptions could influence the study process, encompassing data collection and interpretation. Notes were kept to keep track of these thoughts. The researchers were also aware of "backyard research" issues, which are the possible effects of having connections to the site or participants before the study began. To avoid this affecting the responses of participants or the interpretation of data too much, the researchers took careful steps (Pannucci & Wilkins, 2010).

Participants in the Research and Sampling

Ten classroom instructors who work at a public secondary school in Hunza took part in this study. Purposive sampling was employed to guarantee the inclusion of information-rich participants capable of offering profound insights into the phenomenon under investigation (Creswell & Creswell, 2017). To be chosen, participants had to be teachers of math, computer science or science topics (Physics, Chemistry, Biology) for grades 9 and 10. This sample approach made sure that the main STEM fields were represented. To get to the research site, the school principal had to give their consent verbally and later in writing. After that, all teachers who were eligible got Letters of Interest and Informed Consent forms. There were ten teachers in the final sample. Table 1 below shows a summary of their traits. They used pseudo names to keep their identities secret.

Table 1
Characteristics of Participants

Participant	Subject Taught	Highest Degree	Gender	Teaching Experience (Years)
A	Biology	MSc	F	8
B	Physics	BS	M	6
C	Chemistry	MSc	M	11
D	Computer Science	BCS	F	5
E	Mathematics	MSc	M	9
F	Biology	MSc	M	7
G	Physics	MSc	M	12
H	Chemistry	BS	M	4
I	Computer Science	BCS	F	6
J	Mathematics	MSc	M	10

Data Collection Methods and Procedures

To ensure credibility, trustworthiness, and a comprehensive understanding, a multi-method approach to data collection was employed over four phases, facilitating triangulation. Triangulation is the process of employing more than one approach to research the same thing. This helps to cross-validate data and give a stronger set of results (Given, 2008; Baxter & Jack, 2008). Table 2 shows the phased strategy in

Table 2.

Table 2
Phases of Data Collection

Phase	Week	Data Collection Method	Process
I	1	Personal Meaning Mapping (PMM)	Face-to-face
II	2	Photo Elicitation Instructions	Face-to-face
III	3	Semi-structured Interviews	Face-to-face
IV	4	Document Analysis	On-site

Phase I: Personal Meaning Mapping (PMM)

Personal Meaning Mapping (PMM) is a visual data gathering method derived on concept mapping, enabling participants to freely connect ideas, words, and experiences associated with a primary concept. In this study, participants received a blank piece of paper inscribed with "STEM" at the centre and were guided to write or illustrate any thoughts pertaining to STEM education in their classroom within a one-hour timeframe. This approach yielded preliminary insights into how educators conceptually structured and individually articulated STEM, encapsulating the scope and interrelations of their ideas in a non-linear manner (Lelliott, 2009).

Phase II: Photo Elicitation

Photo elicitation is when you use pictures in an interview to get people to talk about deeper meanings and have more in-depth conversations than just asking them questions (Harper, 2002). Participants were guided to choose a single photograph from their own collections that they felt most accurately depicted the nature of STEM teaching in their classroom. They have a week to finish this job. These pictures were a visual record of their ideas and were used as a stimulus during the interviews that followed to get people talking about their thoughts in detail (Torre & Murphy, 2015).

Phase III: Semi-Structured Interviews

Semi-structured interviews were conducted to explore the participants' perceptions in depth. This method provides a flexible framework, allowing the researchers to guide the conversation with pre-determined open-ended questions while also permitting the exploration of emergent themes and prompts for clarification (Glesne, 2016). The interview protocol was developed based on the literature review and was informed by the initial analysis of each participant's PMM and photograph. Interviews began with a discussion of the PMM, moved to the photograph, and then broadened to general questions about the definition, benefits, and challenges of STEM education. This process allowed for a detailed understanding of each teacher's unique perspective. Each interview was audio-recorded and later transcribed verbatim for analysis.

Phase IV: Document Analysis

Document analysis is a systematic procedure for reviewing and evaluating documents, both printed and electronic (Bowen, 2009). In this phase, the researchers analysed teachers' lesson plans. This provided tangible evidence of how STEM principles were (or were not) translated into practical instructional planning, offering a counterpoint to the claimed perceptions and practices discussed in the interviews. It helped to identify the gap between espoused theories (what teachers said they do) and theories-in-use (what their plans indicated they do).

Data Analysis

Data analysis was an ongoing and iterative process that occurred concurrently with data collection. The analysis followed the steps outlined by Creswell and Creswell (2017), involving organizing, reducing, and synthesizing the data to identify significant patterns. The transcribed interviews, PMMs, photographs, and lesson plan notes were reviewed multiple times to ensure familiarity. Open coding was initially applied to the interview transcripts and field notes, generating an initial list of codes. These codes were then constantly compared across all data sources. Through a process of refinement, similar codes were grouped into categories, which were subsequently synthesized into overarching themes that directly addressed the research questions. As the study integrated multiple forms of data (visual and textual), a thematic analysis across all datasets was employed to ensure the themes were robust and representative of the complete evidence (Ponelis, 2015).

