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Conceptual Framework for STEM Education: A Thematic Analysis in Bangladesh Perspective

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ABSTRACT

In order to support students in integrating information from the four disciplines, STEM education places a strong emphasis on using real-world contexts. The STEM Framework is a comprehensive STEM educational framework built around challenges that are protracted, persistent, and difficult. The knowledge and abilities needed to tackle those challenges must come from at least one dominant field, with the other disciplines contributing the techniques, procedures, or resources to aid in the process. This method can be used by teachers to create STEM lessons by identifying a central issue whose resolution calls for expertise from two or more STEM fields. The term "STEM education" is not new in the area, but due to pedagogical and curriculum issues, it is still not being taught in the classroom properly. In order to enable teachers to innovate and take charge of STEM education in their classroom, it is crucial to provide them with programs that assist them in applying and implementing STEM pedagogies in the classroom. To integrate STEM into practice, firstly we should identify the key elements of STEM. This study is conducted for addressing the major components of the STEM Education framework in Bangladesh perspective.

INTRODUCTION

STEM education, which stands for the study of science, technology, engineering, and mathematics, has become a separate approach to teaching and learning (Breiner *et al.*, 2012). STEM education allows students to develop skills in these areas and caters to different interests and learning styles (Dakers & Hockings, 2013). Unlike traditional education, which treats subjects as separate entities, STEM education emphasizes technological advancements and connects disciplines through courses (Bybee, 2013). Students from all backgrounds and majors can benefit from the transferable skills taught in STEM classes, including collaboration, communication, inquiry, problem solving, critical thinking, and creative issue solving (National Science Board, 2010). The recognition that invention, creativity, and problem solving are essential for our future led to the development of STEM education, as well as the STEM National Research Council (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007).

The terms "STEM education" and "STEM pedagogy" are interchangeable and refer to a curriculum that emphasizes the study of STEM subjects (Breiner *et al.*, 2012; National Science Board, 2010). STEM majors become experts in science, technology, engineering, or mathematics (National Science Foundation, 2016). The evolution of STEM education has resulted in a pedagogical approach that meets the individual needs and interests of each student (Dakers & Hockings, 2013; Guzey *et al.*, 2016). STEM education's hallmark is its emphasis on technological progress and integration of courses that connect multiple fields, in contrast to traditional education (Bybee, 2013; Guzey *et al.*, 2016).

Introduction to STEM Framework

Introduction to STEM Framework: By outlining the values that underlie high-quality STEM, the STEM Framework directs STEM approaches. It assists administrators, teachers, and community partners who work with schools to promote STEM education. The STEM Framework is based on research into local and international best practice STEM education methods. We must be aware of some of the fundamental STEM Education principles before we can draw the framework (Smith *et al.*, 2017; Wang & Wang, 2020). The following principles form the foundation of STEM education:

1. Complies with and incorporates the content of curriculum frameworks, such as the Early Years Learning Framework and the domains of Science, Technologies, and Mathematics
2. Completes the explicit teaching and evaluation of discipline material and essential concepts in the curriculum's constituent subjects.
3. Employs learner-centered instructional strategies that promote initiative, teamwork, problem-solving, and project management.
4. Enhances general skills, including literacy, numeracy, and critical and creative thinking, in context-rich and applied learning environments.
5. Encourages innovation by developing, designing, and producing solutions to issues in the actual world.
6. Makes use of genuine real-world problems and situations that need for integrating disciplinary methods.
7. Offers learner-relevant applied learning contexts and options for customization.
8. Offers all students access and challenges.
9. Plans, teaches, and assesses using a differentiated

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method.

