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Cultivating Innovators: Planting the Seeds of a STEAM Curriculum at Primary School Level

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ABSTRACT

Science, Technology, Engineering, Arts, and Mathematics (STEAM) education is an interdisciplinary approach that integrates these five areas to promote creativity, critical thinking, problem-solving, and cross-disciplinary learning. This study aimed to examine how the STEAM curriculum is implemented at the primary school level in Islamabad, Pakistan. Using a qualitative research design, data were collected through semi-structured interviews with fifteen curriculum experts selected via purposive sampling. The research instrument was validated by subject specialists, and its reliability was confirmed through pilot testing using Cohen's Kappa for test -retest reliability calculated value of Cohen's Kappa = 0.82 (indicating strong agreement).The findings indicated that STEAM education has strong potential to enhance transdisciplinary learning among primary students. However, challenges remain, particularly in the areas of content integration, teacher training, availability of resources, and continuous professional development. The study recommends strengthening infrastructure, providing adequate teaching materials, and developing clear assessment strategies and supportive policies to facilitate effective STEAM implementation. In conclusion, the study emphasizes the need for systemic improvements in teacher preparation, instructional resources, and educational policies to ensure the successful integration of STEAM education. It contributes valuable insights for educators, policymakers, and curriculum developers aiming to advance STEAM learning at the primary level.

Introduction

Modern education systems are increasingly challenged to prepare a workforce equipped for the demands of the future job market individuals who can think critically, solve complex problems, communicate effectively, and demonstrate creativity. Science, Technology, Engineering, Arts, and Mathematics (STEAM) education has emerged as an innovative approach to meet these evolving needs (Deák & Kumar, 2024). The STEAM framework is grounded in the concept of integrated, transdisciplinary learning, promoting connections across disciplines rather than teaching them in isolation (Almarcha et al., 2023). Unlike traditional education models that offer limited opportunities for creativity, STEAM education emphasizes the development of students' divergent thinking and innovative problem-solving abilities (Erol & Erol, 2023).

Introducing STEAM education at the primary school level lays the foundation for lifelong learning by nurturing curiosity, creativity, and analytical skills from an early age. Research suggests that early exposure to STEAM concepts can greatly enhance students' creativity and problem-solving capabilities (Yakman & Lee, 2012; Morrison, 2020; Almarcha et al., 2023; Erol & Erol, 2023). However, the effective implementation of STEAM education depends on multiple factors, including teacher preparation, community engagement, availability of resources, professional development opportunities, and students' attitudes toward this learning approach (Mehddi, Kazi, & Butt, 2024).

Objectives of the study

1. To explore curriculum experts' perspectives on the implementation of the STEAM curriculum at the primary school level.
2. To understand how the STEAM approach contributes to fostering creativity and innovation among young learners.
3. To identify the challenges and contextual barriers that influence the implementation of STEAM education in primary schools.
4. To generate recommendations for enhancing the design and implementation of STEAM curriculum frameworks for primary education.

Research Questions

1. How do curriculum experts perceive the importance and goals of implementing a STEAM curriculum at the primary school level?
2. In what ways does the STEAM approach promote creativity and innovation among young learners, according to curriculum experts?
3. What challenges and limitations do experts identify in integrating STEAM education into the existing primary curriculum?
4. What recommendations do curriculum experts suggest for improving teacher preparation, curriculum design, and resource allocation for STEAM implementation?

Research Design

This study adopts a qualitative research approach to investigate curriculum experts' perceptions and experiences concerning the implementation of the Science, Technology, Engineering, Arts, and Mathematics (STEAM) curriculum at the primary school level. A qualitative approach is particularly suited for exploring complex educational phenomena, as it allows researchers to capture participants' lived experiences, interpretations, and contextual realities that quantitative methods may overlook (Creswell & Poth, 2018). Qualitative research focuses on understanding meaning and processes within natural settings, emphasizing depth over breadth (Merriam & Tisdell, 2016). In the context of this study, such an approach enables a rich exploration of how curriculum experts conceptualize STEAM integration, identify challenges, and perceive strategies for effective implementation.

