Exploring teacher perceptions, commitment, and beliefs in STEM education: a systematic literature review analysis

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Article Info

Article history:

Received Mar 19, 2024
Revised Jul 11, 2024
Accepted Jul 24, 2024

Keywords:

Educator perspectives
Instructional beliefs
STEM education
STEM pedagogy
Teacher beliefs
Teacher commitment
Teacher perceptions

ABSTRACT

In recent times, science, technology, engineering and mathematics (STEM) education has gained interest in preparing students to face the challenges of the modern world. STEM fields are important for nurturing and shaping a wide range of skills in society. Therefore, to ensure students acquire the necessary skills and knowledge, STEM education has become a priority in education systems around the world, with teachers playing an important role in ensuring the success of STEM education. Therefore, teachers' perceptions, commitments and beliefs need to be explored to gain understanding, needs and challenges for teachers to implement STEM education. This study analyzed past research findings through the systematic literature review (SLR) method with the findings of 28 articles. The findings of this past study reveal the challenges, and opportunities faced by educators through their perceptions, commitments, and beliefs in STEM education for the actions of policymakers and school leaders.

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1. INTRODUCTION

In the realm of education, science, technology, engineering, and mathematics (STEM) fields have gained significant attention due to their pivotal role in preparing students for the demands of the modern workforce and fostering innovation [1]–[3]. Central to the success of STEM education are the teachers, whose perceptions [4]–[7], commitment [8]–[11], and beliefs [12]–[15] play a crucial role in shaping the learning experiences and outcomes of the students. Understanding how teachers perceive, commit to, and believe in STEM education is paramount for developing effective teaching strategies and educational policies [12], [16]–[19].

There are numerous studies that have been conducted around the world on teachers' perceptions, commitments, and beliefs towards STEM education. Therefore, this study explores the factors that shape teachers' perceptions of STEM that influence their attitudes and teaching decisions in STEM education practices and assesses teachers' commitment to STEM education. The study explored the findings of past studies using relevant systematic literature reviews from 2013 to 2024. This study was conducted to address the following research questions:

i) What are the factors influencing teachers' perceptions of STEM education, and how do these factors influence their teaching attitudes and decisions?
ii) How commitment of teachers to STEM education affect the effectiveness of STEM education in teaching practice?
iii) How belief of teachers to STEM education affect the effectiveness of STEM education in teaching practice?

This study is important for various stakeholders, including educators, students, policymakers, and society as a whole. By understanding the factors that influence teachers' perceptions, commitment, and beliefs towards STEM education, we can take appropriate steps to enhance the quality of STEM teaching and learning [20]–[23]. The findings of this study provide guidance on how to improve teachers' skills and confidence in STEM education. Continuous professional training and support from schools can help teachers become more effective in their teaching, which in turn enhances students' achievement in STEM fields [24]–[26]. This is crucial because teachers are the cornerstone of successful STEM education. Furthermore, students benefit greatly when their teachers are more confident and committed to teaching STEM [10], [19], [27], [28]. Teachers with positive perceptions of STEM education tend to adopt more innovative and interactive teaching approaches, making learning more engaging and effective. This not only increases students' interest in STEM subjects but also helps them understand and master concepts that are essential for their future [29]–[32].

For policymakers, this study provides critical information for designing more effective educational policies [17], [33], [34]. Understanding the factors that influence teachers' perceptions and commitment to STEM can help policymakers develop better training programs and support systems, ensuring that necessary resources are always available. This is vital to ensure that the education system can produce a knowledgeable and highly skilled workforce in STEM fields, which is essential in the modern economy [35]–[38].

This study, through the systematic literature review (SLR) analysis, is important because it provides clear guidance on how to strengthen STEM education by deeply understanding teachers' perceptions, commitment, and beliefs. Improving these aspects ensures more effective STEM education, greatly benefiting all involved parties. The aim is to contribute to the growing body of knowledge surrounding teacher perceptions, commitment, and beliefs in STEM education. By synthesizing diverse perspectives and empirical evidence, this study offers practical recommendations for policymakers, educational leaders, and practitioners striving to cultivate a robust STEM learning environment. Ultimately, fostering a deeper understanding of the factors influencing teacher practice in STEM education works towards ensuring equitable access and meaningful learning experiences for all students.

2. METHOD

The systematic review approach was used in three basic stages to choose several relevant papers for this study. The initial stage is to discover keywords and search for synonyms using thesaurus, encyclopedias, dictionaries, and past research. After all pertinent phrases have been selected and are displayed in Table 1, search strings for the databases Scopus and Web of Science (WoS) have been produced. The current study effort effectively pulled 562 papers from the Scopus database and 2 papers from the WoS databases during the first step of the systematic review approach.

Table 1. The search strings

Database	Search equation
Scopus	TITLE-ABS-KEY (("Teacher perceptions" OR "Teacher attitudes" OR "Teacher beliefs") AND ("Teacher commitment" OR "Teacher motivation" OR "Teacher engagement") AND ("STEM education" OR "STEM learning" OR "STEM")) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) Access date: 5 Mar. 2024
Web of Science	ALL=(("Teacher perceptions" OR "Teacher attitudes" OR "Teacher beliefs") AND ("Teacher commitment" OR "Teacher motivation" OR "Teacher engagement") AND ("STEM education" OR "STEM learning" OR "STEM")) Access date: 5 Mar. 2024

2.1. Screening

Paper duplicates should be screened out in the first round of screening. The researchers developed several inclusion and exclusion criteria, and they were used to filter 382 papers in the second phase. In the first phase, no articles were excluded. Since literature is the primary source of usable knowledge, research articles made up the first criterion. It also entails removing from the present investigation books, chapters, book series, reviews, and conference proceedings. Furthermore, the review only included papers written in English. Moreover, certain phrases are restricted to searches for pertinent articles alone. Recognizing that the schedule was chosen with a ten-year timeline (2013-2024) in mind is crucial. Based on certain criteria, 180 publications in total were removed.

