J-IAMSTEM
Journal of Innovation, Advancement, and Methodology in STEM Education
Vol. 1, No. 3, pp. 121-134, May-June 2024
https://so13.tci-thaijo.org/index.php/j_iamstem

Influencing Factors of High School Chemistry Teachers' Understanding of STEM Education

Hu Yuanlong[a,b] Li Jia[a*]

[a]The College of Chemistry, Central China Normal University, Hubei, China.

[b]Shude Middle School, Sichuan, China*

*Corresponding author email: amberlee1117@163.com, 4959695@qq.com

ORCID number: Li Jia (0000-0002-6546-0310)

Received: 20 Apr 2024 Revised: 19 June 2024 Accepted: 22 June 2024

Abstract

There are differences in the understanding of "what is STEM education" among stakeholders such as science education experts, frontline teachers, students, and policymakers, which will not be conducive to the development and implementation of STEM education. Also little has been done to dissect the factors that influence Chinese chemistry teachers' understanding of STEM education. The data (n = 150) were collected from high school chemistry teachers in Sichuan province, China. The study systematically analyzed the current status of high school chemistry teachers' understanding of STEM education from three perspectives: ontological, epistemological, and value-based. High school chemistry teachers exhibited an optimal understanding of the value of STEM education but a poor understanding of the nature of STEM education. Further exploration of the factors influencing teachers' understanding of STEM education included professional identity, school environment, teaching practices, and perceptions of developmental characteristics. Results indicated that the technological environment of the teachers' school had the greatest influence on their understanding of STEM education. Additionally, teachers' perceptions of developmental characteristics significantly impacted their understanding of STEM education. Moreover, a stronger sense of belonging to the teaching profession correlated with a better understanding of STEM education. Finally, the experience of observing and learning was found to enhance teachers' understanding of STEM education. Conclusion, the technological environment of a teacher's school exerts the greatest influence on their understanding of STEM education, strongly correlating with the engineering orientation inherent in STEM education. Teachers' perceptions of developmental characteristics can significantly shape their understanding of STEM education, depending largely on the lineage of STEM education's developmental history.

Keywords: High school chemistry teachers, STEM education, Influencing factors

1. Introduction

To address the national workforce needs, primary and secondary schools need to integrate STEM education into the classroom (Bartels et al., 2019). However, the primary challenge hindering the advancement of STEM education at secondary and tertiary levels is the lack of teaching efficacy(Martynenko et al., 2023). Existing studies have probed into this issue from the perspectives of teachers' STEM instructional design and instructional evaluation, aiming to enhance STEM teaching quality. Nevertheless, scholars increasingly argue that teachers' understanding of the essence of STEM education stands as the pivotal factor for effective STEM teaching. The implementation of STEM education necessitates teachers to possess relevant knowledge and concepts (Leung, 2023; Bell, 2016; Sutaphan and Yuenyong, 2021).

In this context, scholars have conducted empirical investigations regarding high school teachers' understanding of STEM education. However, most studies have merely scratched the surface, focusing on superficial inquiries such as "Do you think that STEM education as effectively integrates the four disciplines of S, T, E, and M?" and "Do you perceive STEM education as important?" Substantive issues such as the concept of integrated STEM education, STEM literacy, and the composition and interrelation of STEM disciplines are often overlooked. Moreover, few scholars have discussed the analysis of the influencing factors on teachers' understanding of STEM education. In light of this gap, a sample of 150 high school chemistry teachers, aims to systematically analyze the current grasp of STEM education from three critical perspectives: ontology, epistemology, and value theory. Simultaneously, we explore the influences of various variables on high school teachers' understanding of STEM education.

2. Literature review

Integrating two or more subjects into teaching in a meaningful and relevant way is a challenging task (Han et al., 2023), and this has led to problems such as low-quality and ineffective STEM teaching. However, teachers' understanding of STEM education is the key factor in their effective STEM teaching (Nugraha et al., 2023). The introduction of STEM education has necessitated a shift in teachers' teaching perception at this stage, which requires STEM teachers to possess knowledge, skills, and concepts related to STEM fields(Suryadi et al., 2023). STEM teachers' understanding of STEM education is inadequate and varied, which may limit effective student learning in STEM education (Falloon et al., 2020).

