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Exploring the Strengths and Weaknesses of STEM Implementation in Public Secondary Schools in Punjab

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Abstract

This research explores the implementation and weakness of STEM education among secondary schools in the public sector of Punjab. It utilizes purposive sampling and semi-structured interviews are used as data-gathering instruments. Through thematic analysis using a compare and contrast technique, several key themes emerged. The results indicate that STEM education markedly improves students' comprehension of science and critical thinking abilities. The existing curriculum shows an improved alignment with STEM principles relative to earlier iterations; however, it continues to prioritize memorization rather than practical application. Training for educators and ongoing professional growth is essential for successful STEM education, with participants observing beneficial shifts in instructional methods and student involvement. Nonetheless, obstacles including financial limitations, restricted access to technology, and inadequate resources were recognized. The role of school leadership and community support emerged as essential elements for effective STEM implementation. Over all this study highlights the necessity for curriculum reform, improved teacher training, and greater financial support to sustain and enhance STEM education in public schools in Punjab.

Keywords STEM Education, Strengths, Weaknesses, Implementation

Introduction

STEM stands for Science, Technology, Engineering, and Mathematics. In the realm of science, disciplines encompass biology, chemistry, and physics, as well as areas like psychology, geology, and astronomy. Technology encompasses areas like computer science, software development, artificial intelligence, and programming (Shafqat & Amjad, 2024). Engineering encompasses four primary disciplines: chemical, civil, mechanical, and electrical engineering. Mathematics encompasses various fields such as geometry, fractions, algebra, and statistics within the educational curriculum.

These subjects integrate and emerge during learning with STEM education techniques. Basically, STEM education reduces the gap between classroom techniques and real-life skills. In STEM education use thinking skills, scientific skills, learning technology, and design thinking to enhance the student capabilities that they use in real-life practice. The importance of enhancing students' skills in the fields of science, technology, engineering, and mathematics (STEM) has been top-focused in recent years (Thibaut et al., 2018). In both established and developing nations, teaching methods for STEM subjects are currently regarded as one of the most developing fields in education (Madani, 2020).

The global emphasis on STEM education has increased in recent years, spurred by fast technological breakthroughs and the growing demand for a highly qualified workforce (National Science Foundation, 2023). Notwithstanding these developments, Punjab's public schools still face

several obstacles to implementing STEM education, such as a lack of funding, a shortage of qualified instructors, and inadequate facilities (Aslam, 2022).

Although there has been progress in incorporating STEM into the curriculum, there is still a significant gap in how to adequately address the differences in teacher preparation and educational resources, both of which are essential for creating a welcoming and productive STEM learning environment.

Objectives of the Study

1. To identify the strengths of STEM programs in Punjab's public schools at the secondary level.
2. To analyze weaknesses in implementing STEM education in public schools at the secondary level.
3. To assess opportunities for improving STEM education in public schools at the secondary level.
4. To evaluate external threats to successful STEM implementation in Punjab public schools at the secondary level.

Research Questions

1. What are the key strengths of STEM education programs in Punjab's public schools at the secondary level?
2. What are the main challenges faced by Punjab's public schools in implementing STEM education at the secondary level?
3. What opportunities exist for enhancing STEM education in Punjab's public schools at the secondary level?
4. What external threats hinder the successful implementation of STEM education in Punjab's public schools at the secondary level?

Statement of the Problem

The execution of STEM education initiatives in Punjab's public schools reveals a multifaceted scenario characterized by several strengths, shortcomings, possibilities, and dangers.

Despite increased acknowledgment of STEM's role in educating students for a technologically sophisticated future, the success of these programs is hampered by a variety of obstacles.

This study seeks to examine the qualities that support STEM education, the shortcomings that hinder its advancement, and the potential for instructors and students to improve their STEM learning experience.

Additionally, it will recognize the external concerns that provide substantial hazards to the effective execution of STEM programs.

The study aims to offer a detailed knowledge of the current situation of STEM education in Punjab by thoroughly analyzing these elements, hence aiding the development of more effective plans and policies for its enhancement.

Significance of the Study

This study holds great importance as it may improve the comprehension of how STEM education is applied in public schools across Punjab.