2.2. Eligibility

A total of 2,830 items have been created for the eligibility level, the third level. At this stage, each article's title and key contents were closely scrutinized to ensure that the inclusion criteria were satisfied, and the papers aligned with the objectives of the current study. Consequently, two papers were eliminated since they were not articles of pure science substantiated by empirical facts. In conclusion, Figure 1 shows that 28 papers are available for review as shown in Table 2.

Table 2. The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2013-2024	<2013
Literature type	Journal (Article)	Conference, Book, Review
Subject area	Social science	Beside social science

2.3. Data abstraction and analysis

One of the assessment methods used in this study was an integrative analysis, which looked at and synthesized a range of research designs (qualitative, mixed, and quantitative). The competence study's objective was to determine pertinent subjects and subtopics. The initial step of the theme's development was the data collection phase. The process by which the authors carefully examined a set of 28 articles in quest of claims or information pertinent to the subjects they were researching is depicted in Figure 1. Important new research on teachers' perceptions, commitments and beliefs in STEM Education was then assessed by the authors. Investigations focus on the research findings and the methods applied in each study. After that, the writer worked with other writers to create themes derived from the information.

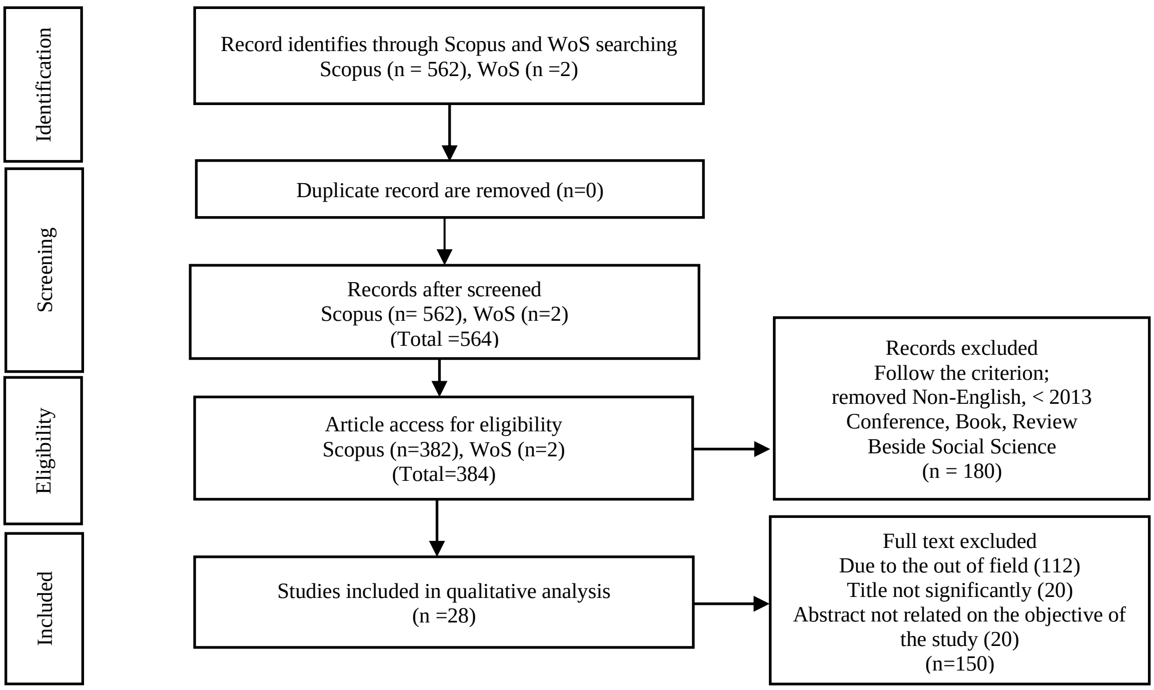

Figure 1. Flow diagram of the proposed searching study

3. RESULTS AND DISCUSSION

Findings from the study conducted from 2013 to 2024 through SLR method have been summarized in Table 3. The research findings indicate insights from teachers' perceptions, commitments, and beliefs in implementing STEM education. Through systematic literature analysis, valuable perspectives from teachers describing pedagogical practices and factors shaping teachers' perceptions that influence attitudes and actions towards STEM Education were discovered.