Ethical Considerations

Ethical considerations were paramount. Formal approval was obtained from the school administration. All participants provided written informed consent before participation, having been thoroughly informed about the study's purpose, procedures, potential risks, and benefits. They were assured of their right to withdraw at any time without penalty. To ensure confidentiality and anonymity, all identifying information was removed. Participants were assigned pseudonyms (Participant A through J), and the school name was withheld in all reporting. All data was stored securely, and access was limited to the researcher.

RESULTS & FINDINGS

The analysis of the rich qualitative data yielded three prominent themes that comprehensively address the research questions: the multifaceted nature of teachers' definitions of STEM, the perceived challenges of implementation, and the recognized benefits for students.

Educators' Multifaceted and Experiential Definitions of STEM

A key finding was that teachers did not have a single, unified definition of STEM education. Instead, they constructed their own meanings based on their experiences, professional development, and individual understanding, aligning with constructivist principles of learning. Their conceptualizations, while varied, consistently highlighted certain core components.

STEM as Integrated Learning

The most prevalent conception, expressed by six out of ten teachers, was that STEM education fundamentally involves the integration of science, technology, engineering, and mathematics into a single, cohesive learning experience. These teachers emphasized that the subjects are intrinsically interlinked and should not be taught in isolation. Participant G, a physics teacher, articulated this after attending a workshop,

> *"Before that workshop, my understanding of STEM was different. However, after that workshop, STEM is simply the integration of all four subjects in one class. Because, they are not isolated. They all are interlinked."*

Participant D, a computer science teacher, provided a concrete example,

> *"For example, now I engage students in different projects and discussions and also use online learning tools to explain a single topic. We use multiple activities in one class like the project is engineering, and using audio and visual aids in class is technology. Therefore, STEM is the integration of if not all four subjects but 2 to 3 subjects in a single class."*

Often, teachers used examples of their practice rather than abstract definitions to explain integration, suggesting their understanding was deeply rooted in practical application.

STEM as Technology-Based Learning

For three teachers, the concept of STEM was predominantly centred on the incorporation of technology into the classroom. They equated STEM with the use of digital tools and audio-visual aids to enhance traditional teaching. Participant C (Chemistry) stated,

> *"STEM education is a good thing where we use audio-visual aids in the classroom to teach any topic... when I teach about atoms I use multimedia to show a 360-degree image."*

Similarly, Participant I (Mathematics) defined STEM as,

> *"a use of a laptop, multimedia, and other audio-visual aids in the classroom is STEM education which develops interest for that subject among students."*

This perspective suggests a more limited, though still positive, view where technology is the primary, and sometimes sole, differentiating factor of STEM.

STEM as a Student-Centred Approach

Four teachers described STEM not just in terms of content but as a fundamental shift in pedagogy from a traditional, teacher-centric model to a student-centred one. They highlighted increased student agency, engagement, and active learning. Participant I contrasted it with traditional methods,

> *"Unlike traditional education method where the teacher is the primary component, STEM education emphasizes students' engagement, creativity and problem solving... we give opportunities to ask questions, conduct projects, and work with peers to find the solutions of the problems."*

This view aligns STEM with constructivist and inquiry-based learning principles, focusing on the process of learning rather than just the tools or subjects involved.

STEM as the Study of Robotics

One teacher (Participant D) provided a highly specific definition, equating STEM education primarily with the teaching and learning of robotics. This teacher viewed robotics as the ultimate application where theoretical knowledge from science and mathematics is synthesized through engineering and technology to create functional solutions, thereby encompassing all elements of STEM in a single, engaging domain that naturally fosters critical thinking and collaboration.

Systemic and Operational Challenges in STEM Implementation

Despite recognizing the value of STEM, all teachers reported facing significant, and often demotivating, challenges when attempting to implement it in their classrooms. These challenges were systemic, pointing to issues beyond individual teacher motivation.

Difficulty in Forming Integrated STEM Instruction

The foremost challenge was the practical difficulty of designing and developing integrated lesson plans. This overarching difficulty was broken down into three specific barriers.

Lack of Cross-Disciplinary Content Knowledge

Teachers expressed a lack of confidence in their knowledge of subjects outside their specialization. Participant K (Mathematics) shared,

> *"it is easy to integrate technology in math but I cannot integrate science and technology in my subject."*

A physics teacher echoed this, proclaiming,

> *"I have an idea of STEM education but when I sit to make a lesson, I always feel difficulty because of poor in-depth knowledge about it."*

This lack of broad content knowledge is a critical barrier to creating truly integrative experiences.

