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Enhancing Students' STEM Learning Through Inquiry-Based Teaching: Evidence From Secondary Schools in Multan

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Abstract

The role of inquiry-based teaching in improving the STEM learning of secondary schools' students of Multan was the focus of this study. In the new STEM world, classroom practices that foster conceptual understanding, engagement, problem solving, and academic success are becoming more prevalent, but many secondary classrooms persist with lecture and exam focused teaching. A quantitative descriptive-correlational design was used, and questionnaire data from 360 grade 9 and 10 students in public and private secondary schools were analyzed. Inquiry-based teaching was assessed using questioning, investigation, experimentation, discussion, evidence-based reasoning, problem-solving activities and teacher scaffolding, while STEM learning was assessed using conceptual understanding, classroom engagement, problem-solving skills and academic achievement. High perceived levels of inquiry-based teaching and STEM learning were revealed from descriptive findings. Pearson correlation showed that there was a significant positive correlation between inquiry-based teaching and overall STEM learning with $r = .67$ and $p < .01$. The regression analysis indicated that the inquiry-based teaching had a significant prediction of the STEM learning, accounting for 45% of the variance. The problem-solving skills showed the highest dimensional effect. Therefore, the study concludes that the use of inquiry-based instruction is a suitable student-centered method to enhance STEM learning in secondary schools of Multan. It suggests teacher training, better lab and digital materials, and curriculum tasks which encourage investigation, evidence-based explanation, and problem solving in the real world.

Keywords: STEM Education, Inquiry-based Teaching, Secondary Schools, Student Engagement, Conceptual Understanding, Academic Achievement.

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Introduction

The need for education systems to prioritize STEM education stems from the linkage of scientific knowledge, mathematical thinking, technological awareness, creativity and problem-solving skills to the needs of modern society. Secondary schools are especially critical for STEM learning as students start to have preferences, academic confidence and even career orientations to STEM. STEM learning is most enriching when it is not the science-as-a-subject and not the math-as-a-subject, but learning that enables students to use knowledge to explain phenomena, solve problems, and make evidence-based decisions. It is thus important that the foundations of K-12 STEM education include integrated, inquiry-based and active methods (Bybee, 2010; English, 2016).

In spite of such a demand, much of the secondary school teaching still presumes a lecturing, book-oriented and test-taking philosophy. These may allow students to regurgitate factual information but may also limit the development of curiosity, investigation, discussion, and the ability to conceptualize. Inquiry-based learning, which gives students the opportunity to ask questions, collect and analyze evidence, create explanations, and share results, is an alternative method. The National Research Council (2000) defined inquiry as a process by which learners "solve scientific questions, value evidence, develop explanations, and relate explanations to science consensus. This process is directly related to STEM learning because STEM subjects involve observation, reasoning, interpretation and application.

Inquiry-based teaching is also in line with the broader evidence in favor of active learning in STEM classrooms. Freeman et al. (2014) found that students in science, engineering, and mathematics were more successful in their studies when learning through active learning rather than traditional lecture. Likewise, inquiry-based science instruction has been reported to aid student learning, particularly when students are supported in conducting investigations in a structured manner rather than being left to their own devices to find out what science is about (Furtak et al., 2012; Lazonder & Harmsen, 2016; Minner et al., 2010). The findings could be significant for secondary schools in Multan as inquiry-based teaching could enable students to shift from memorization to evidence-based thinking, conceptual understanding, and problem solving.

The present study on inquiry-based teaching in local context of secondary schools in Multan is an examination. Multan has public and private schools which vary in terms of facilities, access to educational laboratories, class size, and access to student-centered pedagogy. Thus, there is a need for localised evidence in order to determine the relationship between inquiry-based practices and their effects on the learning outcomes of students in the field of STEM. The study emphasizes four outcomes: Conceptual understanding, Classroom engagement, Problem-solving skills, and Academic achievement. The outcomes were chosen as being both cognitive and participatory aspects of STEM learning.

The study also addresses a practical need for STEM education research. There is a large amount of evidence for inquiry available in international settings, and teachers' preparation, curriculum expectations, and examination pressure vary from one school to another and from one country to another, along with the availability of resources. In Multan, the effectiveness of inquiry-based teaching might rely on teachers' adaptation of the inquiry activities, extent of syllabus coverage, assessment requirements, and school environment. The study focuses on students' perceptions, thereby shedding light on the level of the students' experience of inquiry oriented instruction and the relationship between this experience and students' learning outcomes.