Table 3. Relevant research findings

No.	Study	Research findings
1.	[11]	The study examines STEM teachers' self-efficacy and commitment across multiple roles, showing varying levels influenced by teaching experience, with disseminator self-efficacy notably impacting commitment.
2.	[39]	The study examines integrated STEM education's importance in 21st-century literacy and student engagement in Ireland. It delves into primary school teachers' views through interviews with six teachers. The findings aim to evaluate the actual implementation of integrated STEM education.
3.	[40]	The study explores K-8 pre-service teachers' readiness to teach computer science, particularly programming. Maker-focused educational robotics activities enhance teachers' motivation for STEM learning. Despite a decline in programming comprehension within six months, teachers' motivation increases, emphasizing the need to integrate programming instruction into pre-service teacher curricula.
4.	[41]	This study focuses on assessing teachers' readiness for STEM education using the TRi-STEM scale, validated for teachers in Greece. The scale comprises four dimensions: affective conditions, cognitive conditions, self-efficacy, and STEM commitment.
5.	[42]	This study highlights the necessity for STEM teachers to cultivate self-efficacy and commitment across diverse roles to improve integrated STEM education.
6.	[43]	The study illustrates how an active learning module enhances STEM teachers' understanding and confidence in action research, yet logistical challenges may impede its implementation.
7.	[44]	The study analyzes factors influencing teaching career choices, noting intrinsic, altruistic, and extrinsic motives, with gender differences. Women prioritize intrinsic and altruistic reasons, while men favor extrinsic factors, influenced more by social norms, impacting their preferences. Women express greater career satisfaction and less discouragement. To improve diversity, especially in STEM and among males, targeting undecided potential teachers is advised.
8.	[45]	The study analyzes the impact of job resources, demands, and self-efficacy on American STEM teachers' job satisfaction. Job resources significantly contribute to enhancing their job satisfaction.
9.	[46]	The study integrates teachers' personal factors and school context to understand STEM teaching practices. A survey of 333 science teachers reveals relationships between these factors and integrated teaching practices.
10.	[47]	The study explores the influence of school support and teachers' STEM knowledge on their self-efficacy and attitudes in teaching science through integrated STEM approach. Findings emphasize the importance of school support and self-efficacy in enhancing teachers' engagement in STEM teaching.
11.	[48]	This study examines the relationship between teachers' self-efficacy and their intention to implement STREAM teaching, indicating a direct influence on teaching practices.
12.	[49]	The study found that principals with STEM majors significantly improved secondary STEM teacher retention.
13.	[50]	Qatari primary school teachers were initially unprepared for project-based learning (PjBL) due to poor policy communication, leading to low confidence and understanding. Supportive environments, however, fostered positive attitudes towards PjBL.
14.	[51]	Teachers' social-emotional competence and commitment influenced students' prosocial behavior and community engagement, moderated by social justice beliefs and child gender.
15.	[52]	The study explored science teachers' adoption of robotics in STEM education, finding positive correlations with perceived usefulness and ease of use. Intrinsic motivation, like autonomy, also influenced adoption.
16.	[53]	The study investigates how a cross-disciplinary program enhances pre-service teachers’ readiness to integrate engineering in classrooms, boosting confidence and beliefs, thus increasing their intention to integrate it.
17.	[54]	The study explores early childhood teachers' commitment to implementing ‘Tools of the Mind’ finding belief in program benefits predicts commitment.
18.	[55]	The study explores how high school science and math teachers' background, beliefs, and practices impact students' motivation, persistence, and achievement in STEM.
19.	[56]	The study explores teachers' experiences in a Virtual Pivot PD workshop during COVID-19, emphasizing elements enhancing computational thinking integration.
20.	[57]	The study found skepticism about scientific content relevance linked to lower preference for scientific sources. Enthusiastic teachers showed less skepticism.
21.	[58]	The study in China found that teacher training positively influenced new STEM teachers' perceived competence, mediated by teaching beliefs.
22.	[59]	The study delves into teachers' experiences with interdisciplinary project-based learning, highlighting evolving beliefs, fluctuating motivation, and crucial support needs.
23.	[60]	The study validated TPACK-Games and GTBS instruments. Elementary teachers showed higher game pedagogical knowledge and stronger beliefs in game-based learning.
24.	[61]	The study investigates a STEM teacher's emotional professional identities under China's STEM education reform, revealing intertwined positive and negative emotions shaping her identities.
25.	[62]	The study examines Dutch STEM teachers' attitudes towards supervising research and design projects, highlighting high self-efficacy and advocating for comprehensive teacher education.
26.	[63]	The study explores STEM instructors' awareness and use of evidence-based instructional practices, revealing limited implementation due to perceived barriers influenced by faculty gender and pedagogical beliefs.
27.	[64]	The study presents an effective project-based approach in literacy and social studies, fostering student skills through creating community brochures.
28.	[65]	The study investigates how preschool teachers leverage play-based environments for science teaching, revealing varying levels of engagement and awareness.

Furthermore, understanding the extent of teachers' commitment to STEM education is crucial in recognizing the dedication and resources invested in fostering student learning and exploring teachers' beliefs provides a deeper understanding of teaching practices in STEM education. Findings from the SLR also reveal teachers' beliefs about STEM disciplines, their roles in development, teaching strategies that significantly impact classroom dynamics, and learning outcomes. By examining the alignment between teachers' beliefs and effective STEM pedagogy, this review aims to identify areas where professional development initiatives can enhance educator effectiveness and student engagement.

3.1. What are the factors influencing teachers’ perceptions of STEM education, and how do these factors influence their teaching attitudes and decisions?

Findings from the systematic literature review conducted between 2013 and 2024, there were 10 articles have highlighted the significance of understanding teachers' perspectives on STEM education. Teachers' views on STEM education are notably shaped by various factors that can influence their attitudes and decisions regarding its implementation. Recent studies have identified several key factors affecting teachers' perceptions of STEM education. One such factor is the challenges teachers face in authentically integrating STEM subjects, which affect their confidence in effectively carrying out STEM education. Incomplete integration can lead to confusion and a lack of confidence among teachers, hindering their full adoption of STEM approaches [39]. Furthermore, STEM-focused training such as robotics activities can enhance teachers' motivation for STEM learning. However, a decrease in understanding of specific concepts without continuous training underscores the need for ongoing professional development programs to maintain high levels of readiness and motivation [40].

Another factor is school support, including administrative and peer support, which is critical in enhancing teachers' self-efficacy and commitment to STEM education. Without sufficient support, teachers may feel overwhelmed and less enthusiastic about implementing STEM teaching [41]. Additionally, STEM teachers play various roles such as implementers, disseminators, and designers. Therefore, their self-efficacy and commitment vary depending on the role played. Teachers with high self-efficacy in specific roles are more likely to be committed and effective in implementing STEM education [42].

