JOURNAL OF ACADEMIC RESEARCH FOR HUMANITIES
ISSN 2663-192x

ORCID of the Publisher: https://orcid.org/0009-0000-0723-9485
DOI Number of the Paper: https://zenodo.org/records/11526900
Edition Link: Journal of Academic Research for Humanities JARH, 4(2) April-June 2024
Link of the Paper: https://jar.bwo-researches.com/index.php/jarh/article/view/415
HJRS Link: Journal of Academic Research for Humanities JARH (HEC-Recognized for 2023-2024)

PROBLEM-SOLVING BASED LEARNING IN STEM EDUCATION: ROLE OF EPISTEMOLOGICAL AND MOTIVATIONAL BELIEFS ALONG WITH SELF-REGULATED LEARNING STRATEGIES

Corresponding & Author 1:	**DR. AISHA BIBI**, Assistant Professor, Educational Sciences, National University of Modern Languages, Islamabad. Post-Doc Fellow, Faculty of Social Sciences, University of Religions and Denominations, Iran. aishabibi@numl.edu.pk
Co-Author 2:	**SAIRA AKHTAR**, Lecturer at Department of Educational Sciences, NUML, Islamabad. Email: saakhtar@numl.edu.pk
Co-Author 3:	**DR. SADAF ZAMIR AHMED**, Assistant Professor, Department of Humanities & Education, Air University Islamabad. Pskistan. Email: sadaf.zamir@students.au.edu.pk

Paper Information

Citation of the paper:
(JARH) Bibi, A., Akhtar, S., & Ahmed, S. Z., (2024). Problem-Solving Based Learning in STEM Education: Role of Epistemological and Motivational Beliefs Along with Self-Regulated Learning Strategies. In *Journal of Academic Research for Humanities*, 4(2), 106–115.

Subject Areas for JARH:
1 Humanities
2 Education

Timeline of the Paper at JARH:
Received on: 30-03-2024.
Reviews Completed on: 17-05-2024.
Accepted on: 06-06-2024.
Online on: 08-06-2024.

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Recognized for BWO-R:
HJRS HEC Journal Recognition System

Published by BWO Researches INTL.:
BWO RESEARCHES (PVT) LTD INTERNATIONAL

DOI Image of the paper:
DOI 10.5281/zenodo.11526900

QR Code for the Paper:

Abstract

Problem-solving has a prominent role in STEM education. Several graphical and numerical-based approaches are being used for the integration of problem-solving with STEM education. Apart from these, several efforts were also carried out to integrate epistemological and motivational belief systems along with self-regulated learning strategies as contributing factors for STEM-based problem-solving. In the current study, the potential roles of students' motivational and epistemological beliefs, and self-regulated learning strategies were explored for solving the problem. For this, an adopted questionnaire was utilized to measure the selected factors. The population of the current study included 120 teachers who were teaching in STEM schools. Data from 120 teachers were collected and analyzed. Findings showed that most teachers believed that problem-solving can uplift STEM education in Pakistan. In addition, teachers also believe that the implementation of STEM education is important, and the majority of the teachers agreed that the role of student beliefs play a significant role in enhancing their problem-solving ability. Interestingly, it was observed that the teachers were convinced that students' attitude, motivation and self-regulated learning strategies toward STEM education also play a vital role in their engagement and problem-solving. Based on current findings, important implications were outlined to promote culture for deep and meaningful learning.

Keywords: Beliefs, Motivations, Epistemological, Strategies, Implementation,

Introduction

(Moallemi, 2024), STEM education integrates Science, Technology, Engineering, and Mathematics for effective teaching and learning in recent years. Its significance lies in its ability to address the evolving needs of students, the workforce, and society by providing a complete and interdisciplinary education (Sahito & Wassan, 2024; Wahono et al., 2020). Students' attitudes toward STEM education also play a crucial role in their engagement and success in science, technology, engineering, and mathematics disciplines. Fostering positive attitudes can enhance enthusiasm, motivation, and proficiency in these critical fields (Roberts et al., 2022). An active science teaching methodology contributes to improvements in students' attitudes. (Laghari, Chachar, et.al. 2023), The value of STEM education in the dynamic and quickly changing modern world extends beyond traditional academic limits, becoming a pillar of innovation and advancement in society (Aslam et al., 2022; Nurtamam et al., 2023). By allowing students to see the correlations between various fields of knowledge, STEM education equips them with the ability to address multifaceted real-world problems effectively.