This study is significant for three reasons. First, it fills the void of local evidence on STEM teaching and learning in South Punjab, not just relying on international studies. Second, it links inquiry-based learning to other dimensions of learning, rather than focusing on achievement as the goal. Third, it offers teachers, school leaders, and curriculum developers practical evidence to guide their efforts in enhancing STEM teaching with low-cost, hands-on classroom practices like questioning, discussion, investigation, and evidence-based explanation. Thus, the research not only helps in the teaching-learning process but also in the field of education and research in Multan.

Research Objectives

1. To examine the level of inquiry-based teaching practices experienced by secondary school students in Multan.
2. To determine students' level of STEM learning in terms of conceptual understanding, classroom engagement, problem-solving skills, and academic achievement.
3. To examine the relationship between inquiry-based teaching and students' STEM learning.
4. To determine the effect of inquiry-based teaching on the dimensions of students' STEM learning.

Research Hypotheses

- H1:** Inquiry-based teaching is significantly related to students' STEM learning in secondary schools of Multan.
- H2:** Inquiry-based teaching significantly predicts students' conceptual understanding.
- H3:** Inquiry-based teaching significantly predicts students' classroom engagement.
- H4:** Inquiry-based teaching significantly predicts students' problem-solving skills.
- H5:** Inquiry-based teaching significantly predicts students' academic achievement.

Literature Review

For effective STEM instruction, students must be taught with a method that will promote the transfer of knowledge between disciplines and have a connection to real world situations. English (2016) suggested that integration of STEM into K-12 education needs to be seen as more than the infusion of technology and engineering into the science and mathematics curriculum, but rather as a way to facilitate problem-based learning and interconnections among concepts and disciplines. Bybee (2010) also noted that the goal of STEM education is to help students become scientifically literate, innovative and scientifically literate in their practical applications. The arguments indicate that the teaching or learning of STEM subjects at secondary level does not just need to be about content transmission, but should encourage active learning, enquiry and application.

Even more crucial in educational settings, where access to laboratory facilities and enrichment programs may not be equal, is the importance of effective pedagogies in STEM. In these settings, the pedagogy itself becomes a significant tool. Low-cost activities that can be used to implement inquiry-based teaching include questions posed in the classroom, small group investigation, use of local items, data interpretation, and everyday scientific problems. Thus, inquiry-based teaching can be relevant in any classroom, whether or not it has a dedicated STEM department and whether or not teachers require some strategies to enhance STEM learning in classrooms with limited resources.

Inquiry-based learning is one of the major student-centered techniques that can enhance STEM learning. It is based on the assumption that students learn more deeply when they investigate questions, analyze evidence, construct explanations, and reflect on their learning. The National Research Council (2000) explained that inquiry involves asking questions, prioritizing evidence, formulating explanations, connecting explanations to scientific knowledge, and communicating results. Pedaste et al. (2015) also divided the inquiry-based learning into the following phases: orientation, conceptualization, investigation, conclusion and discussion. These phases reveal that inquiry is not random activity, but rather a process that nurtures students' curiosity to evidence-based understanding.

In general, there is research evidence to support inquiry and active learning in science and STEM education. Minner et al. (2010) reviewed research related to inquiry-based learning of science, and found positive relationships between inquiry practices and student learning of science content. Furtak et al. (2012) concluded that inquiry-based science teaching has proved to be more effective if it was used in combination with the proper guidance of the teacher and student activity. Lazonder and Harmsen (2016) also found guidance to be a key factor in the effectiveness of inquiry. The findings are applicable to secondary schools, as students might need to be scaffolded to perform investigations, analyze evidence, and make links between activities and formal concepts.

Open inquiry and guided inquiry are significant for secondary schools. Open inquiry offers students a lot of freedom in designing questions and methodology, while guided inquiry offers scaffolding for the teacher and still leaves room for students to think, investigate and explain. Guided inquiry tends to be more realistic when implementing school-level STEM learning, as students may not have the background knowledge or methodological skills needed to probe into the subject and find answers independently. Examples of teacher scaffolding include prompts, worksheets, demonstration, guiding questions, feedback and discussion checkpoints. These supports are designed to keep students cognitively engaged, without causing confusion or superficial activity.