Sampling

The participants of this study were curriculum experts, education policymakers, and teacher educators who possess relevant experience in curriculum design, development, and implementation of STEAM education. These individuals are expected to provide informed insights into current practices, challenges, and opportunities related to STEAM education at the primary level. Purposive sampling technique was employed to select participants. Purposive sampling is a non-probability method used to identify and engage individuals who are especially knowledgeable about or experienced with the phenomenon under study (Patton, 2015). This approach ensures that the data collected is rich, relevant, and deeply informative. The sample size was consisted of 15 participants. This range allows for comprehensive coverage of expert perspectives while maintaining the manageability and depth required for qualitative analysis.

Selection criteria:

- Minimum 5 years of experience in curriculum design or education policy.
- Involvement in or familiarity with STEAM or integrated curriculum development.
- Willingness to participate and share experiences through an interview.

Validity, Reliability and Pilot Testing of research Semi -structured interview.

Here is an elaborated evaluation of the reliability and content validity of semi-structured interview for 15 experts in the expert review and 5 participants in the pilot test.

1. Validity (Content validity of semi-structured interview)

Each question of semi-structured interview was check by a panel of 10 experts of relevant field for relevance and clarity. Each question from semi-structured interview was rated on a scale of 1 (not relevant) to 4 (very relevant). Content Validity Index (CVI) and the average relevance rating were calculated. Average Relevance Rating = 3.8/4 CVI = 0.93 (indicating strong content validity).

2. Pilot Testing

Five experts of relevant field were selected for the pilot testing of Semi-structured interview. After the pilot test, feedback was provided by the participants on relevance, clarity, and recommendations for improvement. Clarity: 90% of participants found the questions clear. Relevance: It was believed by 85% of the participant that questions were relevant to evaluating the STEAM curriculum. Recommendations: Minor rewording of three questions was made based on feedback.

3. Reliability

A Inter-rater Reliability

In order to check the inter-rater reliability of the Semi-structured interview. There was a conduction of interview by two independent researchers with a sample of 10 curriculum experts using the same interview guide. All responses were coded by researchers for generation of themes. In order to check the level of agreement between two raters Cohen's Kappa was calculated. Cohen’s Kappa = 0.82 (indicating strong agreement).

B. **Test-Retest Reliability**

The same interview was administered to a subset of 10 curriculum experts two weeks apart. In order to maintain the consistency of interview the interview was conducted by the same researchers. A correlation coefficient was calculated by comparing the responses from both rounds. Correlation (r) = 0.88 (indicating strong correlation between responses)

To sum up, the content validity of Semi-structured interview was confirmed through expert reviews. A strong CVI, and positive feedback from pilot testing. It was ensured by the alignment of questions with key STEAM principles that the guide is designed well gather meaningful insights about the STEAM curriculum. Moreover, strong reliability has shown by the Semi-structured interview guide. Semi- structured interview guide shows with good to excellent inter-rater agreement and high test-retest stability.

4. Data Collection

Data were collected using semi-structured interviews guided by an interview protocol developed from the research objectives and literature review. Each interview had an approximately 45–60 minutes, conducted face-to-face an online (via Zoom & Google Meet).

The interview guide included the below open-ended questions focusing on:

- Experts' perceptions of STEAM curriculum goals and relevance.
- Pedagogical and curricular strategies for promoting creativity.
- Implementation challenges and contextual barriers.
- Recommendations for effective STEAM integration.

All interviews were audio-recorded (with participants' consent) and transcribed verbatim for analysis.

5. Data Analysis

The collected qualitative data were analysed using thematic analysis following the framework of Braunand Clarke (2006). The process includes, familiarization with data (reading and rereading transcripts), generating initial codes to label significant ideas or patterns, grouping codes into themes related to implementation, creativity, and challenges, reviewing and refining themes for coherence and clarity, defining and naming final themes that represent experts' shared perspectives and manual coding techniques may be used for organizing and categorizing data.