The research can assist educators and policymakers in identifying effective practices and areas for enhancement by assessing the strengths and shortcomings of existing STEM programs.

Exploring the hurdles teachers encounter while implementing STEM projects can give useful insights into the assistance they require to succeed.

Furthermore, exploring the possibilities accessible to educators and learners can create approaches that enhance a more efficient STEM educational setting.

This study seeks to provide insights to decision-makers regarding external threats that may affect STEM education, allowing for the development of targeted interventions and policies that foster a successful and sustainable STEM education framework in Punjab.

This study is essential for equipping students for prospective careers in science and technology, thus aiding in the broader advancement of the region.

Literature Review

The Importance of STEM Education in the 21st Century

STEM education has garnered considerable global attention due to its essential role in equipping students for the requirements of the contemporary workforce. Research demonstrates that a robust foundation in STEM disciplines fosters critical thinking, problem-solving abilities, and innovation in

students, hence better preparing them for professions in dynamically expanding sectors (Becker & Park, 2023).

Countries that emphasize STEM education often experience more economic growth and technical progress, highlighting the necessity for robust STEM programs in educational institutions (National Science Foundation, 2023).

Current State of STEM Implementation in Punjab

The execution of STEM education in Punjab has faced several obstacles, such as insufficient funding, a shortage of qualified educators, and inadequate facilities. Recent studies indicate that although several schools have advanced in incorporating STEM into their curricula, numerous institutions continue to face challenges in successful implementation owing to structural difficulties (Khan et al., 2023). Moreover, the differences in resource distribution and teacher preparation among public schools add further complexity to the STEM education environment in the region (Aslam, 2022; Tabassum et al., 2024).

Challenges Faced by Educators in STEM Implementation

Educators frequently lead the charge in STEM education, but they encounter various obstacles that impede their effectiveness. A study conducted by Ahmad and Ali (2024) highlights significant barriers faced by teachers in Punjab, including insufficient professional development, lack of administrative support, and curricular constraints.The challenges encountered may result in frustration and diminished motivation, which can ultimately affect the quality of instruction in STEM fields and the level of student engagement in these areas.

Opportunities for Enhancing STEM Education

In light of the challenges faced, a multitude of opportunities exists to improve STEM education within the schools of Punjab. Partnerships between educational institutions and nearby businesses can offer essential resources and practical experiences for learners (Shah et al., 2024).

Moreover, government initiatives focused on enhancing STEM education can generate funding opportunities and resources to assist in teacher training and curriculum development.

Utilizing technology, including online learning platforms and educational software, can effectively address disparities in access to STEM education (Ali & Rehman, 2023).

External Threats to Successful STEM Implementation

Various external factors may jeopardize the efficacy of STEM education in Punjab Socio-economic disparities can restrict access to high-quality STEM resources and instruction for students from lower-income families (Iqbal, 2023).

Moreover, political instability and policy inconsistencies might hinder educational reforms and financing for STEM efforts, resulting in schools lacking the essential assistance to execute effective programs (Maqsood, 2023). Confronting these challenges is crucial for maintaining the sustainability and advancement of STEM education in the area.

Role of Teacher Training in Effective STEM Education

The successful execution of STEM education significantly depends on the caliber of teacher training and ongoing professional development.

Studies indicate that continuous training initiatives assist educators in acquiring the essential skills and confidence needed to effectively deliver STEM instruction (Darling-Hammond et al., 2023; Ong et al., 2024).

In Punjab, improving teacher training programs by incorporating hands-on workshops, collaborative learning, and access to up-to-date STEM resources can greatly elevate the overall quality of STEM education.

Moreover, mentoring and support systems can enable educators to adopt innovative teaching strategies and involve students in significant STEM experiences (Amin et al., 2024; Saleem et al., 2024).

Impact of Curriculum Design on STEM Learning

The curriculum design is crucial to the efficacy of STEM education. An organized curriculum that incorporates interdisciplinary methods might enhance students' comprehension of STEM ideas (Reddy & Fennell, 2023).

In Punjab, education system is going through enormous changes leading the need to the technology (Amjad et al., 2024, a, b, c). The goals can be achieved by modifying the STEM curriculum to align with local contexts and challenges can enhance the relevance and engagement of

the learning experience for students. Moreover, integrating project-based learning and real-world applications into the curriculum can significantly improve students' problem-solving abilities and foster critical thinking, which are crucial for success in STEM disciplines (Khan et al., 2023).