10. Helps all students develop resilience and a growth mentality when faced with difficulties and uncertainty.

11. Encourages students to think about their futures.

12. Establishes links between existing and potential learning and career pathways.

13. Connects learning to relevant local, regional, national, and international contexts for the students.

14. Creates connections with partners in the community, industry (including business), and education.

15. Gains understanding of the value of STEM in society and the workplace. A conceptual framework for integrated STEM education grounded in learning theory and pedagogy will help students improve their chances of meeting important learning objectives (Wang & Wang, 2020). Constructing a conceptual framework for STEM education necessitates in-depth familiarity with the challenges inherent in the dissemination of STEM subject matter. Findings suggest that educators benefit both students and the curriculum when they have a firm grasp of both STEM content and effective pedagogy (Smith *et al.*, 2017; Wang & Wang, 2020). The goal of an integrated approach is to provide students a context for the knowledge they gain in their STEM classes. This is in contrast to the traditional approach of teaching students material and skills and then letting them work out their applications in the actual world on their own (Wang & Wang, 2020). The real-world applications of STEM subjects should continue to inform how educators present these subjects. According to Bybee *et al.* (2013), a conceptual framework for integrated STEM education grounded in learning theory and pedagogy can improve students' chances of meeting important learning objectives. However, constructing such a framework requires in-depth familiarity with the challenges inherent in the dissemination of STEM subject matter. Educators who have a firm grasp of both STEM content and effective pedagogy can benefit both their students and the curriculum (Honey *et al.*, 2014). In contrast to the traditional approach of teaching students material and skills and then letting them work out their applications in the actual world on their own, an integrated approach provides students with a context for the knowledge they gain in their STEM classes (Bybee *et al.*, 2013; Honey *et al.*, 2014).

The proposed framework is specifically for high school instructors and students, and it provides a clearer representation of how a conceptual framework for integrating STEM education should look. The framework illustrates the fundamental concepts underlying interdisciplinary STEM education, including situated STEM learning. The accompanying graphic represents situated STEM learning as a block and tackle system that includes four pulleys, each linked to the practices that are common to the four STEM professions. This graphic ties together a number of different types of learning, including learning in real-life circumstances, mathematical reasoning, scientific inquiry, and technology literacy (Honey *et al.*, 2014; National Academy of Engineering, 2014; NRC, 2012). Educators should continue to incorporate real-world applications of STEM subjects to inform how they present these subjects.

Objectives of this study

This study is conducted to identify the components of the conceptual framework for STEM Education in Bangladesh perspective.

METHODOLOGY

A qualitative methodology was employed to gain insight into the study (Smith, 2018). The researcher analyzed components of STEM education using data collection protocols, including common institutional practice. The study also included a review of existing research from the fields of science, technology, engineering, and mathematics education to identify a unified set of STEM elements suitable for traditional classroom settings as well as those facilitated by digital tools (Bybee *et al.*, 2013). However, further validation of the proposed framework can be accomplished through factor analysis. The implications of the study's findings for the development of STEM education policies in Bangladesh are significant, and the proposed framework can serve as a valuable resource for policymakers.

STEM Framework

The GSA STEM Education Framework, which is based on contemporary, widely accepted best practices and informed by recent findings in educational research, delineates numerous attributes of effective STEM education in three key domains (GSA, 2020)

Fundamental Skills

Refers to the degree to which pupils are given the chance to acquire the 21st-century abilities necessary to succeed in the contemporary job market. There are two parts:

Essential Competencies

In order to succeed in the modern workplace, students must develop these competencies in addition to their subject-matter knowledge. These include data literacy, digital literacy, computer science, creativity, problem solving, communication, collaboration, and critical thinking.

Supporting attributes

Skills that help one develop and hone these core capacities. Some examples include having a STEM mindset, having the ability to take initiative and persevere, being socially and culturally aware, being a good leader, and having strong ethical principles.

