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Impact of Secondary School Science Teachers' Instructional Preparedness for STEM on their Students' Attitude towards Science

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ABSTRACT

This quantitative, descriptive study examined how secondary school teachers' instructional preparedness for STEM relates to students' attitudes toward science in Skardu. The analytic sample comprised 400 respondents from twelve secondary schools. Students' attitudes were measured using the Urdu version of the Test of Science-Related Attitudes (TOSRA), and teachers' preparedness was assessed with a 41-item questionnaire covering ten instructional domains. Data underwent reliability checks and expert review before analysis. Descriptive statistics summarized attitudes and practices; Pearson correlations evaluated associations between teacher practices and student attitudes; and ANOVA and t-tests examined demographic effects. Results show broadly positive student attitudes: high agreement that science lessons are interesting and a strong preference for experimentation. Moderate-to-strong positive correlations were found between student attitudes and teacher planning ($r = 0.61$), emphasis on scientific language ($r = 0.63$), and capacity to attract students to STEM activities ($r = 0.58$). Teacher experience and qualifications had significant effects on preparedness ($F = 4.12$; $F = 3.97$), and a small gender difference in attitudes was observed ($t = -2.58$, $p < .01$). Findings suggest that strengthening teacher practice through sustained professional development and improving access to appropriate technology can enhance student engagement in STEM in remote contexts.

Introduction

The accelerating pace of scientific and technological change has elevated the priority given to education in Science, Technology, Engineering, and Mathematics (STEM) as a cornerstone of national development and individual opportunity. STEM education encompasses not only the transmission of factual knowledge but also the cultivation of analytic reasoning, problem-solving capacities, and an enquiring disposition that enable learners to engage creatively with complex, real-world problems (Granovskiy, 2018). International bodies and policy forums have repeatedly underscored the centrality of STEM competence to future labor markets and societal resilience; as technological transformations reshape employment structures, education systems must equip students with the dispositions and skills that permit effective participation in a knowledge-driven economy (National Academies of Sciences, Engineering, and Medicine, 2018). Consequently, the quality of STEM provision at the school level has become a decisive factor in determining whether young people develop the interest and preparedness necessary to pursue advanced study and careers in science and technology (Kyere, 2017; Kayan-Fadlelmula et al., 2022).

Within this broader policy and pedagogical landscape, the attitudes that students form toward science are of critical importance because attitudes influence engagement, persistence, and eventual educational and occupational choices. Empirical studies indicate that positive classroom experiences in STEM, characterized by active, hands-on learning and opportunities for inquiry, tend to strengthen students' interest and self-efficacy in science, thereby increasing the likelihood that they will continue to study STEM subjects (Fechner, 2009). Conversely, exposure to uninspiring instruction, limited practical opportunities, or curricula that do not connect with students' lived experiences can diminish both interest and achievement. Ensuring that STEM instruction is meaningful, accessible, and engaging for a diverse student population remains an urgent challenge internationally, especially in contexts where structural barriers constrain equitable access to high-quality learning environments (National Research Council, 2011).

Teachers occupy a pivotal position in shaping these classroom experiences and in mediating the relationship between curriculum intent and student learning. Teacher instructional preparedness for STEM, encompassing deep subject-matter knowledge and the pedagogical skills necessary to design and implement inquiry-based, contextually relevant lessons, is consistently identified in the literature as a primary determinant of instructional quality (McDonald, 2016). When teachers possess confidence in their content knowledge and familiarity with active pedagogies, they are better able to translate abstract concepts into comprehensible activities, scaffold student learning effectively, and foster an environment in which curiosity and critical thinking flourish (Wilkins, 2008; Krajcik, 2018). Equally important is the teacher's capacity to connect instruction to students' social and cultural backgrounds; such responsiveness enhances relevance and engagement and mitigates the risk that STEM will be perceived as remote or irrelevant to students' aspirations (Shohel et al., 2021).

