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THE SURVEY ON STEM LITERACY OF SCIENCE TEACHERS IN CHINA

Zu Xiaoqing
***Rose Amnah Abd. Rauf**
Faculty of Education, Universiti Malaya
**rose_amnah@um.edu.my*

ABSTRACT

As the key to STEM education, teachers' level of STEM literacy plays a crucial role in teaching and learning. The purpose of this study is to assess the current STEM literacy of science teachers in China. This is a survey study using a questionnaire instrument to gain both quantitative and qualitative data. The quantitative data were analyzed by Statistical Package for the Social Science (SPSS) to evaluate the status of STEM literacy among China's school science teachers. Interpretive methods were applied for qualitative data analysis to support the quantitative data. The researcher found that current science teachers generally have a poor understanding of STEM education, lack STEM knowledge and teaching skills, but have the awareness to improve their own literacy. It is hoped that by investigating the STEM literacy of science teachers, the research will have a positive impact on improving science education and is expected to contribute to the development of science education in China.

Keywords: *Education Policy Makers, Statistical Literacy, Attitudes Towards Statistics, Statistics Anxiety*

INTRODUCTION

Nowadays, most countries in the world are committed to nurturing innovative talents, and STEM education has gained much attention in many curriculum documents and policy reports (English, 2016). This is due to its multidisciplinary and integrated classroom characteristics and its objective of enhancing the cultivation of innovative and practical skills. As promoters and practitioners of STEM education, the quality of teachers' implementation does have an impact on student performance (Ekmekci & Serrano, 2022). Worldwide efforts are being made to raise the calibers of STEM teachers as nations have started to acknowledge the crucial role they play in society. For instance, the United States has introduced a series of policies on the development of STEM teachers to attract public attention to STEM teachers, such as "STEM Support for Teachers in Education and Mentoring (STEM) Act", "STEM Master Teacher Corps Act", "National STEM Education Tax Incentive for Teachers Act"; the UK has established a national STEM teacher training network. In 2011, the Korean Ministry of Education issued the STEAM Program, which proposes the implementation of a STEAM curriculum centered on mathematics and science, combined with engineering and technology, in order to cultivate comprehensive human resources with STEAM literacy for society. In China, government agencies have also continued to focus on the development of STEM education in the country. China has issued a series of guiding documents such as the "STEM Education White Paper in China" and the "China STEM Education 2029 Innovation Action Plan". The STEM Teacher Competency Level Standards (Trial) released by the National Institute Education Sciences clearly states the requirements for teacher competency. In March 2017, China issued the Primary School Science Curriculum Standards, which specifies the main subjects of STEM development in China in the implementation recommendations and specifically states that science teachers can try to apply STEM to their own teaching (Fu, 2021). As a result, the elementary school science curriculum has been hailed as China's STEM curriculum and the reform hotspot of compulsory basic education in China has also shifted to the integration of STEM education concepts with the primary school science curriculum (Sai, 2017). Under the active guidance of STEM education, the modernized and reform of the science curriculum has become a top priority for educational development, it has also improved the comprehensive level of current science teachers, especially in terms of STEM literacy, which, as one of the main criteria for measuring teachers' competence, has a non-negligible impact on the development of science education.

The National Research Council (2011) advocates that in order to increase the possibilities for these students to proceed to STEM careers, students could be exposed to STEM education early in their schooling in order to maintain their interest and increase their chances of competency in related fields. However, this initiative is currently at risk of failure because teachers lack a comprehensive understanding of STEM and mastery of STEM education theory (Greene et al., 2006; Breiner, 2012), and STEM teaching concepts cannot be passed on to students, resulting in a serious disconnect between STEM theory and STEM teaching practice (Ryu et al., 2019). Lu (2018) investigated theories and practices associated with STEM education and discovered that STEM instructors' knowledge of disciplinary pedagogy needed to be enhanced and that their understanding of STEM education devoted to disciplinary integration was not in depth (Manduca et al., 2017). Fang reported that STEM teachers in primary and secondary schools in China are still immature in terms of their understanding and behavior of STEM education.