Affirmative Action

(Asal, Yousuf, et. al, 2023), The implementation of integrated STEM in learning is significantly impacted by the teachers toward STEM education A negative attitude toward STEM education tends to make teachers hesitant to adopt the integrated STEM approach, while a positive attitude influences students' perspectives. (Nalipay, Huang, et. al. 2024), Overall cultivating a positive stance is a crucial and initial foundation for enhancing knowledge about STEM education and its application in learning (Hali et al., 2021; Kiazai et al., 2020).

Rationale

(Syed, Samina, Ishrat, 2023), In STEM education, problem-solving has an essential role. The idea of problem-solving is used to solve different tasks and articulate the phenomena from one discipline to others such as science to engineering (English, 2024). Therefore, there is a high need for problem-solving to be integrated into STEM education(Nurtamam et al., 2023; Rahman et al., 2021). Despite its prominence and frequent applications, problem-solving is still considered one of the most difficult, particularly at school levels. (Sarwar, Khurram, 2023), In the previous studies, while making a critical analysis, it was found that students use different approaches including algebraic, graphical, numerical, technological, and inquiry-oriented both at different school levels are being utilized for problem-solving (Bibi et al., 2017). At the junior level, problem-solving is mostly carried out using algebraic, graphical, and numerical-based approaches. However, it was observed that only memorization of steps or processes is not enough for effective learning (Altaf et al., 2023). In addition to these techniques, beliefs were also considered important contributing factors in problem-solving (Roberts et al., 2022; Schommer-Aikins et al., 2005). Context familiarity was also observed as an additional factor in solving a problem (Bibi, 2017; Bibi et al., 2018). Even in non-routine-based problem-solving, context familiarity was observed effective (Bibi et al., 2019).

Problem Statement

Besides teacher's and students' beliefs, learning strategies also enhance students' problem-solving skills and attention for problem-solving (Al Said et al., 2019). Numerous studies also interlinked SRL strategies with goal-orientation beliefs and problem-solving (Nu'man & Retnawati, 2021; Pintrich, 2000; Tise, 2019; Zheng et al., 2020). Further work revealed that other factors including epistemological beliefs, SRL strategies, and motivations can improve problem-solving skills (Couso & Simarro, 2020; Elby, 2022; Ortiz-Revilla et al., 2020; Schommer-Aikins et al., 2005).

Research Questions

1. Do students' motivational beliefs enhance problem-solving?
2. Do self-regulated strategies promote problem-solving?
3. Do students' epistemological and usefulness beliefs enhance problem-solving?

Literature Review

In stem education, problem-solving activities such as defining problems and looking for possible ways to solve them remained central to the development of discipline or to interrelate different disciplines (Santos-Trigo, 2020). Educators have developed different processes and approaches for formulating and solving problems at both school levels and university levels (Akben, 2020; Al Hamad et al., 2024; He et al., 2024). Apart from these problem-solving approaches, students' mental condition was also considered important for problem-solving and mathematics learning. Students' belief systems regulate the solving of problems. These beliefs include mathematics as well as problem-solving which enhance the student's problem-solving ability in learning mathematics (Schoenfeld, 1989; Simamora & Saragih, 2019). Cobb (1985) argued for the incorporation of students' belief systems because there is a strong correlation between beliefs about mathematics and mathematical achievement (Beghetto & Baxter, 2012; Muhtarom et al., 2019; Schommer-Aikins et al., 2005; Schommer-Aikins & Duell, 2013). In addition, several researchers also highlighted the role of self-regulating strategies in problem-solving (Fang et al., 2023; Nu'man & Retnawati, 2021; Topsakal et al., 2022). Therefore, to integrate problem-solving into STEM education, these important contributing factors were required to be explored further to add useful literature for STEM education-related problem-solving.