7. Ethical Considerations

Ethical approval was obtained from the relevant institutional review board. Participants were informed about the study's purpose, their voluntary participation, confidentiality of responses, and right to withdraw at any stage. Pseudonyms were used to protect identity, and data were securely stored for research purposes only.

Data analysis and interpretation of Semi- structured interview

The Semi-structured interviews with experts provided valuable insights into the evaluation and implementation of the Science, technology, engineering, arts and mathematics (STEAM) curriculum at the primary school level. Each theme includes key codes derived from the responses, highlighting the experts' perspectives.

Theme 1: Curriculum Content and Objectives

Questions

1. How would you define STEAM curriculum, and what are its core principles?
2. What objectives guided your selection and arrangement of STEAM curriculum content to promote interdisciplinary learning?
3. Can you describe the key components of STEAM curriculum and how you ensure its relevance to current technological and scientific advancements?

Codes:

1.Definition and Core Principles: STEAM education has been defined by experts as an integrated approach that can enhance the critical thinking, creativity and focused on real world problem with their innovative solutions.

2.Objectives for Content Selection: According to curriculum experts' objectives of the science, technology, engineering, arts and mathematics (STEAM) curriculum have been focused on developing problem-solving skills, promoting creativity, by ensuring that content of the STEAM curriculum is relevant to contemporary issues.

3.Key Components: key components of science, technology, engineering, arts and mathematics (STEAM) curriculum were defined by experts as hands-on projects, with integration of technology, and inclusion of Arts to keep the pace of student engagement and its relevance to current progressions. Science, technology, engineering, arts and mathematics (STEAM) curriculum was viewed by experts as an integrated curriculum which have the capability of holistic development of child. Science, technology, engineering, arts and mathematics (STEAM) curriculum emphasized on the important skills which required for the future job market.

Moreover, experts highlighted the science, technology, engineering, arts and mathematics (STEAM) curriculum as a holistic approach that not only integrates disciplines but also prioritizes the development of essential 21st-century skills. The experts emphasized that selection of Science, technology, engineering, arts and mathematics (STEAM) curriculum content must be relevant to STEAM ideology and they must address the issues of 21st century job market.

Theme 2: Teaching Methodologies and Teacher Training

Questions

1. What types of professional training do you provide to teachers to effectively deliver the STEAM curriculum?
2. What instructional strategies have you found most effective for STEAM education, and how do you integrate various disciplines during lessons?
3. Do you believe a background in STEAM disciplines is necessary for teachers?

Codes

1.Professional Training: It was elaborated by experts and principals that training of teachers is very important for the successful implementation of STEAM curriculum. It was further explained by the experts for STEAM curriculum the training of the teachers must be based on innovative training techniques and pedagogies with the meaning full integration of technologies added with the flavor of art and creativity.

2.Effective Instructional Strategies: in addition to, experts were of the view that Project-based and inquiry-based learning, collaborative learning, problem-based learning, individualize instruction were proved to be effective strategies which can engage students and promote interdisciplinary (transdisciplinary) learning.

3.Background in Science, Technology, Engineering, Arts and Mathematics (STEAM): in response to, question regarding the background of teacher in STEAM the experts were of the view that, although it is beneficial that teachers having background in science, technology, engineering, arts and mathematics (STEAM) discipline. But a formal background in science, technology, engineering, arts and mathematics (STEAM) is not as essential as professional development and training in science, technology, engineering, arts and mathematics (STEAM) is important. They further said that effective training in STEAM and teachers' willingness to learn and is very important. While beneficial, a formal background in STEAM is not deemed essential; effective training and a willingness to learn should prioritized.

In brief, experts viewed professional development and training crucial for equipping teachers with the necessary skills to successfully implement the science, technology, engineering, arts and mathematic (STEAM)curriculum. Moreover, Experts were agreed that innovative teaching methodologies are important for the proper delivery of STEAM curriculum. However, they had the view that science, technology, engineering, arts and mathematics (STEAM) background can be supportive for the implementation of STEAM but it is not a rigid and strict prerequisite.