Lack of Specialized In-Service Training

Teachers universally reported a deficiency in professional development. Participant K stated,

> *"lack of proper in-service training about STEM integration is missing in our education system."*

Participant E added,

> *"Unfortunately many teachers were not trained... and also after starting our teaching journey, because of that STEM integration remained complicated for us."*

Participant I's confession was particularly telling,

> *"I want to use hands-on activities... but without training, I am confused from where to start, therefore, I use traditional methods... as I am comfortable with them."*

This highlights how a lack of training directly reinforces reliance on traditional methods.

Lack of Teacher Interest and Comfort

Some teachers admitted to a personal reluctance, finding the STEM approach complicated and preferring the familiarity and perceived efficiency of traditional lecture-based methods. Participant H stated,

> *"I am comfortable in the traditional way of teaching and I feel STEM is quite challenging for me."*

Another biology teacher acknowledged the benefits for students but added,

> *"for teachers it is a bit complicated due to which I am hesitant toward it."*

This suggests that without adequate support and training, STEM can be perceived as a threat rather than an opportunity.

Overwhelming Time Constraints

Time was a universal constraint cited by every participant. The challenges related to time were twofold: time for planning integrated lessons and time for delivering them within the school schedule. Participant E was emphatic,

> *"time is very important in the lesson... there is not enough time to deliver a lesson that he made which includes hands-activities, classroom discussion, classroom assessment, and so on."*

Teachers also highlighted their additional school responsibilities, which further limited their planning time. The pressure of exam-focused curricula loomed large; Participant J shared,

> *"We have to focus on completion of course which is important for good grade."*

This indicates a fundamental conflict between the deep, slow process of project-based STEM learning and the breadth-focused, time-pressured reality of the standard curriculum.

Lack of Administrative Support

A significant systemic barrier was the perceived lack of support from school administration. Teachers felt that administrators failed to provide the necessary conditions for STEM to thrive. Participant G summarized this in the following words,

> *"Without uncertainty, the absence of help with administration is one of our greatest problems."*

This lack of support manifested as inadequate financing for materials, a lack of opportunities for professional growth, and a failure to officially prioritize or acknowledge the value of STEM education within the broader school mission and curriculum. Without this top-down endorsement and resource allocation, teachers' grassroots efforts were often stifled.

Perceived Multifaceted Benefits for Students

Despite the challenges, all teachers were unequivocal about the positive benefits they observed or believed would result from effective STEM education. Their perceptions aligned closely with the purported benefits found in international literature.

Enhanced Student Motivation and Active Engagement

The most frequently cited benefit was a noticeable increase in student motivation and active participation in learning. Teachers reported that students enjoyed subjects more when taught with integrated and technology-enhanced methods. Participant E (Mathematics) observed,

"in STEM education students felt more engaged and active during the lesson."

The use of projects, multimedia, and group work transformed students from passive recipients into,

"active members of the class."

Participant D (Computer Science) noted,

"Since the inclusion of STEM education... I see a great transformation in terms of class participation."

Eight of the ten teachers used terms like high engagement, teamwork, and active participation to describe this effect.

Development of Problem-Solving and Critical Thinking Skills

Teachers directly linked STEM activities, particularly project-based learning, to the development of higher-order cognitive skills. Participant D explained using projects where students worked in groups to solve problems, with the teacher acting merely as a monitor. Participant I described giving coding challenges that required students to apply bookish knowledge to real-world problem-solving. These practices were seen as directly exercising and enhancing students' problem-solving and critical thinking abilities, moving learning beyond rote memorization.

Raising STEM Career Awareness

Two teachers highlighted the important role of STEM education in exposing students to potential future careers. Participant D expressed surprise at how current students were

"talking about robotics, app development, and game development"

whereas past students were solely concerned with exam grades. This shift was attributed to STEM exposure. Teachers saw themselves as role models responsible for guiding students towards future opportunities. Participant H stated,

"I think this is the best time to teach the skills and strategies that a student can apply in their careers after 10 to 20 years."

This indicates a long-term perspective on the value of STEM education.

Building Student Confidence

An important affective benefit noted by teachers was the development of students' confidence. Participating in hands-on projects, discussions, and presentations provided opportunities for success and growth. Participant B stated,

"I like STEM education because of it I have seen confidence in students increase a lot."

Notably, this enhanced resilience and confidence in students. Participant B further added.

> *"not only in completing the activities but the failure in the activities also develops the confidence to handle the failure."*

This suggests that the experiential nature of STEM fosters not just academic skills but also crucial personal development.