Conceptual understanding is a core learning product of STEM education. It is common for students to learn formulas, definitions and explanations in textbooks, but not be able to explain why a concept works and how it applies to real-life situations. Inquiry-based teaching can overcome this limitation since students are able to observe phenomena, test their ideas, compare evidence, and change their explanations. The teacher in a guided inquiry classroom does not just give answers, rather, the teacher designs experiences by asking questions, giving prompts, feedback, and conversing. This process is conducive to constructivist learning as students construct meaning based on their experiences and interactions (Vygotsky, 1978).

Participation in STEM learning is also a critical component of STEM learning. Engagement is defined as attention, interest, participation, effort and emotional involvement in classroom activities. Active learning research indicates that students learn better by engaging in activities, discussions, and problem-solving as opposed to listening to lectures (Freeman et al., 2014). Inquiry-based learning can thus enhance engagement by shifting the responsibility for exploring a problem and communicating explanations to the student. In the secondary schools of Multan where some classrooms continue to focus on teacher-centered explanation and preparation for tests, inquiry-based teaching can bring about a more participatory and meaningful learning experience in STEM classrooms.

Problem solving is also a key skill in STEM education. Students identify problems, choose relevant information, apply evidence, explore options, and explain and validate conclusions in STEM

learning. These skills are developed naturally through inquiry-based teaching as students seek answers to questions and present explanations with the support of data. But the design of inquiry-based teaching is important. Guided discovery is not an equal exchange of student thinking, but unstructured discovery can be overwhelming for students. There is meta-analytical evidence that guided inquiry yields better learning than minimally guided methods (Furtak et al., 2012; Lazonder & Harmsen, 2016).

Theoretical Framework

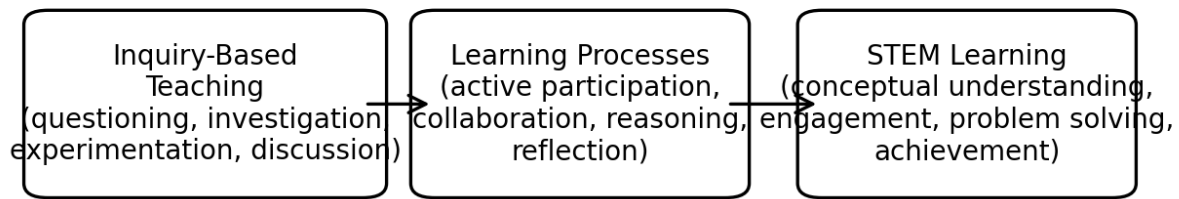
This study is based on constructivist and social constructivist theories. Constructivism theory states that learning is a process that is experienced by a learner to build knowledge for himself by linking new experiences with previous experiences. In inquiry-based STEM classrooms students make sense by questioning, observing, investigating, discussing, and reflecting. The social constructivism theory also asserts that learning can be facilitated by social interaction, dialogue and scaffolding provided by teachers and peers (Vygotsky, 1978). The following ideas are significant to the study of STEM education because students tend to learn and understand science and mathematics better when they have the opportunity to share their thinking, to compare ideas, and to have feedback from the instructor.

This study is also guided by the 5E instructional model that consists of engaging, exploring, explaining, elaborating and evaluating. The 5E model is a useful framework for lessons that use inquiry to engage students in their learning, as it starts with a question, goes to investigation, then explanation, application and evaluation. In this study, using inquiry-based teaching is anticipated to enhance STEM learning through an active, guided and reflective classroom experience.

Conceptual Framework

Conceptual framework: The independent variable is inquiry-based teaching, while the dependent variable is the students' STEM learning. The components of inquiry-based learning are questioning, investigation, experimentation, discussion, evidence-based reasoning, problem-solving activities and scaffolding by the teacher. Conceptual understanding, student engagement in class, problem-solving abilities, and academic performance are all indicators of students' STEM learning. The framework is based on the premise that inquiry-based learning activities foster STEM learning by engaging students in active participation, exploration, collaboration, reasoning, and reflection.

Figure 1: *Conceptual Framework of the Study*



Context: Secondary Schools in Multan

Research Methodology

The design used to study the relationship between the inquiry-based teaching and students' STEM learning was a quantitative descriptive-correlational design. This design was suitable for the present study because the study did not involve making changes in the classroom setting and it assessed students' perceptions of what was happening and obtaining information on learning outcomes. When there is an interest in describing the levels of variables and testing relationships between measurable constructs, quantitative survey designs are frequently used (Creswell & Creswell, 2018).