To fully grasp the current situation and level of teachers' understanding of STEM education, relevant scholars have carried out empirical exploration with the help of different research tools and methods. Lo et al. (2021) investigated the current situation of teachers' understanding of STEM education through a questionnaire survey, and the conclusion pointed out that problems such as the lack of a clear understanding of the nature of STEM education and the cognition of integrated STEM education concepts are prevalent in the pre-service STEM teacher group. To a certain extent, the research paradigm of self-reporting scale alone cannot accurately measure the current status of teachers' understanding of STEM education. Based on this, Pimthong et al.(2020), Dare et al.(2019), Ring et al.(2017) based on the theory of constructivism, used the research paradigm of graphical representation supplemented with qualitative interviews to explore in depth K-12 teachers' understanding of STEM education, the conclusion further states that most of the pre-service chemistry teachers' understanding of STEM education remains at the horizontal level of which subjects STEM education consists of, and there is less understanding of how to conduct STEM teaching and the principles of integrated STEM education. To improve this situation, relevant scholars have also carried out empirical explorations. Scholars such as Bartels et al.(2019), and Suryadi et al.(2023) have asked pre-service teachers to watch, analyze, and reflect on other people's STEM teaching videos to improve their views on the nature of STEM education and integrated STEM education, and this intervention effectively improved teachers' understanding of STEM education. Lin et al.(2019) advocated the use of informal venues, such as museums, to develop STEM teachers' practical skills, and proposed the establishment of a special scholarship for STEM teachers to reward those who excel in STEM fields, this program increased the percentage of qualified STEM teachers at the K-12 education level. Meanwhile, to better help novice STEM teachers quickly enter the profession, accelerate the professional development of STEM teachers, and reduce the turnover rate of STEM teachers, Jones et al.(2016) developed an online training platform that employs professional STEM teachers to exemplify the problems of STEM novice-type teachers, in the areas of teaching strategies, teaching practices, and teaching evaluation or answers. This strategy has won the esteem of a wide range of STEM novice teachers for its efficient instructional efficiency, professional instructional team, and rich peer-to-peer exchanges.

Meanwhile, to effectively guide the construction of STEM teachers' professionalization system, many scholars have analyzed the factors influencing teachers' understanding of STEM education, which in general include the following aspects: 1)STEM Professional Identity, 2)School Environment, 3)STEM Teaching Practices, 4) STEM Teacher Development Characteristics Perception. In addition, the teachers' teaching periods, subject of teaching, level of education, and years of teaching experience also affect the teachers' understanding of STEM education, which informed the sampling for this paper. Studies have shown that secondary school teachers have a more accurate and adequate understanding of STEM education than elementary school teachers (Yoo et al., 2016). Among all science teachers, math teachers had the lowest level of understanding of STEM education(Thibaut et al., 2017). The higher the level of education of a teacher, the more he/she can perceive STEM education from two perspectives: the connection between STEM education and life and the relationship between subjects (Khuyen et al., 2020). Compared to experienced teachers, novice teachers are more fully exposed to and understand STEM education through informal areas such as visiting venues (Khuyen et al., 2020).

3. Conceptual framework

STEM teacher identity and teachers' STEM education understanding. Teachers who are more identified with their own identity are more likely to use diverse teaching methods, significantly enhancing secondary school students' interest and curiosity in the field of science, thus increasing students' tendency to choose science majors in higher education (Bayanova et al., 2023). At the same time, based on social cognitive career theory and Hollander's theory concluded that more emphasis on the social impact of STEM can enhance the identity of STEM teachers, thus increasing the rate of STEM career choice (Van et al., 2020).

School environment and teachers' understanding of STEM education. Thibaut et al. (2017) classified the school environment into social, technological, and organizational environments. First, the social environment can promote teachers' understanding of STEM education. Collaboration and communication with peers can provide novice STEM teachers with more resources and learning opportunities, prompting them to self-reflect on how to effectively implement STEM education in their teaching and thus deepen their understanding of STEM education (Lo, 2021). Empirical research confirmed after collaborating with STEM professionals, teachers' understanding of the STEM teaching philosophy shifted from teacher-driven to student-centered, from single-subject-driven to multidisciplinary integration of content, and from lecture-driven to integration of problem-based and project-based learning (So et al., 2020); secondly, the technological environment can provide teachers' understanding of STEM education. The National Research Council pointed out that teachers, after receiving relevant technical support, can not only enhance their understanding of STEM education but also improve their understanding of STEM careers, which also plays an important role in promoting students' STEM career tendencies; finally, the organizational environment can enhance the level of teachers' understanding of STEM education. Empirical investigations show that curricular resources, standardized class patterns, time allocated to science in the curriculum, and the time and effort required to prepare for the curriculum can potentially influence teachers' perceptions of STEM education (Liang et al., 2023).