Methodology

Research Paradigm

This study on the strengths, weaknesses, opportunities, and threats of STEM implementation in Punjab's public schools is guided by a primarily constructivist research paradigm.

This framework highlights the significance of comprehending individuals' viewpoints and experiences with their educational environments. Kilag et al, (2023) stated that the constructivist approach really works for practical subjects in education.

The study uses qualitative approaches, such as interviews, this methodology facilitates a comprehensive analysis of educators' subjective experiences, uncovering insights into their navigation of the complexity associated with delivering STEM programs.

The constructivist paradigm recognizes the impact of social, cultural, and institutional aspects on educational practices, offering a thorough framework for examining the complex terrain of STEM education in Punjab. Ben et al, (2023) highlighted in their study that constructive approach and interviews provide deeper insights.

Ultimately, this paradigm supports the study's goal to gain a deeper understanding of how STEM is implemented, making it easier to find ways to make things better based on teachers' real-life experiences.

Population of the Study

Population denotes the complete set of persons or stuff that a researcher intends to investigate and derive conclusions from. The population of interest in this study comprised all secondary public school teachers employed in Punjab.

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Sampling

This study utilized a purposive sample strategy to choose secondary school teachers as interview participants. Nyimbili et al, (2024) stated in their study that the purposive sampling technique is crucial for qualitative research studies.

This method of non-probability sampling was used to make sure that the teachers selected had the right experience and knowledge to help their schools adopt STEM education.

The study aims to collect comprehensive, contextually relevant data by focusing on educators who have actively participated in the STEM curriculum, reflecting their views on the strengths, shortcomings, opportunities, and risks related to STEM implementation.

This method not only enabled the gathering of many perspectives but also guaranteed that the views of people actively engaged in the educational process were sufficiently represented.

Participants were selected from public secondary schools in Punjab, enabling a comparative comparison of experiences across various educational environments.

Instrumentation

This study utilized semi-structured interviews as the principal method for data collection, enabling a comprehensive examination of participants' experiences and viewpoints about the implementation of STEM education in secondary schools.

This qualitative approach combined structured inquiry with adaptability, allowing the interviewer to ask set questions while also facilitating additional inquiries based on the responses of participants.

Semi structured interviews are very powerful in providing deep insight stated by (Treier et al, 2024).

The semi-structured format facilitated open dialogue, creating a comfortable environment for educators to express their perspectives on the strengths, weaknesses, opportunities, and threats associated with STEM education.

The interview guide was crafted in alignment with the study's objectives, ensuring that essential themes were covered while allowing participants the opportunity to bring up other pertinent topics, thereby enhancing the richness of the data gathered.

Reliability and Validity

The study emphasizes the significance of reliability and validity to guarantee that the findings can be deemed trustworthy. For subjective measuring of the instrument reliability and validity are vital stated by (Sobral-Monteiro-Junior et al. 2024) To enhance reliability, a standard interview guide was employed for all semi-structured interviews, ensuring that the questions remained consistent across participants. A pilot study was conducted to check the reliability of the instrument.

The interviews were also audio-recorded and transcribed word for word, ensuring that the researcher correctly captured the participants' responses while reducing bias.

To address validity, the semi-structured interviews were validated by the experts, and necessary amendments were made in the light of instructions.

Ethical Consideration

During interviews done over Zoom and in person with educators, significant ethical requirements were adhered to. Ethical considerations are very important for any research Lim, 2024 established in the overview of qualitative research.

All participants were provided with informed consent, detailing the study's purpose, the procedures involved, and their right to withdraw at any point.

Responses were maintained confidentially through the use of pseudonyms or codes, with the data being securely stored.

Interviews were arranged at times that suited the teachers to minimize any disruption to their schedules.

A private and secure setting was established for Zoom interviews to safeguard their privacy.

Participants were treated with dignity, ensuring the research process was conducted without causing any harm or discomfort.