The significance of teacher preparedness acquires particular weight in geographically remote or resource-constrained settings, where limitations in infrastructure, professional development opportunities, and curricular resources can constrain instructional practice and student exposure to contemporary STEM concepts (Zakir, 2015). In such environments, the absence of well-resourced laboratories, up-to-date materials, and sustained teacher training may not only impede the delivery of effective STEM instruction but also shape students' attitudes toward science through repeated experiences of limited or fragmented learning opportunities (Moreno, 2016; Khan et al., 2020).

Addressing these constraints, therefore, requires a dual focus on enhancing teacher capacity and adapting pedagogical approaches to local conditions so that instruction remains rigorous, relevant, and engaging despite contextual limitations (Khan & Butt, 2018).

Skardu, located in the Gilgit-Baltistan region of Pakistan, exemplifies many of the contextual challenges that have been observed in similarly situated regions. Its geographic remoteness, distinctive cultural practices, and variable access to educational resources create a setting in which the alignment between international or national STEM standards and classroom realities is likely to be imperfect (Iqbal et al., 2021). These contextual factors can affect both the supply side of STEM education, through teacher training, resource allocation, and curricular support, and the demand side, insofar as students' attitudes and aspirations are shaped by the perceived utility and accessibility of science education within their communities (CIIT, 2017). Understanding how teacher instructional preparedness in this specific context relates to students' attitudes toward science is, therefore, important not only for local policy and practice but also for broader efforts to design equitable, contextually appropriate models of STEM education for remote and underserved regions.

Against this background, the present study examines the instructional preparedness of secondary school science teachers in Skardu and investigates the extent to which that preparedness influences secondary students' attitudes toward science. By focusing on both teacher capacity and student perceptions within a clearly defined geographical and cultural context, the research aims to generate evidence that can inform targeted professional development, curricular adaptation, and resource strategies to strengthen STEM teaching and learning. Such evidence is intended to support efforts to narrow educational disparities and to foster conditions under which students in remote settings can develop the knowledge, skills, and positive dispositions necessary to engage with STEM pathways.

Research Objectives

1. To determine the strength and nature of the association between secondary school science teachers' overall instructional preparedness for STEM and their students' overall attitude toward science in the study sample.
2. To identify the individual instructional preparedness dimensions that have the highest positive correlation with students' reported enjoyment of science lessons and preference for hands-on, experimental learning.
3. To examine the statistically significant effects of teacher experience and formal qualifications on instructional preparedness, and to assess the observed gender difference in student attitudes toward science.

Research Questions

1. What is the relationship between secondary school science teachers' instructional preparedness for STEM, across the identified ten instructional domains, and their students' attitudes toward science in the Skardu region?
2. Which specific dimensions of instructional preparedness (e.g., planning, scientific language, capacity to attract students) exhibit the strongest positive correlation with favorable student attitudes toward science?

3. To what extent do teacher demographic factors, specifically accumulated experience and formal qualifications, influence the overall level of instructional preparedness for STEM instruction?

Research Methodology

The study employed a quantitative, descriptive approach to examine the relationship between secondary school science teachers' instructional preparedness for STEM and their students' attitudes toward science in Skardu. This approach was selected because it permits systematic measurement of the key variables in their natural educational setting and supports statistical examination of relationships and group differences. The research sought to produce findings that are generalizable to the target population within the geographic scope of the study while preserving the transparency and replicability expected by peer-reviewed journals.

The target population comprised all secondary school science teachers and secondary school students enrolled in science courses in Skardu. In total, the population included 144 science teachers working across thirty-six secondary schools and 3,600 students attending science classes at the secondary level. To ensure that the sample reflected the structure of the population, schools were treated as clusters and selection proceeded in proportion to the size of each cluster; within those clusters, participants were selected using practical, on-site selection procedures that balanced feasibility with representativeness. This sampling approach was intended to capture the diversity of educational settings in Skardu while remaining manageable given logistical constraints.

A pragmatic decision was made to sample approximately one-half of the defined population, yielding a sample of 72 teachers and 1,800 students. This sample size was determined to provide sufficient observations for reliable descriptive statistics and for inferential tests such as correlation, t-tests, and analysis of variance, while taking into account the resources and time available for data collection across a geographically dispersed region.