Teaching practices and teachers' STEM education understanding. Due to the dynamic and mobility nature of STEM education (Palid et al., 2023), teachers must deepen their understanding of STEM education by continuously providing feedback and updating their teaching concepts through STEM education teaching practices. Training of thematic instructional design in the professional training of teachers can deepen their understanding of STEM education in practice (Thuy et al., 2020). Lacking necessary classroom practice can make teachers stay in the situation of "I don't think I can do STEM teaching" and "I don't think I understand STEM education", which will negatively affect teachers' understanding of STEM education (Sungur-Gul et al., 2023). In addition, the empirical findings of related scholars showed that there is a two-way positive feedback mechanism between STEM teaching practice and understanding of STEM education and that real classroom practice environments are the best "soil" for cultivating positive perceptions of STEM teachers (Sungur-Gul et al., 2023).

The developmental characteristics and cognitive aspects of teachers' understanding of STEM education. The development of STEM teachers is a non-linear trajectory, and it will be affected by various factors from society, schools, and individuals (Mumcu et al., 2023). STEM education, characterized by problem-based learning (PBL), requires teachers to actively engage in authentic real-world challenges and have a deep grasp of the integrative essence of STEM education. Collaborative efforts and robust communication among STEM teachers amplify their appreciation of the interdisciplinary essence of STEM education (Hu et al., 2024). Johnson et al. (2015) pointed out that STEM education is centered on solving real-world problems, so STEM curricula have a short lifecycle, and there will be no jack-of-all-trades STEM curricula, and teachers' understanding of this key element is conducive to teachers' comprehension of the essence of STEM education amidst the ever-evolving curriculum landscape.

4. Research hypotheses

We systematically analyzed high school chemistry teachers' understanding of STEM education, examining it through the three lenses of ontology, epistemology, and the value theory of STEM education. Meanwhile, we explored how factors such as STEM teacher identity, school environment, teaching practice, and cognition of developmental traits affect high school teachers' understanding of STEM education. The research hypotheses are as follows:

Hypothesis 1: A positive correlation exists between STEM teacher identity and high school chemistry teachers' understanding of STEM education.

Hypothesis 2: School environment can positively influence high school chemistry teachers' understanding of STEM education.

Hypothesis 3: Engaging teaching practices contribute positively to high school chemistry teachers' understanding of STEM education.

Hypothesis 4: Awareness of developmental characteristics fosters a positive influence on high school chemistry teachers' understanding of STEM education.

5. Methods

5.1 Instrument

To explore high school chemistry teachers' understanding of STEM education across its ontological, epistemological, and value-driven dimensions, a questionnaire was designed using a Likert 4-degree scale. The questionnaire was composed of three parts: the first part is the teachers' understanding of the nature of STEM education. This part gauged teachers' grasp of the essence of STEM education, developed by Radloff et al.(2016) based on the conceptualization theory of the phenomenon and the constructivist theory. The second part delved into teachers' perceptions regarding STEM education's instructional aspects, referencing definitions and frameworks outlined by Johnson et al.(2015) and Bybee(2013) on integrated STEM concepts and STEM literacy. The third part explored teachers' appreciation of the value inherent in STEM education, drawing from empirical studies on the subject, particularly considering teachers' perspectives across different tenure levels (Peng et al., 2020). This part further differentiated between national and individual values of STEM education, assessing both the domestic and international perspectives at the national level and evaluating individual perspectives based on the integration of the five educative disciplines.

The influencing factors questionnaire was composed of four parts. The first and second parts, focusing on STEM teacher identity and perception of developmental characteristics, draw upon findings from El-Nagdi et al. (2018). The existing questionnaire topics and structure were adapted according to the characteristic attributes of the STEM teachers and the measurement purpose. The third part delved into the school environment, referencing the definition and categorization of the social environment, organizational environment, and technological environment by scholars such as Thibaut et al.(2017). The fourth part is teaching practice, and the questionnaire was prepared from practical experience, observation experience, and training experience.(Sungur-Gul et al., 2023).

To bolster the credibility of the empirical finding, rigorous quality checks were performed on the questionnaire. Firstly, the content and structure of the questionnaire were consulted with educators specializing in STEM education across primary to college levels. Certain questions were revised based on the consultation feedback received. Additionally, the reliability of the questionnaire was tested by expert consultation via the Delphi method. The results showed that Clonbach's alpha coefficients of the status quo and the influencing factors scales were 0.957 and 0.962, respectively. Furthermore, the scales exhibited high Kaiser-Meyer-Olkin (KMO) values of 0.857 and 0.873, with Bartlett's test of sphericity yielding significant results. Notably, the cumulative explained variances of the components reached 74.579% and 81.090, which indicated that the reliability of the status quo and influence factor scales were good.