The respondents were Grade 9th and 10th students of public and private secondary schools in the city of Multan. The study was conducted with students who were studying STEM related disciplines such as science, mathematics, computer science, and general science. Multi-stage sampling procedure was used. Initially, secondary schools were picked up from various localities of Multan. Secondly, schools were classified according to the sector. Third, students in Grades 9 and 10 were chosen based on available and proportional representation. There were 360 students in the final group of samples.

The data were obtained by a structured questionnaire with a five point Likert scale ranging from strongly disagree (1) to strongly agree (5). The first part gathered demographic data such as gender, grade level, school sector, subject group etc. The second part was the inquiry-based teaching and STEM learning. Inquiry-based teaching items that included questioning, investigation, experimentation, discussion, evidence-based reasoning, problem-solving activities, and teacher scaffolding. The conceptual understanding, classroom engagement, problem-solving skills, and academic achievement of STEM learning items were measured.

The questionnaire was designed keeping in mind the objectives and concept of the study. The following questions were asked about inquiry-based teaching, asking students if they felt that the teacher: asked questions, used classroom discussion, related lessons to real problems, provided practical activities, and guided students to make use of evidence. For items requesting students' perspective on STEM learning, students were asked about their understanding of concepts, involvement in classroom activities, problem solving skills in STEM and assessment skills. The more positive the perception of inquiry-based teaching and STEM learning the higher the mean score.

Content validity was achieved by having experts in education and STEM teaching review the content. They were supplied with the feedback on how to enhance the clarity, relevance and relevance to the study aims of the items. The test of reliability was Cronbach's alpha. An internal consistency score of .70 or higher was regarded as good. Descriptive statistics, Pearson correlation, regression analysis and independent samples t tests were used to analyze data. The p level used was .05. School permission, informing participants about the study and anonymity and confidentiality were considered ethical principles.

Results

This section includes a demographic description of the respondents, reliability values, descriptive statistics, correlation analysis, regression analysis, comparisons between groups and conducting hypothesis tests. The statistical values are given in APA format.

Table 1: *Demographic Characteristics of Respondents*

Variable	Category	f	%
Gender	Male	185	51.4
	Female	175	48.6
Grade level	Grade 9	178	49.4
	Grade 10	182	50.6
School sector	Public	210	58.3
	Private	150	41.7
Subject group	Science	245	68.1
	Computer science	75	20.8
	General group	40	11.1

Note. N = 360.

As can be seen in Table 1, the sample in this study was almost balanced in terms of gender and grade level. The majority of students were from public schools and most of the subjects were science.

Table 2: Reliability Analysis of the Study Variables

Variable	Items	Cronbach's α
Inquiry-based teaching	10	.86
Conceptual understanding	6	.82
Classroom engagement	6	.84
Problem-solving skills	6	.81
Academic achievement	5	.79
Overall STEM learning	23	.88

Note. All reliability coefficients exceeded the commonly accepted .70 thresholds.

Table 2 shows acceptable internal consistency of the reliability results for all the variables. The instrument was thus judged to be appropriate for subsequent analysis.

Table 3: Descriptive Statistics of Study Variables

Variable	N	M	SD	Level
Inquiry-based teaching	360	3.72	0.68	High
Conceptual understanding	360	3.81	0.64	High
Classroom engagement	360	3.76	0.71	High
Problem-solving skills	360	3.69	0.66	High
Academic achievement	360	3.58	0.73	Moderate to high
Overall STEM learning	360	3.71	0.62	High

Note. Scale interpretation: 1.00–1.80 = very low, 1.81–2.60 = low, 2.61–3.40 = moderate, 3.41–4.20 = high, and 4.21–5.00 = very high.

The results of students' perceptions regarding the presence of inquiry-based teaching and STEM learning are presented in table 3. The mean scores for the STEM learning dimensions were highest in concept, and lowest in academic achievement.