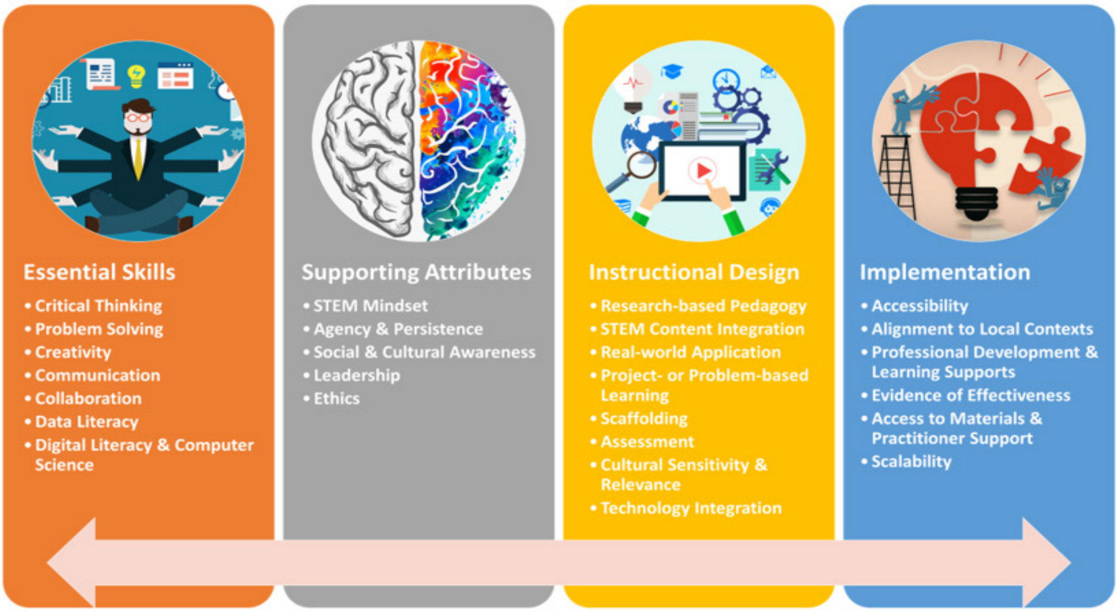

Figure 1: STEM Education Framework

Instructional Design

The term "instructional design" refers to the extent to which research-based pedagogy and learning theory were utilized in the creation of a set of instructional resources. This includes project- and problem-based learning, scaffolding, evaluation, cultural awareness and relevance, the use of technology, practical applications, and pedagogy grounded in research (National Research Council, 2012).

Implementation

The term "implementation" refers to the extent to which necessary services or supports are made available to ensure that distribution is facilitated and that implementation is completed efficiently. This includes scalability, efficacy evidence, materials availability, practitioner support, contextual fit, learning resources, and professional development (National Research Council, 2012).

Critical Thinking

The development of critical thinking skills is supported by encouraging students to assess a variety of information, evidence, and original sources; identify relevant evidence to support arguments; offer constructive critique of others' work; and distinguish between fact and opinion. Students' hypotheses are tested using scientific methods. Students are also encouraged to apply computational, systems, or design thinking to reason about issues, experimental methodologies, and phenomena while generating arguments, criticisms, or hypotheses. Teachers and students can debate sources and provide each other comments with help (National Research Council, 2012; Next Generation Science Standards, 2013).

Problem Solving

The development of problem-solving skills is supported by providing students with opportunities to practice solving STEM problems by obtaining knowledge, formulating goals, and implementing techniques. Design thinking and the scientific approach are supported by materials. Students are encouraged and given the chance to solve STEM problems. Teachers and students are supported in problem-solving with an emphasis on strategy, creativity, teamwork, and tenacity (National Research Council, 2012; Next Generation Science Standards, 2013; Partnership for 21st Century Skills, 2009).

Creativity

The development of creativity skills is supported by providing students with opportunities to discuss issues from their own perspectives, value innovative solutions publicly, and explore multiple ways to achieve a goal. Teachers and/or student supports enable synthesis of activity results and reflection on the significance of fresh and innovative ideas and solutions. Materials assist students to generate work products (such as presentations, explanations, or representations) that reflect their views or techniques for completing tasks (National Research Council, 2012; Partnership for 21st Century Skills, 2009; Next Generation Science Standards, 2013).