Data Collection

The data for this study was collected through in-person interviews and online sessions conducted via Zoom. This approach enabled adaptability in involving participants, guaranteeing that those who could not be present physically due to distance or other circumstances could still take part. All interviews were conducted with participant consent and subsequently transcribed.

Data analysis

Table 1

Demographic Information of Participants

Serial #	Gender	Qualification	School
1	Male	M.Phil.	Govt Boys School Iqbal Town
2	Male	M.Phil.	Govt Central Model School
3	Male	PhD	Govt Boys School Sabzazar
4	Male	M.Phil.	Govt Boys School Sabzazar
5	Female	M.Phil.	Govt Girls School Sabzazar
6	Female	PhD	Govt Saeeda but School Gulshan Ravi
7	Female	Masters, B.Ed.	Saleem Model School Lower Mall
8	Female	M.Phil.	LDA School Iqbal Town
9	Female	M.Phil.	Govt Pilot Secondary School Wahdat Road
10	Female	Masters, B.Ed	Govt Comprehensive School
11	Female	M.Phil.	GGES Aziz-i-Millat Sandha Lahore
12	Female	Masters, B.Ed	GGES Begum Kot Shahdrah
13	Female	M.Phil.	GGES Santnaghar
14	Female	Masters, B.Ed	GGES Chahmira

Table 1 provides the details of the study’s participants. The detail of the themes is presented in Figure 1.

Figure 1
Showing Themes

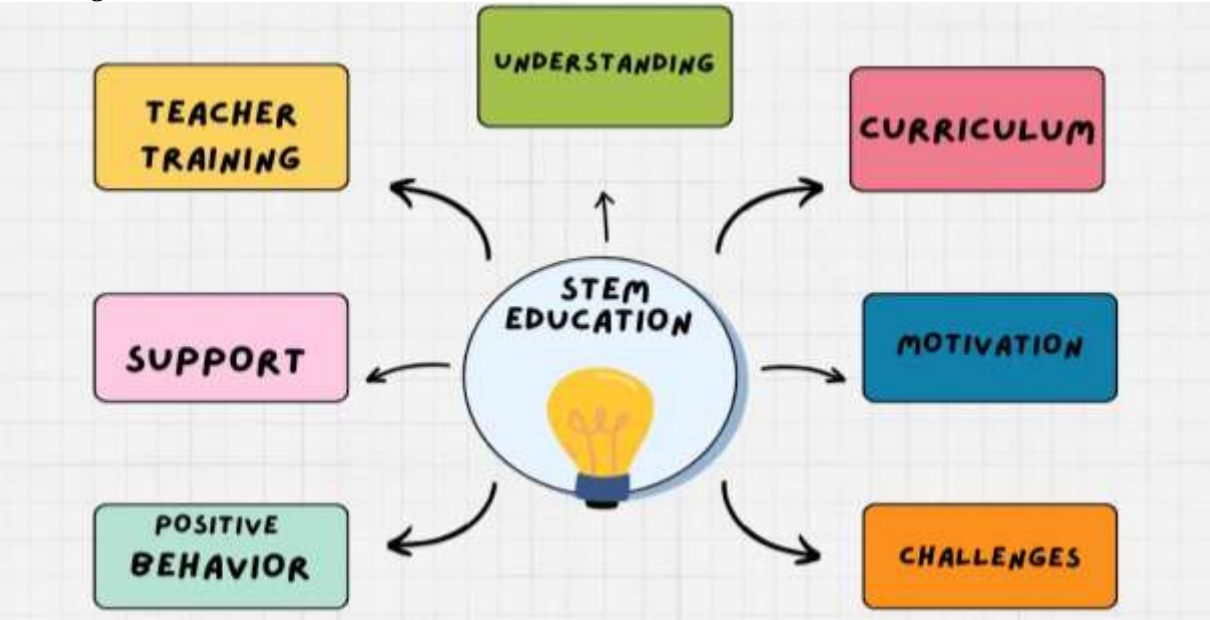

Table 2
Themes

Serial #	Themes
1	Understanding and Value of STEM Education
2	Curriculum Alignment and Improvement
3	Teacher Training and Professional Development
4	Engagement and Motivation of Students
5	Support and Resources for Implementation
6	Challenges and Threats to Implementation
7	Positive Behavioral Changes in Students

Themes Derived from Interviews

Understanding and Value of STEM Education

Most educators showed a good understanding of STEM and indicated that STEM education greatly improves students' comprehension of scientific concepts and fosters critical thinking skills. Participants observed that students are engaging in more than mere memorization of facts; they are also developing the ability to apply their knowledge, as demonstrated by their shifting career aspirations towards fields such as astrophysics and engineering.