Teachers' STEM Literacy

Teachers' STEM literacy refers to the personal qualities and external behaviors of teachers engaged in STEM teaching activities which are in line with the concept of STEM education. The efficiency of STEM education is largely determined by the level of teachers' STEM literacy. Therefore, more and more countries and scholars around the world are concerned about the development of STEM teacher literacy, and different levels of competencies are required of teachers.

For instance, the Irish National Department of Education released a document (2018) suggesting that STEM teachers should have STEM subject knowledge, subject teaching knowledge, teaching skills and confidence. Meanwhile, American scholars (Eckman et al., 2016) suggest that, in addition to STEM pedagogical knowledge, STEM teachers should have the ability to integrate STEM subjects. Spanish scholars consider mastery of STEM subject content and interdisciplinary knowledge, pedagogical skills, attitudes and values as key to teacher literacy development. Similarly, Lee and Nason (2013) and Rinke et al. (2016) consider good knowledge of STEM subjects, knowledge and skills in STEM teaching, attention to interdisciplinary approaches and integration of STEM educational content as key factors in teacher literacy development. More importantly, many countries have issued authoritative STEM teacher competency level standards based on national contexts. For example, the STEM Educator Standards for Primary Schools issued by the Indiana Department of Education in the US, Ireland's STEM Education Policy Statement 2017-2026, etc.

At the same time, a large number of scholars have begun to study STEM teachers from different perspectives. Terrie and Nancy (2022) proposed a structural model to explain differences in how teachers learn and implement STEM in the classroom, informing teacher educators' development of an integrated STEM teacher identity. The model interweaves components of professional teacher identity and STEM learner identity models. Similarly, Holincheck and Galanti (2022) use variability to make recommendations for STEM teachers. Two universities in the United States tested teachers' understanding of STEM concepts before offering graduate courses for PK-12 teachers, revealing differences in practicing teachers' knowledge of STEM education as they embarked on for STEM courses, and therefore, teacher educators can use differentiation to expand teachers' understanding of STEM education. The subject competence of teachers is a great challenge for STEM teaching, at present, STEM teaching is currently not sufficiently interesting, engaging and fun in formal school settings (Engström, 2022). Although teachers have a positive attitude towards STEM education, some teachers implement STEM activities in the classroom that are not applicable (Betül Küçük Demir 2021). The researchers therefore suggest that teachers should learn how to integrate STEM education into their curriculum and understand the applicability of STEM cases. In addition, teacher self-efficacy is a major factor in the development of STEM education (Velasco et al., 2022), and participating in professional development programs with a specific emphasis on policy knowledge building and advocacy activities helps STEM teacher leaders build and sustain their advocacy self-efficacy. Professional development, leadership, curriculum design, pedagogy and school culture all play an indispensable role in the development of effective school-based learning programs and activities for STEM education (Fallon et al. 2021).

Successful STEM education is influenced by a variety of factors, such as teachers' conceptions of STEM, pedagogical competencies, and professional development, yet most of the current literature only addresses one or two of these factors to explore STEM teachers' competencies, and few scholars have provided a comprehensive analysis of STEM teachers. Therefore, this study builds on previous research to assess teachers from multiple perspectives in order to identify the current state of science teachers' STEM literacy.

Based on the objective, the researcher set the following research question:

What is the current literacy status of STEM literacy of elementary school science teachers in China?

METHODOLOGY

Research Design

In order to assess the STEM literacy of science instructors, the study used a survey research design in which quantitative and qualitative data were gathered via an online questionnaire. Online surveys are convenient, have the advantages of timeliness, low administration costs, speed, easy follow-up, and provide researchers with the flexibility to start, pause, or continue data collection (Nayak & Narayan, 2019).

Sample
130 science teachers participated and answered the survey for this study. When respondents accepted the offer, they were informed that taking part in the study was entirely optional and that all information gathered, especially personal data, would be handled in the strictest of confidence. A clause of agreement question at the start of the survey was necessary to make sure that respondents understood these terms.