Theme 3: Learning Experiences

Questions

1. How are hands-on and collaborative learning experiences incorporated into the STEAM curriculum to enhance student engagement?
2. What types of learning experiences are incorporated in the STEAM curriculum?
3. Can you share an example of a hands-on project or activity that had a significant impact on student learning? What made it effective?

Codes

1.Hands-On Learning experiences: In response to question regarding hands on learning experiences experts agreed on the collaborative learning, team work and practical experiment-based learning (experiential learning). They said they are core for the effective implementation of science, technology, engineering, arts and mathematics (STEAM) curriculum to enhance student's engagement.

2.Types of Learning Experiences: it was elaborated by the experts that Science, technology, engineering, arts and mathematics (STEAM) curriculum provides learning experiences such as community service projects, field trips, and thematic interdisciplinary learning which can connect classroom learning with real-world situation.

To conclude, experts were agreed that the merging of hands-on and collaborative learning experiences is considered as vital for active involvement and deeper learning. Furthermore, experts advocate for diverse learning experiences that connect students to their communities and the real world.

Theme 4: Curriculum Implementation

Questions

1. What challenges have you encountered in implementing the STEAM curriculum across different educational settings, and what resources are essential for success?
2. How can we infuse the STEAM curriculum with traditional education to step up?
3. What type of feedback have you received from teachers regarding the implementation process, and how have their experiences varied?

Codes

1.Implementation Challenges: Experts were of the view that following are the challenges they are facing while implementing Science, technology, engineering, arts and mathematics (STEAM) curriculum. These include, limited resources, lack of proper professional development and training, varying levels of teacher readiness, and institutional and community support.

2.Infusion with Traditional Education: Question regarding the infusion of science, technology, engineering, arts and mathematics (STEAM) curriculum with traditional model. It was described by the curriculum developer that basically three models are working in science, technology, engineering, arts and mathematics (STEAM) one is customize model in which the curriculum is customized according to the needs of school. Whereas second one is addition model in which a separate text book of science, technology, engineering, arts and mathematics (STEAM) curricula is added with traditional curriculum and this book taught separately as par STEAM ideology provided with STEAM robotic kits. Third one, is the systematic model which is book free and based on transdisciplinary learning.

3.Teacher Feedback: Experts were of the view that feedback from the teachers is very important for further development of science, technology, engineering, arts and mathematics

(STEAM) curriculum this feedback includes both appreciation and criticism.

In brief implementation of science, technology, engineering, arts and mathematics (STEAM) curriculum is not an easy task there are various challenges which were faced while implementing the science, technology, engineering, arts and mathematics (STEAM) curriculum these includes, limitation of resources, technology integration with flavor of Arts, teacher's readiness, teacher's professional development and training, integration of Science, technology, engineering, arts and mathematics (STEAM) curriculum with traditional curriculum.

Theme 5: Curriculum Assessment and Evaluation

Questions

1. What assessment methods do you use to evaluate student learning in the STEAM curriculum, and how do you balance formative and summative assessments?
2. How is feedback from assessments communicated to students and parents, and what role does this feedback play in student improvement?
3. What specific outcomes (e.g., skills, knowledge, attitudes) do you look for in students as a result of the STEAM curriculum?

Codes

1.Assessment Methods: Experts were of the view that a mixture of process and product assessment was applied the basic object to provide comprehensive evaluation of student learning.

2.Feedback Communication: Regarding questions about feedback is communicated through parent-teacher meetings. Regular provision of progress reports, playing an important role in guiding student progress.

3.Desired Outcomes: Moreover, desired outcomes can include enhanced, problem-solving critical thinking, collaboration skills, creativity, and a passion for lifelong learning. However, experts were of the view that to include an innovative and well-rounded assessment techniques are the important for evaluation of student learning in the Science, technology, engineering, arts and mathematics (STEAM) curriculum. Furthermore, they said that feedback seen as important for enhancement of student growth.