Conceptual Framework

This study has utilized the previously established conceptual framework (Aisha et al., 2018). Figure 1 illustrates the conceptual framework for the current study. This framework was used to assess the problem-solving ability of students while solving mathematics tasks. In a current study, the experts' views were assessed concerning perceptions about the addition of these aspects to stem education. (Ortiz, Hernandez, et. al. 2023).

Research Methodology

Research Design

This was a quantitative descriptive study to investigate the effects of different factors in the proposed model.

Participants

The population for the study will be all those teachers who were teaching at the elementary level. This population is vast and diverse, representing a wide range of ages, socioeconomic backgrounds, and urban/rural settings. In total, 40 schools are operating under the Ministry of Federal Education and Professional Training, each of which has implemented STEM education. The population of interest for this study comprises approximately 120 teachers who were currently employed in these schools/ institutions where STEM education initiatives are being implemented under the Federal Directorate of Education. The large population will facilitate better representation of various subgroups within the population. This inclusivity ensured that the study captured the diversity present in the broader population, leading to more comprehensive and nuanced findings. Besides, the research study also targeted the population consisting of the teaching faculty of 05 public sector institutions located in Pakistan's twin cities, Rawalpindi and Islamabad. A total of 120 teaching faculty members participated in the current study. This was a quantitative descriptive study. To minimize the errors in self-reported data, participants' demographic information was compared and verified with institutional data. Regarding work experience of teachers, 9% had 1-5 years of experience, whereas, 49% had 11-15, and 36% had 16–15 years of experience, respectively.

Research Instruments: Questionnaires

This was a quantitative descriptive study based on a previously established instrument (questionnaire) to investigate the effects of different factors in the proposed model. All items were written in English languages with easy and better understanding (Aisha et al., 2018; Bibi & Ahmad, 2022). Previously, this instrument was used to assess the problem-solving ability of students while solving mathematics tasks.

Results

An online questionnaire was sent to collect data. Participants were encouraged to participate voluntarily. To preserve confidentiality only the researcher had access to the collected data. Table 1 reveals that statistically significant differences exist between different groups. For the current study, most teachers (60%) believe that problem-solving can lift STEM education in Pakistan. In addition, 60 percent of teachers were believing the importance and implementation of STEM education in Pakistan. Similarly, 90 percent of teachers agreed that the role of the student psyche in enhancing student's problem-solving ability, respectively. Interestingly, it was observed that 10 percent of faculty members were not sure about this question. Similarly, almost all of the teachers were convinced that students' attitudes and motivation toward STEM education also play a crucial role in their engagement and problem-solving in science, technology, engineering, and mathematics disciplines. 80 percent of faculty members had also recommended SRL for problem-solving.