DISCUSSION

The findings of this study offer a nuanced understanding of how secondary school teachers in a remote region of Pakistan perceive STEM education. The discussion interprets these findings within the broader context of existing literature and highlights their implications. The varied definitions of STEM held by teachers—as integration, technology, pedagogy, or robotics—reflect the definitional ambiguity prevalent in the wider literature (Hasanah, 2020). The most common definition, integrated learning, aligns with the scholarly view of STEM as an interdisciplinary and applied approach (Wang et al., 2011; Bybee, 2013). However, the narrower views, such as equating STEM solely with technology use, indicate a potential oversimplification or incomplete understanding of the integrative ideal. This suggests that while teachers are engaging with the concept, there is a critical need for professional development to develop a more comprehensive and shared understanding that emphasizes the meta-disciplinary nature of STEM beyond just tools or subjects.

The challenges reported are consistent with global research but are acutely felt in this resource-constrained context. The absence of interdisciplinary knowledge and training reflects the conclusions of Shernoff et al. (2017) and Margot and Kettler (2019), underscoring a pervasive necessity for efficient teacher preparation. Time limits and conflicts with exam-focused curricula are well-documented obstacles (Srikoom & Faikhamta, 2018). El-Deghaidy and Mansour (2015) pointed out that the lack of administrative support shown in this study is an important result. They said that teacher-level efforts are not enough without systemic, top-down support in the form of policy, time allocation, and resources. All these problems together make a big gap between the goal of STEM and the reality of how it is being used.

The advantages recognised by educators—enhanced engagement, cultivation of problem-solving abilities, career awareness, and self-assurance—closely align with the benefits delineated in international research (Chittum et al., 2017; Cohen et al., 2013). It's great that everyone agrees that these changes will have a positive effect on pupils. This gives us a lot of motivation to get past the problems we've found. Teachers in Hunza, Gilgit-Baltistan see the same potential in STEM as teachers in other parts of the world, which shows how important this way of teaching is around the world.

One interesting thing was that 7 out of 10 instructors had gone to a STEM program put on by a private group, which was where they learnt much of what they knew. This started their learning, but they all said that short, one-time courses weren't enough for them to really master the material and feel secure using it. This directly supports Margot and Kettler's (2019) claim that school support, guidance, and flexibility are necessary for STEM initiatives and that teachers need long-term, ongoing professional development opportunities, not just short ones (Altan & Ercan, 2016).

CONCLUSIONS

This study finds that Science and Maths instructors in Hunza, Gilgit-Baltistan have a positive and nuanced concept of STEM education. They mostly see it as a student-centered, integrated approach that helps students learn and grow. They are quite aware of how it could help people learn skills that will be useful in the 21st century. But this good view is being blocked right now by a number of big problems with the system and how it works. A significant deficiency in comprehensive, interdisciplinary content knowledge and targeted pedagogical training renders teachers inadequately prepared to formulate integrated lessons. This is made worse by a strict, test-focused curriculum that puts too much pressure on students' time and a serious lack of administrative support and resources needed to make an environment that encourages new ideas.

The main problem is the gap between what people think is valuable and what they can actually do. To close this gap, we need a coordinated, multi-level plan.

Conceptual Clarity and Ownership: Facilitate collaborative forums involving teachers, administrators, and curriculum experts to develop a clear, contextually appropriate, and operational definition of STEM education for the region, moving beyond abstract concepts to practical guidelines.

Investment in Sustained Professional Development: Move beyond one-day workshops to implement comprehensive, long-term, and practice-oriented training programs. These should focus on integrated curriculum design, project-based learning pedagogy, and developing cross-disciplinary content knowledge.

Strategic Curriculum and Assessment Reform: Re-evaluate the national curriculum to create flexibility for deep, inquiry-based learning. Explore alternative assessment methods that can measure the complex skills fostered by STEM, reducing the overwhelming pressure to "complete the syllabus."

Stronger Administrative Advocacy and Support: School leaders must be targeted for awareness and training to become champions of STEM. Their role is crucial in providing tangible support: allocating time for collaborative planning, securing funding for resources, and fostering a school culture that values innovation and experimentation over traditional rote learning.

Limitations and Future Research

This study is limited by its focus on a single school and a small sample size, which affects the generalizability of the findings. The reliance on self-reported data through interviews and PMMs, while rich, may not fully capture actual classroom practices. Future research should expand to include a larger number of schools across various districts in Gilgit-Baltistan and Pakistan. Incorporating direct classroom observations would provide a more objective measure of how perceptions translate into practice. Longitudinal studies could track the impact of the recommended professional development programs on teachers' practices and, ultimately, on student outcomes. Furthermore, research exploring the specific perceptions of school administrators towards STEM would be invaluable in addressing the critical barrier of leadership support.

Competing Interest

The authors declare no conflict of interest.

Authors' Biography

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