The questionnaire survey can collect a large sample size in a short period, laying the foundation for quantitative analysis of the study. However, the nature of the reasons behind the current situation and the influencing factors are diversified and will present complexity, multidimensionality, unpredictability, and other characteristics, so it is necessary to conduct case interviews with some teachers based on the questionnaire to gain a deeper understanding of the mechanisms involved and to provide a basis for the interpretation of the results. We interviewed six high school teachers, with four specializing in high school chemistry and two in STEM subjects. The group comprised both novice and experienced educators.

5.2 Participants

A total of 150 high school chemistry teachers from X province in China took part in the survey. Teachers' gender, teaching age, education level, and the region and type of school can cause differences in their level of understanding of STEM education. Based on this, a random sampling method was employed to collect data. The sample consisted of 62 male teachers (41%) and 88 female teachers (59%); 87 teachers with less than 5 years of teaching experience (58%), 35 teachers with 6-10 years of experience (23%), 16 teachers with 11-15 years of experience (11%), and 12 teachers with 16 years or more of experience (8%); 75 teachers from urban schools (50%), 43 teachers from suburban schools (28%), and 32 teachers from rural schools (22%); 5 teachers held doctoral degrees (3%), 82 teachers held master's degrees (55%), and 63 teachers held bachelor's degrees (42%); in terms of school type, 96 were from public schools (64%) and 54 were from private schools (36%).

6. Results and discussion

6.1 Status of High School Chemistry Teachers' Understanding of STEM Education

As shown in Table 1, high school chemistry teachers demonstrate a favorable comprehension of the significance of STEM education, while exhibiting a limited grasp of the essence of STEM education. The primary factor contributing to this deficiency is the intricate, multifaceted, and pioneering nature of engineering disciplines.

In terms of the understanding of the nature of STEM education, we measured teachers' understanding of features of STEM education, such as dynamics and mobility of STEM education, and engineering and practical orientation of STEM education. The dynamics and mobility of STEM education mean that the disciplines of STEM education will change according to different environments, and its composition should be in line with the developmental rules and characteristics of students, who are at different educational stages. The engineering and practical orientation of STEM education refers to the fact that, practical activities using engineering as a vehicle, can promote the integration of STEM education across multiple disciplines, and improve the development of higher thinking in students. The results of the study show that the dynamics and mobility of STEM education have become a consensus among teachers (more than 70% of teachers agree), but some teachers (more than 40%) have overlooked the important educational value of engineering disciplines in interdisciplinary teaching and learning.

In terms of the understanding of STEM teaching, we measured teachers' understanding of STEM literacy and integrated STEM education conception. STEM literacy consists of four components: identifying STEM problems, engaging in STEM discussions, interacting with heterogeneous groups, and exploring solutions to problems. Integrated STEM education conception consists of the following five components: teaching contexts that emphasize realism, teaching goals that highlight STEM literacy, teaching conception that emphasizes student-centeredness, teaching methods that focus on project-based instruction, and teaching processes that emphasize the purposeful and meaningful integration of STEM disciplines. The results of the study showed that the majority of teachers (more than 90%) were concerned with exploring problem-solving solutions, which is mentioned in the STEM literacy, and more than 85% of teachers agreed most with the "life orientation", which is emphasized in the integrated STEM education philosophy.

In terms of understanding the value of STEM education, we measured teachers' awareness of the value of STEM education at the national level and the individual level. The value of STEM education at the national level consists of two aspects: providing a prerequisite for the cultivation of national composite talents and guaranteeing the enhancement of the country's international competitiveness. The value of STEM education at the individual level consists of five aspects: enhancing the students' correct understanding of the value of cooperative generation, promoting the integration and development of students' higher thinking, cultivating students' skills for social adaptation in the new era, enhancing the value aesthetics of students' rational thinking, prompting students to apply multidisciplinary knowledge, such as scientific principles and technology, to creatively solve problems in the labor process. The results of the study showed that 88% of teachers showed high recognition of the value of STEM education at the national level, in terms of cultivating composite talents and enhancing international competitiveness. Moreover, 85% of the teachers acknowledged the importance of STEM education at the individual level, particularly regarding the integration of the five areas of education and the cultivation of labor literacy among individuals.