Communication

The development of communication skills is supported by providing students with many opportunities to practice and demonstrate their STEM communication skills to formal and informal audiences. Drawings, pictures, visual representations, and models are common ways students express ideas. Instruction's goals and actions depend on communication. It's easier for teachers and students to discuss STEM area communication and assess their own and others' communication skills (National Research Council, 2012; Partnership for 21st Century Skills, 2009; Next Generation Science Standards, 2013).

Data Literacy

The development of data literacy skills is supported by requiring students to use qualitative and quantitative data for analytical tasks, including problem solving, inquiry, and design. Materials help teachers and students use tools and technology and guide data-related tasks. The resources utilized with students promote the use of ethical and moral data and data methods in varied contexts, as well as data collection, analysis, representation, and interpretation.

STEM Mindset

According to the STEM education framework, students should approach issues with an open mind, consider several options, seek innovation, and articulate their opinions in different ways. Students are encouraged to formulate and test ideas and gather and evaluate supporting facts to investigate issues impartially. By providing a variety of objectives and problem scenarios, activities promote students' interest and flexibility. Supports are provided to facilitate teacher and student debate and reasoning regarding good STEM dispositions (such as curiosity, objectivity, and adaptability) and STEM epistemologies (such as empiricism, design thinking, and mathematical proof) (Jones, 2019).

Leadership

The framework also emphasizes the development of leadership skills among students. Group communication, consensus-building, and initiative-taking are practiced and assessed. The materials can be used to form groups, assign leadership roles, evaluate students' leadership skills, and discuss leadership (Jones, 2019).

Ethics

Education framework also emphasizes the importance of ethics in STEM education. Educational materials are designed to help students learn about STEM ethics, think ethically about their work, and understand other perspectives. Ethics discussions in STEM jobs and student work can be facilitated by teachers using resources (Smith *et al.*, 2017).

Research-Based Pedagogy

Research-based pedagogy is another key component of the STEM education framework. The materials are designed to match with recent findings and are well-documented. To support identified pedagogical techniques, detailed materials, tools, and/or instructions are provided (Smith *et al.*, 2017).

Integration of STEM Material

The integration of STEM material is also an important aspect of the STEM education framework. Where practicable and strategically suitable, STEM content is integrated, multidisciplinary, and gives students many opportunities to apply their STEM knowledge and abilities to STEM activities, issues, and practices (Smith *et al.*, 2017).

Curriculum

The curriculum of STEM education is designed to link to significant policy initiatives (such as regional or national labor demands and economic development activities) and pedagogical frameworks that are apparent and well-documented (such as grade-level standards). Students will experience real-world challenges, hence the subject is given in settings. The program emphasizes real-world relevance, helps identify and use difficult situations (Smith *et al.*, 2017).

Assessment

Lastly, tools are available for continuous and end-of-term assessments according to the STEM education framework. When relevant, assessments use several assessment methodologies. Assessments include scoring instructions, ideas for using results in decision-making, and instructional solutions for conceptual issues (Smith *et al.*, 2017).

Technology Integration

Students use technology in all subjects. Technology enhances learning, teamwork, and a variety of activities. Activities encourage students and instructors to use technology creatively. Technology training for educators and students is provided (Smith *et al.*, 2017).

Accessibility

Kids' experiences, abilities, and histories are considered while planning activities. To better serve students and instructors, all resources and support systems follow the Universal Design for Learning principles. In order to meet students' needs, teacher supports propose using a variety of representation, expression, and interaction methods (Smith *et al.*, 2017).

Professional Development & Learning Help

Teachers and school leaders receive enough preparation time before implementation, ongoing, individualized planning and reflection help, and coaching, mentoring, or teaming during implementation. Professional development gives teachers a chance to preview or prepare upcoming lessons (Chen *et al.*, 2016).

Evidence of Efficacy

All stakeholders have access to meticulously evaluated evidence of efficacy. There are resources for continuous data collection and analysis to measure impact and promote data-driven decision-making (Chen *et al.*, 2016) .

Scalability

All resources and support are supplied locally, locally online, or via a flexible distribution channel. There's a proven way to scale learning and professional growth (e.g., train-the-trainer model). Reviewing and updating information ensures examples and real-world applications (Chen *et al.*, 2016).