Figure 2: Mean Scores for Inquiry-Based Teaching and STEM Learning Dimensions

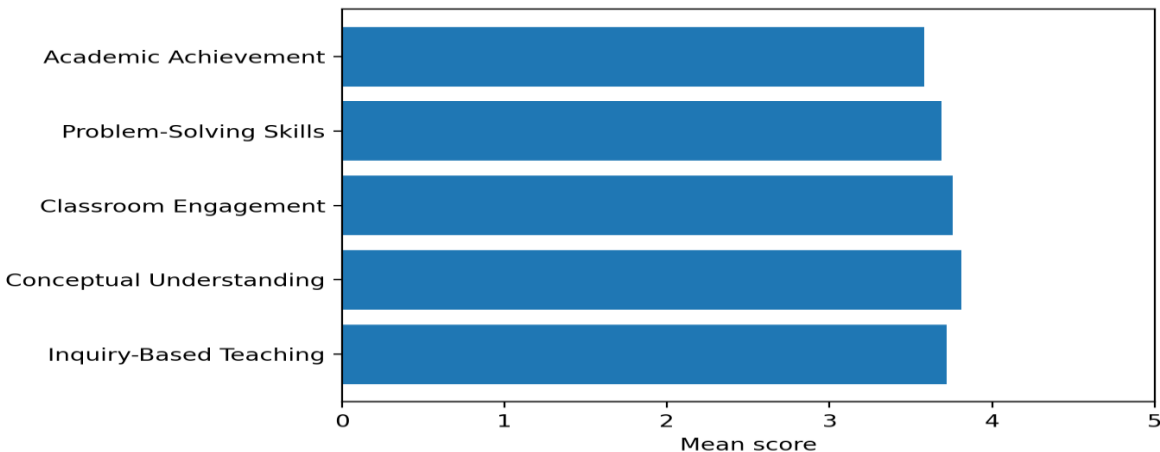


Table 4: Correlation Between Inquiry-Based Teaching and STEM Learning

Variable	1	2	3	4	5	6
1. Inquiry-based teaching	—					
2. Conceptual understanding	.61**	—				
3. Classroom engagement	.58**	.55**	—			
4. Problem-solving skills	.63**	.59**	.57**	—		
5. Academic achievement	.49**	.52**	.46**	.54**	—	
6. Overall STEM learning	.67**	.78**	.76**	.81**	.72**	—

Note. **p < .01.

Table 4 shows that inquiry-based teaching was found to have significant positive correlations with all dimensions of students' STEM learning. The highest correlations were with overall STEM learning and problem-solving skills, with conceptual understanding next.

Table 5: Regression Analysis Predicting Overall STEM Learning

Predictor	B	SE B	β	t	p
Constant	1.43	0.18	—	7.94	< .001
Inquiry-based teaching	0.61	0.04	.67	15.32	< .001

Note. R = .67, R² = .45, adjusted R² = .44, F (1, 358) = 234.70, p < .001.

The results of regression are presented in Table 5, indicating that the inquiry-based teaching significantly explained the overall STEM learning. The model accounted for 45% of the variability in STEM learning outcomes, suggesting that the use of inquiry-based teaching made a meaningful contribution to students' STEM learning outcomes.

Table 6: Effect of Inquiry-Based Teaching on STEM Learning Dimensions

Dependent Variable	B	SE B	β	R ²	t	p
Conceptual understanding	0.57	0.04	.61	.37	13.08	< .001
Classroom engagement	0.60	0.05	.58	.34	12.01	< .001
Problem-solving skills	0.62	0.04	.63	.40	14.18	< .001
Academic achievement	0.53	0.05	.49	.24	10.67	< .001

Note. Predictor variable = inquiry-based teaching.

As presented in Table 6, inquiry-based teaching accounted for significantly high prediction of all dimensions of STEM learning. Problem solving skills showed the greatest influence and the following effects were conceptual understanding, classroom engagement, and academic achievement.

The findings indicate that an inquiry-based learning approach could have a greater impact on deeper learning processes than the results from examinations. Inquiry activities directly foster problem-solving and conceptual understanding as students need to interpret data, compare explanations, and justify conclusions. Other factors affecting achievement include assessment

design, home support, school resources and examination preparation, and academic achievement may improve as well. Thus, it is important to note that the results do not imply that inquiry-based teaching is the only factor influencing STEM learning but serves as a strong pedagogical contributor.

Table 7: Comparison of Overall STEM Learning by School Sector and Gender

Grouping Variable	Group	N	M	SD	t	p
School sector	Public	210	3.64	0.61	2.41	.016
	Private	150	3.81	0.59		
Gender	Male	185	3.70	0.63	0.32	.749
	Female	175	3.72	0.61		

Note. Independent samples t tests were used.

Table 7 shows a significant difference between STEM learning by school sector with private school students slightly higher than public school students. There was no significant difference between the two sexes.