The use of training modules that incorporate active learning and action research can enhance teachers' self-efficacy and knowledge of STEM teaching processes. However, logistical challenges such as time constraints and resource limitations need to be addressed to ensure the effectiveness of such training [43]. Other factors influencing motivation to become STEM teachers are intrinsic, altruistic, and extrinsic factors, with noticeable gender differences. Women tend to be influenced by intrinsic and altruistic factors, while men are more likely influenced by extrinsic factors. Social norms and expectations also influence their decisions in choosing specific teaching fields [44].

Moreover, studies also indicate that job resources, job demands, and self-efficacy play crucial roles in determining job satisfaction among STEM teachers. Job resources are found to be the most significant factor affecting teachers' job satisfaction, highlighting the importance of providing adequate support to teachers [45]. Another factor affecting teachers' perceptions is understanding integrated teaching practices. Studies suggest integrated models that consider personal beliefs, self-efficacy, attitudes, and school contexts to understand how changes in these factors can lead to changes in STEM teaching practices [46].

The final factor is teachers' attitudes and beliefs toward integrated STEM teaching, which are also influenced by school support and their knowledge of STEM. Improvement in STEM knowledge and peer support can enhance teachers' self-efficacy and attitudes toward STEM teaching [47]. In conclusion, to enhance STEM education, it is important to understand and address the factors influencing teachers' perceptions. Providing adequate support in the form of professional training, quality learning resources, and supportive school environments can help overcome the challenges faced by teachers. Additionally, understanding teachers' roles and identities and providing continuous professional development programs can enhance their self-efficacy and commitment to STEM education. With this comprehensive approach, STEM education can be strengthened, ensuring that teachers feel more prepared and confident in implementing STEM teaching practices [48].

3.2. How commitment of teachers to STEM education affect the effectiveness of STEM education in teaching practice?

Through a systematic literature review, 9 articles have been identified focusing on findings related to the increasing emphasis on the crucial role of teacher commitment to STEM in teaching practice. Teacher commitment to STEM education plays a vital role in shaping the effectiveness of STEM education in teaching practice. Teachers are steadfast in their commitment to teaching and learning STEM if school leaders have backgrounds in STEM fields [49]. However, challenges arise when teachers are not ready for new pedagogical approaches, such as project-based learning (PjBL), due to a lack of clear communication or policy changes regarding new teaching strategies not being clearly conveyed to teachers. In such cases, teachers may face a lack of confidence and struggle to deliver STEM teaching and learning to students [50].

Furthermore, teachers' commitment to empowering students' emotional, social, and academic aspects reflects their dedication to implementing STEM education holistically. This shows that committed teachers not only focus on academic aspects alone but also on the holistic development of students, including their socioemotional aspects [51]. Similarly, teachers' commitment to the use of robotics in STEM teaching and learning is notable. Teacher commitment tends to drive teachers to strive to understand the importance and benefits of using technology such as robotics in teaching. Teachers' intrinsic motivation also influences their readiness to integrate such technology into the STEM curriculum [52].

Moreover, teachers' readiness to implement STEM teaching and learning in the classroom is enhanced through STEM integration programs, which boost teachers' confidence [53]. Additionally, teachers' commitment to evidence-based programs, such as "Tools of the Mind," is crucial for achieving desired learning outcomes and increasing teacher confidence [54]. This is supported by other study [55], stating that teachers have a significant impact on students' success in STEM fields through their experience, beliefs, and teaching methods. Research indicates that teachers' backgrounds, beliefs, and practices influence students' motivation, resilience, and achievement. Therefore, teacher readiness and professional development are essential for improving the effectiveness of STEM teaching and learning in secondary schools [55], [56].

However, a teacher's proficiency affects their commitment to implementing STEM education [11]. Teachers' proficiency varies based on teaching experience [11]. Teachers not only teach but are capable of bringing new ideas to students through effective delivery. In conclusion, teachers' commitment to STEM education affects the effectiveness of STEM education in teaching practice through various dimensions, including teacher retention, pedagogical innovation, emotional support, technology integration, and professional development. Increasing teacher commitment through targeted support initiatives and training is essential for improving STEM education outcomes and building student success in these critical areas.

3.3. How belief of teachers to STEM education affect the effectiveness of STEM education in teaching practice?

Findings from 9 articles using the SLR technique have shown that teachers' beliefs about STEM education play a crucial role in determining the effectiveness of their teaching. Studies indicate that teachers who have a positive belief in the scientific content and relevance of STEM education tend to use scientific resources more frequently and effectively in their teaching. Conversely, skepticism and the belief that teaching ability is an innate trait often reduce efficiency in teaching STEM [57].

The training experiences and support that teacher receive also influence their self-efficacy and effectiveness in teaching STEM. Comprehensive training in STEM knowledge and practices, along with the beliefs formed through such training, enhances teachers' competence and confidence, which in turn improves their effectiveness in teaching STEM [58]. Additionally, facilitator support in project-based learning helps teachers overcome challenges and boosts their confidence in STEM approaches, highlighting the importance of continuous support and an autonomy-supportive climate in STEM education [59].

Beliefs about alternative teaching methods, such as game-based learning, also impact the effectiveness of STEM teaching. Teachers with high pedagogical game knowledge and strong beliefs in the effectiveness of game-based learning are more successful in integrating this approach into their STEM curriculum [60]. Furthermore, professional identities shaped by positive and negative emotions related to their roles as STEM teachers demonstrate that strong beliefs and professional identities are essential for successful STEM teaching [61].