Teaching Soft Skills in STEM

A field is frequently seen as imparting technical knowledge relevant to STEM fields. The contrary is also true, though: by adding STEM into soft skill activities, we can use our STEM classrooms to improve soft skills. Students will have a broader understanding of how STEM applies to many disciplines and professions, not just the field of study (Kuo *et al*., 2017; Walsh *et al*., 2017; Zhang *et al*., 2017).

Enhancing STEM Pedagogical Content Knowledge

Pedagogical content knowledge refers to the combination or synthesis of instructors' subject matter knowledge and their pedagogical knowledge. This includes what they know about teaching and what they know about what they teach. In order to prepare students for the challenges of teaching subjects that are always changing in a world that is always changing, teachers must act as learners, researchers, creators, problem solvers, and reflective practitioners. With the right support, teachers can become confident leaders and successful STEM teachers (Kuo *et al*., 2017; Walsh *et al*., 2017; Zhang *et al*., 2017).

Perspective on STEM Education in Bangladesh

Science and mathematics are two courses that have the same names at the secondary and higher secondary levels of education in Bangladesh. However, despite having Information and Communication Technology (ICT), Engineering, and Industrial Drawing, there are no specific disciplines named Technology or Engineering (Hossain & Karim, 2020; Mahbub *et al*., 2018). To address the declining interest in STEM fields among secondary and upper secondary pupils, the Bangladeshi Ministry of Education has recognized the need to increase the profile of STEM subjects in classrooms. According to a survey, there are fewer students studying science at the SSC and HSC levels than in previous years, with two-thirds of students being routed away from science streams as early as ninth grade (World Bank, 2014). The current mandatory inclusion of ICT courses in lower- and upper-level secondary schools is a positive step towards promoting STEM education, and further adoption of the concept by educators and administrative bodies can help improve STEM education in Bangladesh.

This is a commendable effort. The most recent National Education Policy (2010) reflects the importance of good instruction of English and mathematics, which has also been acknowledged by the government. It is now time to adopt the concept together with all of its implementers, such as our esteemed educators and the administrative bodies of educational institutions.

Factors Influencing Student Attitude Towards the Transition to STEM

Aspects of the learning environment that affect students' attitudes on the shift to STEM fields include a lack of adequately equipped science laboratories, insufficient funding to purchase learning materials, large class sizes, negative attitudes towards STEM subjects among some students, and minimal parental involvement in their children's education (Islam *et al*., 2019; Rahman *et al*., 2021).

Limitations of the Study

The main limitation of the study is that it relied on document analysis, and data could not be collected from the teacher and administration end, and there is a lack of sufficient prior research on the prospects and challenges of implementing a conceptual framework of the STEM education system in Bangladesh.

CONCLUSION AND RECOMMENDATION

Given the steady rise in the interest in STEM fields worldwide, the incorporation of STEM into the educational system of a nation is a logical next step. However, Bangladesh lags behind in adopting the STEM education paradigm to enhance economic and technical growth. Therefore, research into the most significant elements and risks associated with incorporating STEM into Bangladesh's educational system is critical (Islam *et al*., 2019; Rahman *et al*., 2021).

The study aims to investigate the feasibility of introducing STEM education in Bangladesh by focusing on its essential components and devising strategies to circumvent existing barriers (Rahman *et al*., 2021). However, obstacles to implementing STEM include a lack of adequately equipped science laboratories, insufficient funding to purchase learning materials, particularly chemicals, large class sizes, negative attitudes towards STEM subjects held by some students, and minimal parental involvement in their children's education (Islam *et al*., 2019; Rahman *et al*., 2021). To incorporate a STEM curriculum into the public school system, appropriate facilities, materials, and funding need to be provided. The report calls for more research with larger samples from urban and rural schools to gain deeper knowledge and pave the way for creating a national framework for STEM education (Islam *et al*., 2019; Rahman *et al*., 2021).

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