Table 1 Status of High School Chemistry Teachers' Understanding of STEM Education

Dimension		Measurement and Meaning	Mean ± Standard Deviation
Nature of STEM Education	Dynamism and mobility	Continuous variables (0 to 2, high score, good understanding)	3.41±0.69
	Experimental orientation and engineering orientation	Continuous variables (0 to 16, high score, good understanding)	10.61±3.29
Teaching of STEM Education	STEM literacy	Continuous variables (0 to16, high score, good understanding)	12.69±3.30
	Integrated STEM Education Philosophy	Continuous variables (0 to 24, high score, good understanding)	19.71±3.69
Value of STEM Education	National level	Continuous variables (0 to 8, high score, good understanding)	6.55±1.44
	Individual level	Continuous variables (0 to 20, high score, good understanding)	16.48±3.55

6.2 Factors Influencing High School Chemistry Teachers' Understanding of STEM Education

A multiple regression model was built. In this model, high school chemistry teachers' understanding of STEM education is the explanatory variable, and professional identity, school environment, teaching practice, and developmental characteristics perception as the explanatory variables：

F (Understanding of STEM education)= f (Professional Identity, School Environment, Teaching Practices, Developmental Characteristics Perception)

Specifying each explanatory variable, the multiple regression model can be expressed as：

$$y=\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_4x_4+\beta_5x_5+\beta_6x_6+\beta_7x_7+\beta_8x_8+\beta_9x_9+\varepsilon \quad (1)$$

After organizing, the model can be obtained：

$$y=\beta_0+\sum_{i=1}^{j}\beta_i x_i+\varepsilon \quad (2)$$

In equations (1) and (2), y denotes high school chemistry teachers' understanding of STEM education, x1 is the sense of professional belonging, x2 is the sense of professional value, x3 is the technological environment, x4 is the social environment, x5 is the organizational environment, x6 is the practicum experience, x7 is the training experience, x8 is the observation experience, and x9 is the perception of developmental traits, β0 is the intercept of the regression line, βi is the regression coefficient, and j is the variable total, and ε is random error.

With the help of SPSS 25.0 statistical software, the stepwise method was used to regress in four steps, and finally, regression model II was obtained (see Table 2). From the data, the model meets the criteria of residual independence and shows no signs of multicollinearity among the four explanatory variables. Furthermore, the model's adjusted R^2 of 0.424 indicates these variables can collectively account for 42.4% of the variance, suggesting a good model fit. The model's P-value of 0.000, less than the conventional threshold of 0.05, signifies at least one of the explanatory variables significantly influences the dependent variable. Upon examining the significance of each explanatory variable, it is confirmed they all have a significant impact. Subsequently, the regression equation derived from evaluating the significance values associated with each explanatory variable is as follows:

High School Chemistry Teachers' Understanding of STEM Education = 51.560 + 0.449×Technical Environment + 0.392×Developmental Characteristics Perception + 0.256×Teachers' Sense of Belonging Identity + 0.185×Observation Experience

Table 2 Multiple Linear Regression Analysis of Factors Influencing High School Chemistry Teachers' Understanding of STEM Education

Model variable		Standardized Coefficient	*P*	Tolerance levels	*VIF*
β_0	Constant Term	51.560	0.000	--	--
x_1	Teachers' Sense of Belonging Identity	0.256	0.001	0.870	1.149
x_3	Technical Environment	0.449	0.000	1.000	1.000
x_8	Observation Experience	0.185	0.009	0.967	1.034
x_9	Developmental Characteristics Perception	0.392	0.000	0.980	1.020
adjusted-R^2		0.424			
F		11.150			
DW		2.063			
P		0.000			
implicit variable		high school chemistry teachers' understanding of STEM education			

From the model regression results, it was found that the influence of professional identity, school environment, teaching practice, and developmental characteristics perception on STEM education understanding varied in significance, and the influence of each explanatory variable on teachers' understanding of STEM education was elucidated as follows：

The technological environment of the teacher's school has the greatest influence on the explanatory variables, research hypothesis 2 was partially established. This is related to the engineering and practical orientation of STEM education, which refers to the fact that practical activities using engineering as a vehicle can promote the integration of STEM education across multiple disciplines and improve the development of higher thinking in students. The interviewed teachers pointed out that the engineering discipline is more comprehensive, complex, and innovative than other disciplines, but we did not have any materials to carry out STEM education. Even if schools are equipped with the appropriate materials, there is still a lack of expert guidance on how to use the materials; at the same time, the inquiry-based nature of STEM teaching requires that students, based on the existing programs and tools, be able to utilize knowledge of the relevant disciplines and ways of thinking, to improve and enhance the quality of the existing programs, or create new programs to solve real problems. The technical support and guidance emphasized in the technological environment, can affect teachers' understanding of STEM education, by influencing their understanding of engineering, and practical orientation of STEM education, and the inquiry orientation of STEM teaching (Chng et al., 2023).