One of the respondents shared "*At the outset, there was a lack of practical application of scientific principles." Having undergone rigorous training in the sciences, I have effectively integrated scientific principles into my classroom instruction*. R2

Another teacher shared "*In the past, when inquired about their aspirations, children would express a desire to pursue careers as teachers or doctors. Upon grasping the concepts of STEM, children express a desire to pursue careers in science*" R5

According to one educator, *"STEM focuses on educating children through hands-on science projects, fostering a deep and enduring comprehension of the subject matter. It encompasses learning through engaging activities*" R7

Curriculum Alignment and Improvement

A significant number of educators assert that the existing curriculum is more in tune with STEM principles than earlier versions. They identified gaps, notably the extensive syllabus that prioritizes memorization rather than practical application, as a significant obstacle to effective STEM education.

One of the respondents shared *"The existing curriculum shows significant improvements compared to its predecessor." A multitude of elements correspond with the principles of STEM*" R3

Another teacher highlighted "*It does to a certain degree, though not completely. Changes are necessary*" R10

One of the educators mentioned, "*The extensive syllabus that requires memorization followed by examinations presents the most significant challenge*." R12

Another participant expressed "*The extensive syllabus frequently compels us to hastily cover subjects, resulting in minimal opportunity for activities when disruptions arise" R 9*

Teacher Training and Professional Development

The importance of STEM training for educators emerged as a prominent topic, with contributors highlighting the need for all science instructors to undergo training to enhance their abilities and instructional techniques. The implementation of effective training has resulted in significant improvements in teaching methodologies and heightened student involvement. Almost all teachers endorsed teacher training and professional training regarding STEM implementation.

One of the participants highlighted "*It is essential. All science educators need to receive STEM training, rather than limiting it to just one individual*". R6

Another educator highlighted "*It is essential that every science teacher receives STEM training, rather than just a select few*." R9

According to one teacher "*Following the training, I underwent a significant personal transformation. My approach to teaching and my conduct underwent a significant transformation*." R11

One of the respondents reported, "*Indeed, it offered us valuable guidelines and strate*gies." R14

Engagement and Motivation of Students

According to most of the teachers at first, students exhibited minimal enthusiasm for STEM activities; however, as time progressed, their involvement grew considerably. Educators observed that engaging in practical activities and contests enhances student interest and participation, while acknowledgment and incentives for involvement are essential for sustaining motivation.

One of the participants asserted" *At first, there was a noticeable lack of interest among the students. Over time, there has been a notable increase in their interest and involvement*." R8

An educator shared "*Learners exhibit increased alertness and engagement. They redirect their attention from various activities to the content being delivered by the educators*."R12

One of the participants explained, "*When a child engages in an activity or creates a model without receiving any form of reward or recognition, their morale significantly declines, leading to a lack of motivation for future preparations"* R11

Support and Resources for Implementation

The majority of the educators had a similar opinion that the involvement of school leadership, particularly principals, was a critical factor for successful STEM implementation. However, all participants noted a lack of financial support from the government, which threatens the sustainability of STEM initiatives. They called for greater community involvement to enhance resource availability.

According to one participant, "*The primary factor contributing to our school's success is the active participation of the principal. When the principal is engaged, successful implementation is achievable" R1*

One of the respondents revealed "*We do not receive any support from the government. Educators and learners manage all aspects independently" R3*

Another educator asserted "*It is interesting to note that individuals often contribute financially to mosques, yet there seems to be a lack of similar support for schools, even though education also represents a form of charitable giving. When the community actively engages with the school and contributes resources for students, the overall environment can significantly improve*." R14

According to another teacher, "*Teachers and students independently handle these activities without assistance from the government*" R9

Challenges and Threats to Implementation

According to most educators, significant challenges encompass financial limitations, restricted access to technology, and inadequate resources for activities and model development.