Teachers' confidence in supervising research and design projects also shows that high self-efficacy is linked to effective teaching in STEM fields. Teachers who are confident in their abilities perform better in research and design activities, which are key components of STEM education [62]. Although there is high awareness of evidence-based instructional practices (EBIPs), implementation is still limited due to perceived barriers, suggesting that belief in the effectiveness of these practices is crucial for their adoption [63].

Project-based teaching approaches also demonstrate that teachers who believe in the benefits of this method and are enthusiastic about integrating STEM into their teaching show higher effectiveness. This helps students develop the necessary skills more effectively, indicating that teachers' beliefs in teaching approaches play a significant role in the effectiveness of STEM education [64]. At preschool level, beliefs about science education and the use of play-based environments to teach science concepts show that teachers' awareness and engagement with science affect how STEM concepts are taught and learned at an early stage [65].

Overall, the findings indicate that teachers' beliefs about STEM education are a critical factor influencing the effectiveness of teaching practices. Comprehensive training, facilitator support, self-confidence, and beliefs in alternative teaching methods all play roles in shaping teachers' beliefs and, subsequently, the effectiveness of STEM education. Therefore, strengthening positive beliefs about STEM education among teachers is key to improving the quality and effectiveness of STEM teaching in their practices.

4. CONCLUSION

A comprehensive discussion and conclusion regarding the findings related to teachers' perceptions, commitment, and beliefs towards STEM education reveal several key points that are crucial for enhancing STEM education. Firstly, understanding and addressing the factors that influence teachers' perceptions is essential. Providing adequate support through professional training, quality learning resources, and supportive school environments can help overcome the challenges faced by teachers. Additionally, recognizing teachers' roles and identities and offering continuous professional development programs can boost their self-efficacy and commitment to STEM education. This comprehensive approach is vital for strengthening STEM education, ensuring that teachers feel more prepared and confident in implementing STEM teaching practices. This aligns with the conclusion that enhancing STEM education requires a multifaceted strategy that addresses teachers' needs comprehensively.

Secondly, teachers' commitment to STEM education significantly impacts the effectiveness of STEM teaching practices. This commitment influences various dimensions, including teacher retention, pedagogical innovation, emotional support, technology integration, and professional development. Increasing teacher commitment through targeted support initiatives and training is crucial for improving STEM education outcomes and fostering student success in these critical areas. Ensuring that teachers are committed can lead to sustained improvements in STEM education practices and student engagement.

Thirdly, the findings show that teachers' beliefs about STEM education are a critical factor influencing the effectiveness of teaching practices. Comprehensive training, facilitator support, self-confidence, and beliefs in alternative teaching methods all play significant roles in shaping teachers' beliefs and, subsequently, the effectiveness of STEM education. Strengthening positive beliefs about STEM education among teachers is key to improving the quality and effectiveness of STEM teaching in their practices. By fostering positive beliefs and providing robust support systems, educators can be better equipped to implement effective STEM teaching strategies.

The implications of these findings for the development of STEM education in Malaysia are profound. By focusing on professional development, providing quality resources, and creating supportive environments, policymakers and educational leaders can address the challenges faced by teachers. Continuous professional development and recognizing the professional identities of teachers can enhance their commitment and self-efficacy. Strengthening teachers' beliefs in the value and effectiveness of STEM education can lead to more innovative and effective teaching practices.

Further studies could explore the specific types of support and training that are most effective in enhancing teachers' perceptions, commitment, and beliefs towards STEM education in the Malaysian context. Investigating the impact of different professional development models and their long-term effects on teaching practices could provide valuable insights. Additionally, research into how these factors influence student outcomes in STEM subjects would be beneficial, helping to tailor interventions that can maximize both teacher and student success in STEM education.

ACKNOWLEDGEMENTS

We express our gratitude to the Ministry of Education for their financial support (reference letter no KPM.BT.700-30/22/114(5)). Additionally, this research contract may pave the way for future studies. Consequently, the researcher extends sincere appreciation to the entities and any related individuals who contributed to the accomplishment of this study.

REFERENCES

[1] L. S. M. Yusoff, S. Amat, and M. I. Mahmud, "The STEM career education intervention module through career exploration activities," in *Proceedings of the 2nd International Seminar on Guidance and Counseling 2019 (ISGC 2019)*, Paris, France: Atlantis Press, 2020. doi: 10.2991/assehr.k.200814.061.

[2] A. Alfama Zamista, "Increasing persistence of college students in science technology engineering and mathematic (STEM)," *Curricula*, vol. 3, no. 1, p. 26, 2018.

[3] A. L. Cabell, D. Brookover, A. Livingston, and I. Cartwright, "'It's never too late': high school counselors' support of underrepresented students' interest in STEM," *The Professional Counselor*, vol. 11, no. 2, pp. 143–160, Jun. 2021, doi: 10.15241/alc.11.2.143.

[4] N. A. Rahman, R. Rosli, A. S. Rambely, N. C. Siregar, M. M. Capraro, and R. M. Capraro, "Secondary school teachers' perceptions of STEM pedagogical content knowledge," *Journal on Mathematics Education*, vol. 13, no. 1, pp. 119–134, 2022, doi: 10.22342/jme.v13i1.pp119-134.

[5] S. Hamad *et al.*, "Understanding science teachers' implementations of integrated STEM: teacher perceptions and practice," *Sustainability (Switzerland)*, vol. 14, no. 6, 2022, doi: 10.3390/su14063594.