Findings

Thematic Analysis of Experts' Perspectives on the Evaluation and Implementation of the STEAM Curriculum at primary school level is given below:

Semi-structured interviews with curriculum experts provided valuable insights into the evaluation and implementation of the Science, Technology, Engineering, Arts, and Mathematics (STEAM) curriculum at the primary school level. The data analysis revealed five major themes: Curriculum Content and Objectives, Teaching Methodologies and Teacher Training, Learning Experience, Curriculum Implementation, and Curriculum Assessment and Evaluation. Experts highlighted the strengths, weaknesses, challenges, and opportunities associated with the integration of the STEAM curriculum.

1. STEAM Curriculum Content and Objectives

Experts emphasized that the careful selection of content is essential to align the STEAM curriculum with the demands of the future job market. Curriculum developers and STEAM specialists designed content that promotes real-world applications, creativity, innovation, problem-solving, robotics, and critical thinking. The experts noted that STEAM content should encourage interdisciplinary learning and be closely connected to contemporary global and local issues. Moreover, the curriculum objectives should not only focus on knowledge acquisition but also on nurturing students' capacity for collaboration, inquiry, and innovation across multiple domains.

2. Teaching Methodologies and Teacher Training

Participants highlighted that the successful implementation of the STEAM curriculum depends heavily on teacher preparation and continuous professional development. Effective instructional approaches such as project-based learning (PBL), problem-based learning, and inquiry-based learning were identified as key strategies for promoting active and meaningful learning. While having a background in STEAM-related disciplines is beneficial, experts stressed that pedagogical training in STEAM methodologies is far more critical. Teachers need adequate support and training to integrate technology and engineering principles within creative, student-centered learning environments.

3. Learning Experience

Experts agreed that the quality of the learning experience in STEAM education relies on hands-on, collaborative, and experiential learning opportunities. They emphasized the use of robotic kits, design challenges, and group projects to promote engagement and creativity. Real-world experiences, such as field trips, experiments, and community-based projects, were identified as effective ways to deepen students' understanding and application of STEAM concepts. Such experiences enhance not only cognitive skills but also teamwork, communication, and innovation, which are essential for 21st-century learners.

4. STEAM Curriculum Implementation

Experts highlighted that integrating STEAM with the existing traditional curriculum is vital for contextual relevance and sustainability. However, they acknowledged several implementation challenges, including limited resources, inadequate teacher training, lack of community awareness, and varying levels of teacher readiness. To overcome these barriers, a supportive ecosystem involving schools, policymakers, and communities is necessary. Experts suggested that localized adaptation of the STEAM model would ensure alignment with cultural and contextual realities, making it more practical and impactful in primary education settings.

5. STEAM Curriculum Assessment and Evaluation

Experts emphasized the importance of balanced assessment strategies, combining both formative and summative approaches to measure students' learning outcomes effectively. They proposed that assessment should not only focus on content knowledge but also on creativity, problem-solving, collaboration, and critical thinking skills. Regular and constructive feedback for students and parents was identified as an essential element in supporting continuous learning and improvement.

In conclusion, experts provided a holistic perspective on the current state and potential of the STEAM curriculum at the primary level. While significant challenges exist such as teacher preparedness, resource limitations, and community awareness there are also substantial opportunities for transformation. By promoting interdisciplinary and transdisciplinary learning, encouraging innovative pedagogies, and ensuring contextually relevant implementation, educators can effectively prepare young learners for the complexities of the modern world. Investment in teacher training, infrastructure, and stakeholder collaboration will be crucial to realizing the full potential of STEAM education, leading to improved student outcomes and the development of a creative, future-ready generation.

Discussions:

The current study supports the findings of Chung et al., (2022), emphasizing the significance of project-based learning in implementing the STEAM curriculum. Their research demonstrated notable improvements in student engagement and motivation through this approach, particularly at the secondary education level. In contrast, the present study focuses specifically on primary school students, offering valuable insights into how integrating project-based learning within the Science, Technology, Engineering, Arts, and Mathematics (STEAM) framework can foster students' overall growth and development at the foundational stage.