Teachers also expressed apprehension regarding the restricted internet access of students, which hinders their capacity to participate in online activities and research related to STEM.

According to one of the secondary teachers, "*The most significant obstacle we encountered was the financing of activities or the development of models*." R11

One of the teachers observed "*The majority of students have extremely limited internet access, necessitating that we provide them with our smartphones to facilitate their research following the activity" R9*

Another teacher revealed "*At times, parents are reluctant regarding their daughters' involvement, and obtaining materials can pose challenges due to gender-related factors*" R6

One of the secondary teachers shared "*Students frequently engage with technology primarily for leisure activities, such as viewing YouTube videos. They lack awareness of its potential for education" R5*

Positive Behavioral Changes in Students

The majority of the participants noted that the implementation of STEM has a positive impact on student behavior, resulting in heightened curiosity and a greater willingness to ask questions. This transition reflects a wider involvement in education and a more profound comprehension of scientific principles.

One of the respondents observed, "*Indeed, one observation I have made is that in the past, students would remain silent after lectures, but now they actively engage by asking questions such as 'Why is this so?' or 'In what context is this applied?" R7*

According to another participant," *The enthusiasm among students has been remarkable, and their feedback has been overwhelmingly positive. I did not perceive any threats. Positive changes are evident; activity-based learning effectively maintains student engagem*ent" R 6

Discussion

The implementation of STEM education in schools across Punjab has demonstrated considerable advantages for both students and educators. Educators have noted that STEM education enhances students' comprehension of science and fosters critical thinking, leading to a shift in their career aspirations towards areas such as science, technology, engineering, and mathematics.

This is consistent with recent studies that show STEM education fosters problem-solving abilities and encourages innovation (Tabbasam et al., 2023; Watson et al, 2022).

Even with advancements, the existing curriculum continues to prioritize memorization rather than practical application, a discrepancy observed by numerous educators.

This aligns with findings that emphasize the necessity for curriculum reforms to improve hands-on learning experiences (Adebiy et al, 2023).

Training for educators and ongoing professional growth are essential for delivering effective STEM education. Research indicates that educators who receive proper training can greatly enhance student involvement and academic results (Davis & Carter, 2023)

In Punjab, the necessity for thorough STEM training for all science educators emerged as a consistent focus.

Participation in STEM fields has seen growth due to practical activities and contests, yet sustaining enthusiasm necessitate acknowledgment and incentives.

This is backed by findings indicating that student motivation increases with recognition and rewards (Lee & Perret, 2022).

Significant obstacles include financial limitations, restricted access to technology, and a lack of adequate resources. The absence of government support intensifies these issues, as evidenced by research on the allocation of educational resources (DeCoito et al, 2023; Malik et al., 2024).

The role of school leadership is crucial in determining the success of STEM education. Effective leadership guarantees the essential support and resources, cultivating a constructive learning atmosphere. This aligns with findings indicating that effective leadership is crucial for educational reforms (Cordova et al, 2024)

Conclusion and Suggestions

The implementation of STEM education in schools across Punjab has significantly enhanced students' comprehension, conduct, and professional ambitions. Nonetheless, issues like curriculum deficiencies, budget limitations, and restricted resource availability must be tackled. The sustainability of these improvements relies heavily on effective teacher training, robust leadership, and active community involvement.

Streamline the curriculum to emphasize practical, experiential learning opportunities. Research indicates that these reforms have the potential to greatly improve STEM education. Ensure thorough STEM training is available for every science educator. Studies show that ongoing professional development enhances teaching practices. It is essential to push for increased financial backing from both governmental and private entities to ensure that adequate resources are available

for STEM initiatives. Research indicates that sufficient funding is crucial for achieving success in education.

Foster community engagement to enhance resources and share knowledge. Engagement with the community has demonstrated a positive impact on educational results.

Enhance the availability of technology in educational institutions to facilitate STEM education. Studies emphasize the significance of digital resources in contemporary education.

Establish systems for recognizing and rewarding students engaged in STEM activities to sustain their motivation. Research indicates that incentives significantly influence student engagement.

By implementing these suggestions, Punjab's schools can enhance the effectiveness of STEM education, leading to better educational outcomes and preparing students for future careers in science and technology.

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