Discussion

(Bridge, Horey, et. al. 2023), The main aim of this study was to examine the possible role of epistemological beliefs, goal orientations, and SRL strategies in problem-solving. The outcomes of further analysis confirmed that students' motivations "goal orientations", SRL strategies, and beliefs significantly influence the problem-solving (Callan et al., 2021; Roberts et al., 2022; Schommer-Aikins et al., 2005). For the current work, both useful beliefs and epistemological beliefs were anticipated to improve the student's problem-solving. However, the majority of the participants (80%) indicated a significant effect of this kind of belief on problem-solving Table 1). However, several experts opposed the utilization of these factors for problem-solving. A partial negative response against epistemological beliefs for problem-solving was observed. Similar findings were observed in the utilization of SRL strategies. Overall, it may be concluded that motivated students with positive perceptions had more problem-solving. About 20% of experts had the opinion that SRL strategies are not more effective for problem-solving. For negative responses, several factors possibly can be identified. One possible reason for negative responses (or not sure) for the effect of motivational and epistemological beliefs and SRL strategies on STEM-related problem-solving might be the unawareness or less familiarity of educators with classifications of beliefs and SRL strategies and their implementations. In the context of STEM education, where interdisciplinary thinking and creative problem-solving are paramount, understanding the role of teachers becomes essential (Ali & Rehmat Shah, 2023; Anisimova et al., 2020). How do their competencies enhance or hinder the development of critical thinking skills among students Addressing these gaps will not only enrich the theoretical understanding of the subject but will also provide practical implications for educators seeking to optimize the impact of STEM education on students' cognitive skills. In this context, Rahman et al. (2021) reported positive attitudes of female students toward STEM and the authors recommended that future studies explore and elaborate on the specific factors that affect STEM attitudes. Understanding the nuances of how effective teachers' beliefs are important in developing countries within the context of STEM

Education. It is crucial for refining educational approaches and maximizing their impact (Al Hamad et al., 2024; Sahito & Wassan, 2024). Overall, the findings indicated that integrated STEM education applications had a positive influence on students' problem-solving skills.

Implications and recommendations

The result of the research covered the gap to offer crucial insights that remain uncovered. This research has important implications for educational reform, policy formulation, curriculum development, teacher training, and comprehensive development of students. This study was the first of its kind to explore the linkage between teacher beliefs and the problem-solving of students within the context of STEM Education in Pakistan. (Aslam, Khan, et. al. 2023), Understanding how their beliefs influence student outcomes can motivate teachers to seek additional training and resources to improve their teaching practices. Additionally, teachers can identify factors that contribute to effective instruction that can better support student development in this important area. Adding real-life problems to lessons would be beneficial for students by learning how to solve problems and think smartly, they would be ready for both school and work. This may create bottom-up pressure for reforms. It will help students to not only excel academically but also thrive in their professional lives by acquiring good jobs.

Conclusion

Problem-solving has a prominent role in STEM education. In the current study, the potential role of these factors was examined for solving the problem. For this, an adopted questionnaire was utilized to measure the selected factors. Data from 120 teachers were collected and analyzed. Findings showed that most teachers believed that problem-solving can uplift STEM education in Pakistan. (Dost, 2024), In addition, teachers also believed that the implementation of STEM education is important, and the majority of the teachers agreed that the role of student beliefs plays a significant role in enhancing their problem-solving ability. Interestingly, it was observed that the mostly teachers were convinced that students' attitudes, motivation, and self-regulated learning strategies toward STEM education also play a vital role in their engagement and problem-solving. Based on current findings, important implications were outlined to promote culture for deep and meaningful learning.

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Appendix

Annex A:

Table 1

Response of the Teachers for the STEM-related problem-solving

	Response of Participants in Percentage				
Characteristics	Strongly Disagree	Disagree	Uncertain	Agree	Strongly agree
Problem-solving can uplift STEM education	-	26	14	38	22
Problem-solving is important in STEM education	6	26	8	35	25
Students' beliefs can boost up the problem-solving	-	-	10	40	50
Students' awareness can boost up the problem-solving	-	-	10	40	50
Students' motivations (mastery, performance, goal avoidance) can enhance the understanding of problems	-	-	-	70	30
Students' motivations (mastery, performance, goal avoidance) can enhance the problem-solving				70	30
SRL strategies (critical thinking, elaboration) can affect positively for the students to solve problems		20		80	
Epistemological beliefs can affect positively the students to solve problems		20		70	10
Belief about usefulness can affect the confidently of the learners in solving problems				20	80
A blend of beliefs, motivations, and strategies can considerably contribute to problem-solving		15	10	35	40
This inquiry is valuable for teachers and learners equally		5	5	22	68

Annex B:

Figure 1

Conceptual Framework for the current study