[6] M. A. Shahat, A. K. Ambusaidi, A. Al Busaidi, and M. Al Qulhati, "Science teachers' perceptions of social-emotional learning: lessons from Oman," *Alberta Journal of Educational Research*, vol. 68, no. 4, pp. 515–536, 2022, doi: 10.11575/ajer.v68i4.74503.

[7] N. M. Holincheck, T. Kraft, T. M. Galanti, C. K. Baker, and J. K. Nelson, "'Everybody was included in the conversation': teachers' perceptions of student engagement in transdisciplinary STEM learning in diverse elementary schools," *Education Sciences*, vol. 14, no. 3, 2024, doi: 10.3390/educsci14030242.
[8] G. A. Vaishampayan, "Leadership for STEM schools: exploring leadership and teachers' commitment in inclusive STEM high schools," Doctoral Dissertation, University of Illinois at Chicago, 2019.
[9] M. Grillo and M. Kier, "Why do they stay? an exploratory analysis of identities and commitment factors associated with teaching retention in high-need school contexts," *Teaching and Teacher Education*, vol. 105, 2021, doi: 10.1016/j.tate.2021.103423.
[10] M. I. Johari, R. Rosli, S. M. Maat, M. S. Mahmud, M. M. Capraro, and R. M. Capraro, "Integrated professional development for mathematics teachers: a systematic review," *Pegem Egitim ve Ogretim Dergisi*, vol. 12, no. 4, pp. 226–234, 2022, doi: 10.47750/pegegog.12.04.23.
[11] K. L. Yang, H. K. Wu, Y. F. Yeh, K. Y. Lin, J. Y. Wu, and Y. S. Hsu, "Implementers, designers, and disseminators of integrated STEM activities: self-efficacy and commitment," *Research in Science and Technological Education*, vol. 41, no. 4, pp. 1433–1451, 2023, doi: 10.1080/02635143.2021.2008343.
[12] M. Karpudewan, P. Krishnan, M. N. Ali, and L. Y. Fah, "Designing instrument to measure STEM teaching practices of Malaysian teachers," *PLoS ONE*, vol. 17, no. 5 May, 2022, doi: 10.1371/journal.pone.0268509.
[13] M. Hourigan, A. O'Dwyer, A. M. Leavy, and E. Corry, "Integrated STEM-a step too far in primary education contexts?" *Irish Educational Studies*, vol. 41, no. 4, pp. 687–711, 2022, doi: 10.1080/03323315.2021.1899027.
[14] K. Bissaker, "Transforming STEM education in an innovative Australian school: the role of teachers' and academics' professional partnerships," *Theory into Practice*, vol. 53, no. 1, pp. 55–63, Jan. 2014, doi: 10.1080/00405841.2014.862124.
[15] D. Kartini and A. Widodo, "Exploring elementary teachers', students' beliefs and readiness toward STEAM education," *Mimbar Sekolah Dasar*, vol. 7, no. 1, pp. 54–65, 2020, doi: 10.17509/mimbar-sd.v7i1.22453.
[16] S. Gülen, İ. Dönmez, and Ş. İdin, "STEM education in metaverse environment: challenges and opportunities," *Journal of STEAM Education*, vol. 5, no. 2, pp. 100–103, 2022, doi: 10.55290/steam.1139543.
[17] D. Bardoe, D. Hayford, R. B. Bio, and J. Gyabeng, "Challenges to the implementation of STEM education in the Bono East Region of Ghana," *Heliyon*, vol. 9, no. 10, 2023, doi: 10.1016/j.heliyon.2023.e20416.
[18] R. Idris, P. Govindasamy, and S. Nachiappan, "Challenge and obstacles of STEM education in Malaysia," *International Journal of Academic Research in Business and Social Sciences*, vol. 13, no. 4, 2023, doi: 10.6007/ijarbss/v13-i4/16676.
[19] F. Berisha and E. Vula, "Developing pre-service teachers conceptualization of STEM and STEM pedagogical practices," *Frontiers in Education*, vol. 6, 2021, doi: 10.3389/feduc.2021.585075.
[20] H. A. Tuong, P. S. Nam, N. H. Hau, V. T. B. Tien, Z. Lavicza, and T. Hougton, "Utilising STEM-based practices to enhance mathematics teaching in Vietnam: developing students' real-world problem solving and 21st century skills," *Journal of Technology and Science Education*, vol. 13, no. 1, pp. 73–91, 2023, doi: 10.3926/jotse.1790.
[21] A. Mwesiga and J. Masulu, "Effectiveness of school headship and teachers' commitment in Kagera region, Tanzania," *Molecules*, vol. 2, no. 1, pp. 1–12, 2020.
[22] N. Yanthi, B. Milama, H. Choirunnisa, and M. S. Yuliariatiningsih, "STEM learning content in elementary school national curriculum," *Journal of Physics: Conference Series*, vol. 1318, no. 1, 2019, doi: 10.1088/1742-6596/1318/1/012052.