Teachers' perceptions of developmental characteristics can influence the explanatory variables to a greater extent, and research hypothesis 4 is fully established. Relevant scholars have summarized the developmental characteristics of STEM teachers at the professional and personal levels. In other words, the trend of STEM teachers' developmental characteristics depends largely on the developmental history of STEM education. The developmental history of STEM education includes the understanding of the germination and development of STEM education at the national level. The STEM education developmental history lineage requires teachers to understand the germination and development of STEM education at the national level, thus enhancing teachers' recognition of the value of STEM education at the national level, to improve their understanding of STEM education.

The higher the sense of belonging to the teaching profession, the better the understanding of STEM education, and research hypothesis 1 was partially established. With the rise of STEM education, STEM teachers have emerged. STEM teachers are those who are engaged in the teaching of a scientific or technical subject, at the same time they have the concept of interdisciplinary teaching and can carry out teaching practice. However, there are few STEM education-related positions or courses, in terms of the recruitment of teachers in universities and elementary schools, as well as in terms of the curriculum of universities and elementary schools. In conjunction with the excessive burden of the teaching workload, the interviewed teachers indicated that this situation would lead to a reluctance among the majority of teachers to be categorized as "STEM teachers", thereby constraining their comprehension of STEM education.

Observation experiences can enhance teachers' understanding of STEM education, and research hypothesis 3 is partially valid. Practical experiences emphasized that senior high school teachers should have teaching practice experiences and training experiences related to STEM education, but confined to the relatively short time that STEM education has been introduced into China, the interviewed teachers pointed out that, in the realistic context of the lack of relevant high-quality lesson examples, observation experiences that show teachers the way to integrate engineering and technology subjects into teaching and carry out specific lesson presentations on STEM education, would be more helpful for teachers' understanding of teaching and learning in STEM education, thus enhancing the level of understanding of STEM education.

7. Conclusion

The results of the current situation analysis show that teachers' understanding of the dynamics and mobility of STEM education is fair, while the practical and engineering orientation of STEM education is insufficient, which indicates a lack of awareness of the value of STEM education in the informal venue and the important educational value of engineering disciplines in interdisciplinary teaching. Attending relevant lectures is an important way to improve teachers' understanding of STEM education(Nguyen et al., 2021), but due to the special characteristics of STEM education, which requires a brand new education industry chain and new pedagogy(Yang et al., 2022), the top-down mode of training often fails to satisfy its developmental needs, and it is necessary to set up a two-way training mechanism combining the bottom-up and top-down modes: on the one hand, the educational departments should delivering well-targeted training by taking into account national policies, existing empirical research, and local realities; on the other hand, educational departments should set up corresponding mailboxes and WeChat public numbers to enrich the delivery channels of opinions, and at the same time, combined with field research, different batches of guidance can be launched for teachers with different needs to enhance the effectiveness of training. Understanding the nature of STEM education is the core of STEM education understanding. Concerning the survey results, the following suggestions are made for the content of training: first, focus on the introduction of the history of the development of STEM education, it can enhance teachers' understanding of the value of engineering and technology disciplines; second, infiltrate STEM education in museums, which can enhance teachers' understanding of the value implications of STEM education in informal venues; and lastly, regularize the design of excellent classroom cases in STEM education, to deepen the understanding of teachers on the dynamics and mobility of STEM education(Sungur-Gul et al., 2023).

The results of the analysis of influencing factors show that complete technological tools, materials, and adequate funding for technology, are important prerequisites for teachers' understanding of STEM education. On the one hand, the Ministry of Education should strengthen the distribution of funds, to guarantee and encourage schools to integrate artificial intelligence, virtual reality, and other mobile technologies, so that schools can establish public science laboratories to meet the needs of specialized STEM teaching. In addition, governments should designate a third-party agency to resolve the dilemma of supplying and recycling the materials, which is needed to carry out STEM education, to encourage schools and the third-party agency to strengthen their collaboration and to satisfy the needs of regularized STEM teaching simultaneously. On the other hand, external experts are hired to guide the development of STEM education and solve the problem of the lack of specialized leadership. In the era of new media, in addition to using traditional offline communication community, we should also actively explore the "Internet + Education" and other emerging technologies, carry out a series of "experts on campus"and "experts face to face"activities, provide teachers with more high-quality resources to realize the sharing of resources, improve the online communication channels with the relevant experts, and improve teachers' self-efficacy in STEM teaching.