Data were collected using two established instruments. Students' attitudes toward science were measured with the Urdu version of the Test of Science-Related Attitudes (TOSRA), a psychometric instrument comprising thirty-one items designed to probe multiple dimensions of learners' feelings and orientations toward science learning, including interest, perceived relevance, and engagement. Teachers' instructional preparedness for STEM was assessed by a researcher-designed questionnaire grounded in key phases of inquiry-based instruction; the instrument covered ten domains of instructional practice and contained forty-one items addressing teachers' knowledge, planning, classroom enactment, and assessment practices. Both instruments underwent reliability testing before analysis and were confirmed to be suitable for use in the study context.

Instrument validation incorporated a face-and-content review carried out by a panel of experts in science education and STEM pedagogy. The expert review focused on item clarity, cultural and contextual appropriateness, and coverage of the intended constructs; suggested revisions were incorporated to improve the instruments' validity for use in Skardu. Pilot administration and subsequent item analysis informed minor refinements to wording and response formats to ensure comprehensibility for both teachers and students.

Fieldwork was conducted after obtaining formal permission from school authorities and providing participants with an explanation of the study's purpose and procedures. Participation was voluntary, and confidentiality was assured. Student questionnaires were administered under controlled conditions to minimize external influence and to promote honest responding; teachers completed their questionnaires in a similar supervised setting with sufficient time allotted for considered responses. The primary phase of data collection was completed within a carefully scheduled period to reduce temporal variation in instructional practice and student sentiment.

Collected responses were coded and entered into statistical software for analysis. Descriptive statistics were computed to summarize central tendencies and distributions for both teacher preparedness and student attitude measures. Relationships between variables were examined using correlational analysis to assess the strength and direction of associations; subgroup comparisons were performed using independent-sample t tests and analysis of variance to identify statistically significant differences across demographic and institutional categories. Where appropriate, effect sizes were reported alongside significance values to convey the practical importance of observed results.

Throughout the study, ethical standards guided methodological choices. Informed consent was obtained from all participants or their guardians where required, participant anonymity was maintained during data handling and reporting, and respondents were informed of their right to withdraw without penalty. These measures were implemented to uphold the integrity of the research and to protect the rights and well-being of participants.

The study acknowledges certain limitations. The geographic focus on Skardu restricts the direct generalisability of findings to other regions with different socio-cultural or infrastructural conditions. Reliance on self-report instruments introduces the possibility of response bias, and some potentially influential contextual variables could not be observed or measured within the chosen instruments. These limitations were considered when interpreting the results and when formulating recommendations for practice and future research.

Results

The analysis used the full analytic sample of 400 respondents from twelve secondary schools across four Tehsils of Skardu. Results are presented in three parts: (a) sample composition and key descriptive indicators, (b) students' attitudes toward science, and (c) associations between teachers' instructional preparedness and students' attitudes, together with tests of demographic effects. Five compact tables summarize the principal findings; the narrative below interprets those tables and highlights the most important patterns observed in the dataset.

Table 1 reports the sample distribution by tehsil and by gender. Participants were drawn from four tehsils, with Gamba contributing the largest share (39.5%) and Roundu the smallest (12.0%). Gender balance was achieved in the sample, with 49.5% male and 50.5% female respondents.

Descriptive inspection of teacher responses at the school level (detailed item-level tables provided in the dataset) revealed consistent strengths and some recurring gaps in classroom practice. Across multiple schools, female teachers at several sites (for example, Girls SKD-1, Girls SKD-2, and Gultari Girls 1) reported frequent use of preparatory steps (ensuring basic materials are ready, explaining safety and procedures) and of formative assessment activities (providing feedback, discussing results). In contrast, the integration of digital tools and routine use of technology for exploration were less frequent in several male-teacher cohorts, indicating an area for targeted development. The remainder of the reporting focuses on the student attitude results and the statistical associations with teacher preparedness.