Table 8: Summary of Hypothesis Testing

Hypothesis	Decision
H1: Inquiry-based teaching is significantly related to STEM learning.	Supported
H2: Inquiry-based teaching significantly predicts conceptual understanding.	Supported
H3: Inquiry-based teaching significantly predicts classroom engagement.	Supported
H4: Inquiry-based teaching significantly predicts problem-solving skills.	Supported
H5: Inquiry-based teaching significantly predicts academic achievement.	Supported

Note. All hypotheses were evaluated at the .05 significance level.

Discussion

The results revealed that the correlation between inquiry-based teaching and students' STEM learning in secondary schools of Multan is significant and positive. Students who had more experiences with inquiry-based classrooms also indicated better conceptual understanding, engagement, problem-solving abilities and academic achievement. This finding aligns with the idea that active engagement in questioning, investigation, experimentation, discussion, and evidence-based reasoning facilitates improved STEM learning. This result aligns with past studies that found that inquiry-based and active learning strategies have a positive impact on student performance and learning in science and STEM (Freeman et al., 2014; Minner et al., 2010).

A significant implication of this finding is that inquiry-based learning is not a supplement or alternative to regular classroom learning. Rather, it may be incorporated as a fundamental approach to science and mathematics concepts. For instance, a lesson might start with a problem or situation from the real world, then engage students in exploration or analysis of data, followed by students' own explanations. The sequence enables teachers to also teach curriculum content, and reasoning, communication, and problem-solving skills. With proper organization, inquiry-based teaching can have a positive impact on curriculum achievement and higher-order STEM learning.

The most robust findings related to inquiry-based learning were for skills involving problem-solving. Theoretically the finding is significant because inquiry-based teaching puts students in a position to ask questions, look for evidence, test ideas, and draw conclusions. These activities are tightly related to the development of problem solving and higher order thinking. The findings also indicated that this approach had a significant impact on concept attainment, which indicates that the inquiry-based approaches encourage students to shift away from memorative knowledge and proceed to explain knowledge. This discovery is consistent with the constructivist and social constructivist concept in which knowledge is constructed through interaction and scaffolding (Vygotsky, 1978), with active construction of the knowledge.

The impact on academic achievement was greater than that on problem solving and understanding of concepts, but not as great. This could be an indication that inquiry-based learning first enhances deeper learning processes, and its effects on exam performance may be influenced by how it is assessed, the amount of time allocated, and the schools' resources. The difference between the two sectors is significant, which may imply that there are slightly more resources available to students at private schools, class sizes may be smaller or there may be more opportunities for activity-based learning. The lack of difference in the results, however, suggests that inquiry-based STEM instruction has a similar effect on the learning of male and female students when learning opportunities are shared fairly. In general, the results indicate that guided inquiry is more important than unguided inquiry because inquiry is most effective when teachers provide the necessary support (Furtak et al., 2012; Lazonder & Harmsen, 2016).

Conclusion

The study findings revealed that inquiry-based teaching is an effective teaching method for improving students' learning in the area of science, technology, engineering and mathematics in secondary school level in Multan. Inquiry-based teaching was positively and significantly correlated with conceptual understanding, class participation, problem solving, academic performance and overall learning of STEM. The results showed that the use of questioning, investigation, experimentation, discussion, evidence-based explanation, and scaffolding by the teacher is the one strategy that helps students learn STEM concepts better. Thus, inquiry-based learning could be regarded as a pedagogical approach that could help to enhance the quality of secondary STEM education, provided it is done in a well-structured and systematic way with the appropriate classroom materials.

Recommendations

The secondary school teachers in Multan must be trained to create and adopt inquiry-based STEM lessons. Professional development should include effective questioning, planning for investigation, group work, laboratory work, explaining using evidence and formative assessment. Schools need to support the teachers with materials, technology, and supportive schedules for meaningful inquiry activities in the laboratory. In STEM subject's curriculum developers should incorporate more practical problems, experiments, projects, and inquiry activities. However, support is needed from the public schools in terms of resources and teacher training, so that all students can equally benefit from inquiry-based learning. Experimental and/or mixed-method research could be done in the future to investigate the long-term impact of Inq-Based instruction on achievement, creativity, critical thinking, and career interest in STEM.

Limitations

The study employed a quantitative approach and the self-report questionnaire was used in secondary schools of Multan. Thus, care should be taken with generalizing the findings to other districts or educational levels. The study relied on students' perceptions and the cross-sectional design did not address the changes over time. Classroom observation, teacher interviews, experimental design and longitudinal data should be incorporated in future studies to give more convincing evidence of the impact of inquiry-based teaching on STEM learning.

Conflict of Interest

The authors showed no conflict of interest.

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