[23] H. A. Tuong, "Teaching in Vietnam: developing students' real-world," *Journal of Technology and Science Education*, vol. 13, no. 1, pp. 73–91, 2023.
[24] D. Menon, D. A. A. Shorman, D. Cox, and A. Thomas, "Preservice elementary teachers conceptions and self-efficacy for integrated STEM," *Education Sciences*, vol. 13, no. 5, 2023, doi: 10.3390/educsci13050529.
[25] D. Fields and Y. Kafai, "Supporting and sustaining equitable steam activities in high school classrooms: understanding computer science teachers' needs and practices when implementing an e-textiles curriculum to forge connections across communities," *Sustainability (Switzerland)*, vol. 15, no. 11, 2023, doi: 10.3390/su15118468.
[26] J. Han, T. Kelley, and J. G. Knowles, "Building a sustainable model of integrated STEM education: investigating secondary school STEM classes after an integrated STEM project," *International Journal of Technology and Design Education*, vol. 33, no. 4, pp. 1499–1523, 2023, doi: 10.1007/s10798-022-09777-8.
[27] J. R. Wieselmann, G. H. Roehrig, E. A. Ring-Whalen, and T. Meagher, "Becoming a STEM-focused school district: administrators' roles and experiences," *Education Sciences*, vol. 11, no. 12, 2021, doi: 10.3390/educsci11120805.
[28] S. Patton, "Elementary school teacher's beliefs, organizational change, and STEM implementation: factors impacting teacher leadership," Doctoral Dissertation, Kennesaw State University, 2020.
[29] M. Oliver, M. Peggy, and G. Colley, "Implementation of STEM education in the Zambian education system: a failed project?" *International Journal of Arts, Humanities and Social Studies*, vol. 4, no. 3, pp. 133–138, 2022.
[30] S. L. Bartels, K. M. Rupe, and J. S. Lederman, "Shaping preservice teachers' understandings of STEM: a collaborative math and science methods approach," *Journal of Science Teacher Education*, vol. 30, no. 6, pp. 666–680, 2019, doi: 10.1080/1046560X.2019.1602803.
[31] N. Ultay *et al.*, "STEM-focused activities to support student learning in primary school science," *Journal of Science Learning*, vol. 3, no. 3, pp. 156–164, 2020, doi: 10.17509/jsl.v3i3.23705.
[32] E. S. O'Leary *et al.*, "Creating inclusive classrooms by engaging STEM faculty in culturally responsive teaching workshops," *International Journal of STEM Education*, vol. 7, no. 1, 2020, doi: 10.1186/s40594-020-00230-7.
[33] A. L. A Case Study on the Efficacy of STEM Pedagogy in Central New York State: Examining STEM Engagement Gaps Affecting Outcomes for High School Seniors and Post-2007 Educational Leadership Interventions to Reinforce STEM Persistence with Implications of STEM Theoretic Frameworks on Artificial Intelligence/Machine Learning," St. John Fisher University, Fisher Digital Publications, 2020, [Online]. Available: https://fisherpub.sjfc.edu/education_etd/469
[34] J. Zinth and M. Weyer, "Teacher Training for Quality P-3 STEM Education. Policy Brief," Education Commission of the States 2021.
[35] J. Kareem, R. S. Thomas, and V. S. Nandini, "A conceptual model of teaching efficacy and beliefs, teaching outcome expectancy, student technology use, student engagement, and 21st-century learning attitudes: a STEM education study," *Interdisciplinary Journal of Environmental and Science Education*, vol. 18, no. 4, p. e2282, 2022, doi: 10.21601/ijese/12025.
[36] T. D. Holmlund, K. Lesseig, and D. Slavit, "Making sense of 'STEM education' in k-12 contexts," *International Journal of STEM Education*, vol. 5, no. 1, 2018, doi: 10.1186/s40594-018-0127-2.
[37] A. R. Casto, "A re-envisioned multicultural STEM education for all," *Education Sciences*, vol. 12, no. 11, p. 792, 2022, doi: 10.3390/educsci12110792.
[38] M. Keleman, "Assessment of higher order thinking skills through STEM integration project-based learning for elementary level," *International Journal of Social Science and Human Research*, vol. 04, no. 04, 2021, doi: 10.47191/ijsshr/v4-i4-40.