Table 1: Sample distribution

Tehsil / Gender	Frequency	Percent
Gamba	158	39.5%
Skardu	131	32.8%
Gultari	63	15.8%
Roundu	48	12.0%
Total	**400**	**100.0%**
Male	198	49.5%
Female	202	50.5%

Student responses to the attitude instrument indicate generally positive dispositions toward science. Table 2 presents selected attitude items from the student instrument (TOSRA items and related statements) and the combined proportions reporting agreement (agree + strongly agree). These items were chosen to reflect enjoyment, interest, preference for hands-on learning, and career inclination.

Table 2: Selected student attitude indicators (percent agreeing = Agree + Strongly agree)

Item (short form)	Agree + Strongly agree (n / 400)	Percent
Spending on science is a good use of resources	335 / 400	83.8%
I prefer to experiment to discover causes rather than ask	337 / 399	84.5%
Science lessons are interesting	370 / 400	92.5%
I enjoy science class	326 / 400	81.5%
I would like to continue studying science after my education	261 / 400	65.2%

The results in Table 2 indicate strong, positive attitudes on several fronts. Notably, more than nine in ten respondents agreed that science lessons are interesting, and more than four in five preferred hands-on experimentation as a route to understanding. A majority also expressed willingness to continue studying science after completing their education, and most respondents judged public investment in science to be appropriate.

Additional items reinforce this positive orientation. Large majorities regarded science as useful for improving life (Table 52: 80.8% agree/strongly agree), expressed interest in working in scientific settings for a living (Table 43: 68.1% agree/strongly agree), and stated that science is more interesting than other subjects (Table 45: 83.3% agree/strongly agree). Conversely, rejection of negative statements was strong: for example, a large majority disagreed that studying science is a waste of time (Table 49: 85.8% disagree/strongly disagree).

Statistical analysis assessed the relationship between dimensions of teachers' instructional preparedness and students' attitudes, and tested whether demographic variables explained meaningful variation in scores. Table 3 summarizes the Pearson correlations computed between selected teacher preparedness aspects and student attitude measures. All listed correlations are statistically significant at $p < .01$.

Table 3: Correlations between teacher preparedness aspects and students' attitudes

Teacher preparedness aspect	r	p
Planning skills linking knowledge to objectives	0.61	< .01
Ability to attract students to STEM activities	0.58	< .01
Assessing students' prior knowledge	0.49	< .01
Involvement of mathematical disciplines in activities	0.55	< .01
Emphasis on using scientific terms	0.63	< .01

These results show moderate to strong positive associations: higher reported teacher competence in planning, in attracting students to STEM, in integrating disciplinary links, and in using scientific terminology corresponded with more positive student attitudes. The strongest observed association was between teachers' emphasis on scientific language and student attitudes ($r = 0.63$).

Group comparisons evaluated whether teacher qualifications and experience, and student gender, were associated with the principal outcome measures. Table 4 summarizes ANOVA and t-test results for key demographic contrasts.

Table 4: Tests of demographic effects (ANOVA / t-tests)

Variable	Test	Statistic	p	Interpretation
Teacher experience	ANOVA	$F = 4.12$	< .05	Significant effect on instructional preparedness
Teacher qualifications	ANOVA	$F = 3.97$	< .05	Significant effect on instructional preparedness
Student gender	Independent t-test	$t = -2.58$	< .01	Significant difference in attitudes by gender
Teacher gender	Independent t-test	$t = -1.93$	> .05	No significant difference in preparedness by gender

Teachers' years of experience and formal qualifications were both associated with statistically significant differences in instructional preparedness scores, indicating that these background factors are relevant to classroom practice. Student gender showed a small but statistically significant difference in attitude scores ($t = -2.58$, $p < .01$); examination of group means indicated that female and male students differ modestly in their mean attitude scores (details of group means and direction are reported in the supplementary tables). Teacher gender did not show a statistically significant effect on preparedness in this sample.

Finally, Table 5 provides a concise synthesis of the principal descriptive findings at the item level for teacher practice and student attitudinal items (high-level summary). It highlights the areas with consistently high frequencies of positive practice or attitude (>60% reporting the affirmative category) and identifies recurrent gaps where practices were less frequent (notably routine use of technology for exploration).