In recent years, the introduction of the STEAM curriculum at the primary level has gained increasing attention due to its potential to actively engage students through hands-on learning experiences and to promote interdisciplinary or transdisciplinary learning. Similarly, Bagiati and Evangelou (2015) found that STEAM education plays a vital role in enhancing students' motivation and academic performance, particularly benefiting those who perform below average. These findings are consistent with the results of the current study, which suggest that STEAM education can significantly enhance students' interest, motivation, creativity, and critical thinking abilities.

However, the implementation of the STEAM curriculum is not without challenges. Wang et al. (2017) identified a lack of adequate teacher training and resources as major barriers to effective STEAM education. Such limitations often result in inconsistent and less effective classroom practices, underscoring the need for improved professional development and better resource allocation to ensure the successful integration of STEAM in schools.

Conclusions:

The Science, technology, engineering, arts and mathematics (STEAM) curriculum represents a transformative shift in primary education, moving beyond subject learning to integrated, experiential, and student-centered approaches. Its emphasis on creativity, critical thinking, and real-world problem-solving aligns perfectly with the demands of a rapidly evolving technological society.

However, systemic investment in resources, teacher training, and public awareness is crucial to unlock its full potential. Therefore, without these measures, the gap between curriculum intent and classroom reality will persist, limiting opportunities for young learners.

Educators, policymakers, and industry leaders must collaborate to create an enabling ecosystem where science, technology, engineering, arts and mathematics (STEAM) education thrives. By doing so, we can nurture a generation of innovators, problem-solvers, and lifelong learners prepared to tackle global challenges.

This study serves as a foundational reference for future reforms in science, technology, engineering, arts and mathematics (STEAM)education, advocating for equitable access, quality implementation, and sustainable growth in 21st -century learning paradigms.

Challenges

Many teachers express concern about the considerable amount of time required to effectively implement Science, Technology, Engineering, Arts, and Mathematics (STEAM) lessons. They believe that planning STEAM-based activities, preparing assessments, and conducting demonstrations take significantly longer than traditional lessons. Teachers also feel pressured by the limited instructional time available within the school calendar, as they must balance STEAM instruction with other non-STEAM subjects. This time constraint often prevents them from fully covering all intended STEAM activities and lessons.

Another major challenge teachers face involves the effective and meaningful integration of technology into STEAM instruction. Limited access to computers, unreliable internet connections, and electricity shortages further complicate the use of digital tools in classrooms. Many teachers struggle to access online materials due to slow internet speeds, which hinders their ability to incorporate digital resources into their teaching.

Assessment in STEAM education also presents difficulties. While most teachers are familiar with formative and summative assessment methods, applying these techniques effectively within the context of STEAM lessons remains a challenge. Designing assessments that accurately capture students' learning, creativity, and problem-solving skills in an integrated setting requires additional training and support.

Recommendations:

This study recommends that adequate resource allocation is important for meaningful STEAM integration. Schools should be provided with essential facilities such as STEAM laboratories, robotics kits, and other materials that promote experiential and practical learning. Additionally, it is recommended to raise awareness among parents, teachers, and students about the value and future relevance of STEAM education. This can be achieved through community engagement initiatives such as workshops, seminars, and orientation sessions designed to highlight the importance of STEAM in preparing students for future career opportunities.

Suggestions for future researchers:

For future research, it is suggested that longitudinal studies be conducted to evaluate the long-term effects and outcomes of the Science, Technology, Engineering, Arts, and Mathematics (STEAM) curriculum over several years. Comparative studies could also be valuable, examining STEAM alongside other curriculum models to provide a broader understanding of its effectiveness and unique features. Additionally, future researchers may focus on exploring STEAM pedagogies and the continuous professional development of teachers to enhance instructional practices. Both qualitative and quantitative studies can be undertaken to investigate the challenges teachers face during the implementation of STEAM education, offering insights that could inform better training programs and policy development.

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