[39] T. Delahunty, M. Prendergast, and M. Ní Ríordáin, "Teachers' perspectives on achieving an integrated curricular model of primary STEM education in Ireland: authentic or utopian ideology?" *Frontiers in Education*, vol. 6, 2021, doi: 10.3389/feduc.2021.666608.
[40] A. Fegely, C. Gleasman, and T. Kolski, "Evaluating educational robotics as a maker learning tool for pre-service teacher computer science instruction," *Educational Technology Research and Development*, vol. 72, no. 1, pp. 133–154, 2024, doi: 10.1007/s11423-023-10273-6.
[41] T. Papagiannopoulou, J. Vaiopoulou, and D. Stamovlasis, "Teachers' readiness to implement STEM education: psychometric properties of tri-STEM scale and measurement invariance across individual characteristics of Greek in-service teachers," *Education Sciences*, vol. 13, no. 3, 2023, doi: 10.3390/educsci13030299.
[42] K. Y. Lin, Y. F. Yeh, Y. S. Hsu, J. Y. Wu, K. L. Yang, and H. K. Wu, "STEM education goals in the twenty-first century: teachers' perceptions and experiences," *International Journal of Technology and Design Education*, vol. 33, no. 2, pp. 479–496, 2023, doi: 10.1007/s10798-022-09737-2.
[43] D. Esparza, R. L. Lynch-Arroyo, and J. T. Olimpo, "Empowering current and future educators: using a scalable action research module as a mechanism to promote high-quality teaching and learning in STEM," *Frontiers in Education*, vol. 6, 2022, doi: 10.3389/feduc.2021.754097.
[44] B. H. See, E. Munthe, S. A. Ross, L. Hitt, and N. El Soufi, "Who becomes a teacher and why?" *Review of Education*, vol. 10, no. 3, 2022, doi: 10.1002/rev3.3377.
[45] J. Liu, K. Wang, Z. Chen, and Z. Pan, "Exploring the contributions of job resources, job demands, and job self-efficacy to STEM teachers' job satisfaction: a commonality analysis," *Psychology in the Schools*, vol. 60, no. 1, pp. 122–142, 2023, doi: 10.1002/pits.22768.
[46] E. H. M. Shahali and L. Halim, "The influence of science teachers' beliefs, attitudes, self-efficacy and school context on integrated STEM teaching practices," *International Journal of Science and Mathematics Education*, vol. 22, no. 4, pp. 787–807, 2024, doi: 10.1007/s10763-023-10403-9.
[47] K. Sokha, "Examine the impact of contextual, personal, and behavioral factors on high school teachers' engagement in teaching science using an integrated STEM approach," *International Journal of Science and Mathematics Education*, 2024, doi: 10.1007/s10763-024-10447-5.
[48] V. Subramaniam, M. Karpudewan, and W. M. Roth, "Unveiling the teachers' perceived self-efficacy to practice integrated STREAM teaching," *Asia-Pacific Education Researcher*, vol. 32, no. 3, pp. 327–337, 2023, doi: 10.1007/s40299-022-00655-4.
[49] M. I. Suárez and K. B. Wright, "Investigating school climate and school leadership factors that impact secondary STEM teacher retention," *Journal for STEM Education Research*, vol. 2, no. 1, pp. 55–74, 2019, doi: 10.1007/s41979-019-00012-z.
[50] X. Du and Y. Chaaban, "Teachers' readiness for a statewide change to PjBL in primary education in Qatar," *Interdisciplinary Journal of Problem-based Learning*, vol. 14, no. 1, pp. 1–15, 2020, doi: 10.14434/ijpbl.v14i1.28591.
[51] P. W. Garner and K. B. Legette, "Teachers' social emotional learning competencies and social justice teaching beliefs and associations with children's prosocial behavior and community engagement," *Child and Youth Care Forum*, 2023, doi: 10.1007/s10566-023-09784-3.
[52] H. Ateş and C. Gündüzalp, "A unified framework for understanding teachers' adoption of robotics in STEM education," *Education and Information Technologies*, 2023, doi: 10.1007/s10639-023-12382-4.
[53] P. Pazos *et al.*, "Predicting engineering integration in k-12 from the perspective of pre-service teachers," *International Journal of Engineering Education*, vol. 39, no. 2, pp. 441–452, 2023.
[54] T. Cramer, E. Cappella, P. Morris, and A. Ganimian, "Measuring and predicting teachers' commitment to implementing evidence-based programs," *Early Childhood Research Quarterly*, vol. 64, pp. 405–415, 2023, doi: 10.1016/j.ecresq.2023.04.009.
[55] A. Ekmekci and D. M. Serrano, "The impact of teacher quality on student motivation, achievement, and persistence in science and mathematics," *Education Sciences*, vol. 12, no. 10, 2022, doi: 10.3390/educsci12100649.
[56] R. Jocius *et al.*, "Building a virtual community of practice: teacher learning for computational thinking infusion," *TechTrends*, vol. 66, no. 3, pp. 547–559, 2022, doi: 10.1007/s11528-022-00729-6.
[57] L. Nägel, V. Bleck, and F. Lipowsky, "'Research findings and daily teaching practice are worlds apart'- predictors and consequences of scepticism toward the relevance of scientific content for teaching practice," *Teaching and Teacher Education*, vol. 121, 2023, doi: 10.1016/j.tate.2022.103911.
[58] H. Song and M. Zhou, "STEM teachers' preparation, teaching beliefs, and perceived teaching competence: a multigroup structural equation approach," *Journal of Science Education and Technology*, vol. 30, no. 3, pp. 394–407, 2021, doi: 10.1007/s10956-020-09881-1.
[59] D. Malinic, J. Stanisic, and I. Djeric, "The experience of teachers in realisation of project-based learning based on interdisciplinary approach," *Zbornik Instituta za pedagoska istrazivanja*, vol. 53, no. 1, pp. 67–120, 2021, doi: 10.2298/ZIPI2101067M.
[60] C. Y. Hsu, J. C. Liang, and M. J. Tsai, "Probing the structural relationships between teachers' beliefs about game-based teaching and their perceptions of technological pedagogical and content knowledge of games," *Technology, Pedagogy and Education*, vol. 29, no. 3, pp. 297–309, 2020, doi: 10.1080/1475939X.2020.1752296.
[61] H. Jiang, K. Wang, X. Wang, X. Lei, and Z. Huang, "Understanding a STEM teacher's emotions and professional identities: a three-year longitudinal case study," *International Journal of STEM Education*, vol. 8, no. 1, p. 51, Dec. 2021, doi: 10.1186/s40594-021-00309-9.
[62] T. E. Vossen, I. Henze, R. C. A. Rippe, J. H. Van Driel, and M. J. De Vries, "Attitudes of secondary school STEM teachers towards supervising research and design activities," *Research in Science Education*, vol. 51, pp. 891–911, 2021, doi: 10.1007/s11165-019-9840-1.
[63] G. E. Gardner, E. Brown, Z. Grimes, and G. Bishara, "Exploring barriers to the use of evidence-based instructional practices," *Journal of College Science Teaching*, vol. 51, no. 2, pp. 56–66, 2021, doi: 10.1080/0047231X.2021.12290550.
[64] K. Z. Revelle, C. N. Wise, N. K. Duke, and A. L. Halvorsen, "Realizing the promise of project-based learning," *Reading Teacher*, vol. 73, no. 6, pp. 697–710, 2020, doi: 10.1002/trtr.1874.
[65] J. Gomes and M. Fleer, "Is science really everywhere? teachers' perspectives on science learning possibilities in the preschool environment," *Research in Science Education*, vol. 50, no. 5, pp. 1961–1989, 2020, doi: 10.1007/s11165-018-9760-5.

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