In sum, the results indicate that students in the sampled schools of Skardu generally hold favorable attitudes toward science and that several teacher practices associated with inquiry and formative assessment are commonly reported. Statistically significant positive correlations link specific dimensions of teacher instructional preparedness with more positive student attitudes, and teacher experience and qualification show a measurable effect on preparedness. Areas for targeted action include broader integration of technology into exploration activities and extension of professional development to promote consistent multidisciplinary STEM practice across all schools.

Table 5: Summary of principal findings (high-level item summary)

Domain	Strong/frequent finding	Area for development
Teacher preparation and practice	Preparation of materials, safety briefing, guided feedback, and use of formative assessment are commonly reported (>60% at several schools)	Routine integration of digital tools and technology for exploration less frequent in several schools
Teacher-student instructional interaction	Frequent use of questioning, group work and scaffolded guidance reported at many sites	Consistent use of multi-disciplinary links (math/engineering/technology) varied by school
Student attitudes	High interest in science lessons and hands-on experimentation; majority express desire to continue science study	A minority remain neutral or disinclined toward science careers; small pockets of resistance to extended scientific study

Discussion

This study examined the relationship between secondary school teachers' instructional preparedness for STEM and students' attitudes toward science in Skardu. The main findings are (a) generally positive student attitudes toward science, especially enjoyment of lessons and preference for hands-on learning; (b) consistent teacher practices in preparation, safety briefings and formative feedback across many schools; (c) weaker and uneven integration of technology for exploration; and (d) statistically significant, moderate-to-strong positive associations between specific teacher preparedness dimensions (planning, attracting students, disciplinary links, use of scientific language) and student attitudes. These findings are considered below in relation to recent literature and to implications for practice and policy.

The high levels of positive student attitudes observed here, strong agreement that science lessons are interesting, pronounced preference for experimentation, and widespread willingness to continue science study are consistent with recent surveys that document favourable student orientation toward STEM when classrooms emphasize practical, inquiry-based tasks (Sahito & Wassan, 2024). The correlations in the current data (for example, $r = 0.61$ for planning skills and $r = 0.63$ for emphasis on scientific language) support the interpretation that certain teacher behaviors are strongly associated with students' interest and engagement in science.

The present finding that teachers commonly report careful preparation (materials, safety steps) and frequent use of formative feedback accords with international studies showing that routine classroom organization and timely feedback are among the most reliably implemented practices in effective STEM instruction (Papagiannopoulou et al., 2024). Where such practices are present, students tend to report greater enjoyment and clearer understanding of scientific concepts, which matches the positive attitude profile seen in this sample.

At the same time, the relatively low and uneven use of technology for exploratory activities that we observed reflects a broader and current challenge documented in the literature. Reviews of recent teacher professional development and technology-enabled programmes note that while digital tools can substantially enhance teacher capacity and student learning, persistent barriers, such as connectivity, access to devices, and context-appropriate training, limit routine classroom adoption, especially in remote or resource-constrained settings (Huang et al., 2024). Our item-level results, which show lower frequencies for technology integration in several male-teacher cohorts and in some schools, echo that pattern and point to the need for support that goes beyond one-off training to sustained, context-sensitive development and infrastructure investment.

The statistically significant effects of teacher experience and formal qualifications on instructional preparedness found in this study also align with recent evidence from Pakistan and comparable settings showing that professional background and access to continuous development explain part of the variation in teachers' readiness to enact STEM practices (Ali et al., 2013; Naz et al., 2024). These findings suggest that credentialing and accumulated classroom experience remain important resources for developing instructional competence; however, they also show that experience alone is not sufficient without targeted professional learning that focuses on inquiry methods and multidisciplinary links.

The strong positive correlations between specific teacher practices and student attitudes carry practical implications. Emphasizing lesson planning that explicitly links prior knowledge to objectives, creating engaging STEM activities, and consistently using precise scientific language are teaching behaviors' that can be reinforced through professional development and peer learning. Experimental and design-based studies of STEM teacher preparation suggest that structured, sustained professional development that includes practice-based tasks, classroom coaching, and follow-up reflection yields stronger changes in teacher practice than brief workshops alone (Awan et al., 2024). For Skardu, adopting models of sustained, locally adapted professional development that combine content knowledge, pedagogical practice, and classroom coaching is likely to be more effective than single-session training.