8. Implication

This research systematically analyzed the status and influencing factors of teachers' understanding of STEM education by organizing the theoretical and practical achievements related to STEM education, which play an enriching and perfecting role in the overall construction of the evaluation system of STEM education, and provides a reference for the development of STEM teacher'training by multiple subjects including the school and the government. High school teachers are important executors for realizing the integration of STEM education in primary school to senior high school, and the chemistry classroom is an important carrier of STEM education. Measuring the current situation of high school chemistry teachers'understanding of STEM education and influencing factors not only enhances students' knowledge of STEM careers and their tendency to choose them, but also broadens the career development paths of high school chemistry teachers and points out the way forward for the professional development of teachers.

8. Limitations

Through interviews with teachers, it was concluded that the university where teachers were educated, the level of the school where teachers were educated, the atmosphere of STEM education within and among disciplines, and the attitude of teachers to continuously learn new educational concepts also affect their understanding of STEM education, and the mediating and moderating effects of the influencing factors have not yet been explored in depth, so that subsequent research can further improve the model of the influencing factors and explore the influencing mechanisms; In addition, the ways to improve teachers' understanding of STEM education require not only theoretical assumptions but also practical tests. From the influencing factors derived from the research results, how to carry out operational training measures in combination with the dilemmas of teachers ‘understanding of STEM education and the national policy guidelines is a growth point for future research.

References

Bartels, S. L., Rupe, K. M., & Lederman, J. S. (2019). Shaping Preservice Teachers' Understandings of STEM: A Collaborative Math and Science Methods Approach. *Journal of Science Teacher Education, 30*(6), 666-680.

Bayanova, A. R., Orekhovskaya, N. A., Sokolova, N. L., Shaleeva, E. F., Knyazeva, S. A., & Budkevich, R. L. (2023). Exploring the role of motivation in STEM education: a systematic review. *EURASIA Journal of Mathematics, Science and Technology Education, 19*(4), 22-50.

Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. *International Journal of Technology and Design Education, 26*(1), 61-79.

Bybee, R. W. (2013). *The case of STEM education: challenges and opportunities.* Arlington: NSTA Press, 73-80.

Chng, E., Tan, A. L., & Tan, S. C. (2023). Examining the use of emerging technologies in schools: A review of artificial intelligence and immersive technologies in STEM education. *Journal for STEM Education Research, 6*(3), 385-407.

Dare, E. A., Ring-Whalen, E. A., & Roehrig, G. H. (2019). Creating a continuum of STEM models: Exploring how K-12 science teachers conceptualize STEM education. *International Journal of Science Education, 41*(6), 1-20.

El-Nagdi, M., Leammukda, F., & Roehrig, G. (2018). Developing identities of STEM teachers at emerging STEM schools. *International journal of STEM education, 5*, 1-13.

Falloon, G., Hatzigianni, M., Bower, M., Forbes, A., & Stevenson, M. (2020). Understanding K-12 STEM education: A framework for developing STEM literacy. *Journal of Science Education and Technology, 29*, 369-385.

Han, J., Kelley, T., & Knowles, J. G. (2023). 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, 33*(4), 1499-1523.

Hu, W., & Guo, X. (2024). *Construction and practice of STEM education system for primary and secondary schools.* In Disciplinary and Interdisciplinary Education in STEM, 81-101.

Johnson, C. C., Peters-Burton, E. E., & Moore, T. J. (2015) *STEM road map: a framework for integrated STEM education.* New York and LonDon: Routledge, 8-10.

Jones, G., Dana, T., & Laframenta, J. (2016). STEM TIPS: Supporting the Beginning Secondary STEM Teacher. *Tech Trends, 6*0(3), 272-288.

Khuyen, N., Bien, N. V., & Lin, P. L. (2020). Measuring Teachers' Perceptions to Sustain STEM Education Development. *Sustainability, 12*, 1-15.

Leung, W. M. V. (2023). STEM education in early years: Challenges and opportunities in changing teachers' pedagogical strategies. *Education Sciences, 13*(5), 490.

Liang, W., & Fung, D. (2023). Designing STEM education in small class teaching environments: The Hong Kong experience. *The Asia-Pacific Education Researcher, 32*(2), 189-209.

Lin, J. L., Hsiao, K. H., & Lin, L. C. (2019). The role of museum to promote STEM education and teacher interdisciplinary training: Introducing the experience of National Science and Technology Museum. *Recent Developments on Information and Communication Technology (ICT) Engineering, 2*, 43.

Lo, C. K. (2021). Design principles for effective teacher professional development in integrated STEM education. *Educational Technology & Society, 24*(4), 136-152.