The technology shortfall we observed requires a twofold response. First, improvements in infrastructure and reliable access to devices and connectivity are necessary so teachers can apply digital resources meaningfully. Second, professional development must explicitly teach how to use modest, low-cost technologies and offline digital resources to support hands-on exploration in contexts with limited connectivity; systematic reviews of technology-enabled teacher development note that adaptability to local constraints is a key determinant of sustained uptake (Jamil, 2020). In the absence of such tailored supports, promising digital innovations remain underutilized.

Several points of contrast with the recent literature merit emphasis. Some studies emphasize that students' socioeconomic background and school resources are the dominant predictors of attitude and achievement (digital divide and access studies in Pakistan), while our results show that teacher practices retain a sizeable and distinct association with students' attitudes even when resource limitations are present. This suggests that, although resource expansion is necessary, improvements in teacher practice can produce measurable benefits for students' interest and engagement in science even before infrastructure gaps are fully closed (digital divide research). Thus, combined strategies, parallel investment in teacher development and in basic resources, are recommended (Shahzad, 2024; Gul et al., 2024).

Limitations of the present study should be acknowledged. The cross-sectional design precludes causal claims; the associations reported here are consistent with teacher influence on student attitudes but could also reflect reciprocal dynamics or unmeasured contextual factors. Measures relied primarily on self-report, which may introduce response bias; however, the use of an instrument with demonstrated psychometric properties in Urdu strengthens confidence in the attitude estimates (TOSRA–Urdu validation work). Future research would benefit from longitudinal designs, classroom observation, and mixed-method approaches that include teacher interviews and direct classroom measures of practice.

In conclusion, the findings indicate a favorable baseline of student attitudes toward science in Skardu and identify specific teacher practices that correlate with that positive outlook. Recent literature supports the view that targeted, sustained professional development, designed with attention to local constraints and combined with pragmatic investments in basic technology, offers a feasible path to strengthen instructional preparedness and further improve student attitudes. Policy responses should therefore prioritize sustained teacher learning programmes, measures to reduce the local digital divide, and modest but reliable resource provision that enables hands-on, multidisciplinary STEM learning in remote settings.

Conclusion

The study shows that secondary students in Skardu generally hold positive attitudes toward science, especially when lessons are engaging and involve hands-on work. Specific teacher practices, careful lesson planning, attention to scientific language, formative feedback, and efforts to link disciplines are consistently associated with stronger student attitudes. Teacher experience and formal qualifications also relate to higher instructional preparedness. However, the routine use of digital tools for exploration is uneven and limited in several schools. Policy and practice should therefore priorities sustained, context-sensitive professional development and modest investments in reliable, low-cost technologies to widen access to inquiry-based STEM learning in remote settings.

Recommendations

Following recommendations are made on the basis of results of this research study.

1. Prioritize sustained, practice-based professional development models that include classroom coaching and follow-up reflection, instead of relying on brief, one-off workshops. This will reinforce effective instructional skills, such as inquiry methods and multidisciplinary links.
2. Implement a strategic, pragmatic plan for investing in basic, reliable educational resources, including devices and stable connectivity, to reduce the local digital divide. These resources are necessary for teachers to apply digital tools meaningfully in the classroom.
3. Develop professional development programs that explicitly teach teachers how to utilize low-cost technologies and offline digital resources. This training must be adapted to local constraints to support hands-on exploration despite limited connectivity.
4. Reinforce the key instructional practices careful lesson planning that links prior knowledge to objectives, and consistent use of precise scientific language. These behaviors demonstrated the strongest statistical association with positive student attitudes.
5. Policy responses should adopt a combined strategy that involves parallel investment in both sustained teacher learning programs and basic resource provision. This ensures that improvements in teacher practice yield benefits even before infrastructure gaps are fully closed.

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