Martynenko, O. O., Pashanova, O. V., Korzhuev, A. V., Prokopyev, A. I., Sokolova, N. L., & Sokolova, E. G. (2023). Exploring attitudes towards STEM education: A global analysis of university, middle school, and elementary school perspectives. *EURASIA Journal of Mathematics, Science and Technology Education, 19*(3), 22-34.

Mumcu, F., Uslu, N. A., & Yıldız, B. (2023). Teacher development in integrated STEM education: Design of lesson plans through the lens of computational thinking. *Education and Information Technologies, 28*(3), 3443-3474.

Nguyen, K. A., Borrego, M., Finelli, C. J., DeMonbrun, M., Crockett, C., Tharayil, S., ... & Rosenberg, R. (2021). Instructor strategies to aid implementation of active learning: a systematic literature review. *International Journal of STEM Education, 8*, 1-18.

Nugraha, M. G., Kidman, G., & Tan, H. (2023). Pre-service teacher in STEM education: An integrative review and mapping of the Indonesian research literature. *Eurasia Journal of Mathematics, Science and Technology Education, 19*(5), 22-62.

Palid, O., Cashdollar, S., Deangelo, S., Chu, C., & Bates, M. (2023). Inclusion in practice: a systematic review of diversity-focused STEM programming in the United States. *International Journal of STEM Education, 10*(1), 2.

Peng, M., & Zhu, D. Q. (2020). Local Understanding of STEM education - A Qualitative Analysis of 52 STEM Teachers Based on NVivo11. *Research on Education Development, 4*0(10), 60-65.

Pimthong, P., & Williams, J. (2020). Preservice teachers' understanding of STEM education. *Kasetsart Journal of Social Sciences, 41*(2), 289-295.

Radloff, J., & Guzey, S. (2016). Investigating preservice STEM teacher conceptions of STEM education. *Journal of Science Education & Technology, 25*, 759–774.

Ring, E. A., Dare, E. A., Crotty, E. A., & Roehrig, G. H. (2017). The evolution of teacher conceptions of STEM education throughout an intensive professional development experience. *Journal of Science Teacher Education, 28*(5), 444-467.

So, W., He, Q., & Chen, Y. (2020). School-STEM Professionals' Collaboration: a case study on teachers' conceptions. *Asia-Pacific Journal of Teacher Education, 1*, 1-19.

Sungur-Gul, K., & Tasar, M. F. (2023). The design, implementation, and evaluation of a STEM education course for pre-service science teachers. *Journal of Education in Science Environment and Health, 9*(2), 85-100.

Suryadi, A., Purwaningsih, E., Yuliati, L., & Koes-Handayanto, S. (2023). STEM Teacher Professional Development in Pre-Service Teacher Education: A Literature Review. *Waikato Journal of Education, 28*(1), 7-26.

Suryadi, A., Purwaningsih, E., Yuliati, L., & Koes-Handayanto, S. (2023). STEM Teacher Professional Development in Pre-Service Teacher Education: A Literature Review. *Waikato Journal of Education, 28*(1), 7-26.

Sutaphan, S andYuenyong, C (2021). Examine pre-service science teachers' existing ideas about STEM education in school setting. *Journal of Physics: Conference Series 1835* (1), 012002

Thibaut, L., Knipprath, H., & Dehaene, W. (2017). How school context and personal factors relate to teachers' attitudes toward teaching integrated STEM. *International Journal of Technology and Design Education, 1*, 1-21.

Thuy, N., Bien, N. V., & Quy, D. X. (2020). Fostering Teachers' Competence of the Integrated STEM Education. *Jurnal Penelitian dan Pembelajaran IPA, 6*(2), 166-179.

Van, R. E., Fokkens-Bruinsma, M., & Goedhart, M. J. (2020). Identifying Potential Secondary School Teachers among Science University Students: A Latent Profile Analysis. Journal of Science Teacher Education, 31(5), 556-577.

Yang, K. C., & Gong, P. (2022). On What Makes STEM Education Special. *China Distance Education, 4*, 48-54.

Yoo, J., Hwang, S., & Hahn, I. (2016). A Comparative Study of Perceptions on STEAM Education by the Primary and Secondary School Teachers who Participated in the Advanced STEAM Teacher Training Program. *Journal of Research in Curriculum Instruction, 20*(1), 50-58.

Author contributions

Corresponding author were responsible for the design of the study and analysis of the data. The author were responsible for data collection, analysis, and manuscript writing.

Funding

Provincial-level teaching reform research project at undergraduate universities in Hubei Province in 2023: Innovative Model for Enhancing the Evaluation and Cultivation of Educational Competence for Outstanding Teachers through Numerical and AI Empowerment.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author upon request.

Competing interests

The author states that there are no competing interests in this manuscript.