Instrument
This study adopted a questionnaire to investigate the STEM literacy of science teachers and to collect authentic and valid data on teachers' STEM literacy. The questionnaire was developed based on the indicator system developed by the STEM Teacher Competency Level (TRAIL) published by the National Institute of Education Sciences (2018) for measuring teachers' STEM literacy. The questionnaire was designed based on the following principles: items reflect the basic characteristics of teachers' STEM literacy from the perspective of teachers' own literacy; the questionnaire is neatly structured and convenient for analysis. Three sections made up the questionnaire, the first of which contained the instructors' demographic profile, including their age, level of education, and teaching experience. A five-point Likert scale makes up the second section (Definitely Disagree, Disagree, Not Sure, Agree, Definitely Agree). This section is divided into four dimensions: teachers' understanding of STEM education, STEM subjects and integration, STEM teaching abilities and professional development. The third section was four open-ended questions.

The researcher calculated the validity of the questionnaire items through the Statistical Package for Social Sciences (SPSS). After testing, KMO value was 0.773, which was higher than 0.7, so the questionnaire was valid. A preliminary reliability test was also conducted. The Cronbach alpha values for the four dimensions were 0.865, 0.879, 0.734 and 0.832 respectively, which means that These values suggest high internal consistency.

Data Analysis
Examining, purifying, and changing data with the goal of highlighting pertinent information, suggestions, and conclusions is the process of data analysis (Giddens, A.& Griffiths, 2006). To further comprehend of participants in this study, the researcher first analyzed their demographic profiles. Secondly, analyze the data collected in the second section of the questionnaire, the researcher divided it into four sections based on the dimensions of the questionnaire, analyzing, and describing each dimension separately. The Statistical Package for Social Sciences (SPSS) was utilized to gain the mean score and standard deviation of each item. For the analysis of each item, the interpretation of mean scores shown in Table 1 was applied to determine the teachers' STEM literacy level. The mean score between 1.00 and 3.50 indicates that the teacher is not performing well on the item. Meanwhile, if the mean score is between 3.67 and 5.00, it indicates that the lecturer is performing well in the program.

Table 1

Interpretation of Mean Score

Mean Score	Interpretation
1.00 - 3.50	Low/Negative
3.51-5.00	High/Positive

The researcher employed an interpretive technique (Erickson, 1985) to examine the qualitative data from the open-ended questions to seek the participants' unique viewpoints. Coding, memo writing, focused coding, and integrated memo writing were all done iteratively (Emerson & Shaw, 1995). The researcher first collected the teachers' responses into a spreadsheet and categorized the responses by noting similarities and differences. The data were then reorganized into categories and coded by the researcher after being cross-checked by the study team. An illustration of a Category for "What Students Will Gain from STEM Education" may be found in Table 1. The categories "Knowledge" and "ability" were created by grouping and refining the codes.

Table 2

Examples of codes and categories emerging from teachers' response

Coding	Category
"Students gained a deeper understanding of science through STEM education"	Students could gain more knowledge
"Students could study more knowledge that could not acquire from textbooks"	
"Knowledge about engineering technology"	
"Students could enhance the science thinking systematically by learning STEM course."	Students' abilities will be enhanced
"Students learn to help each other and work together."	
"STEM education is helpful for cultivating the logic thinking."	
when finished a project, complete a task or solve a problem, students will gain a sense of achievement.	

RESULTS AND DISCUSSION

With the help of descriptive statistics like frequencies and percentages, the data gathered from the online survey was tallied and condensed. The majorities of respondents were female (56.2%), 68.5% of teachers were in the 20-25 age group and only 12 (9.2%) science teachers were over 30 years of age. 67 of the 130 respondents had been teaching science for 1-2 years, and less than a third had 3-4 years of teaching experience. Additional details of the respondents' demographics are given in Table 2.

Table 3

Demographics profiles of respondents

Item		Frequency	Percentage
Gender	Male	57	43.8%
	Female	73	56.2%
Age	20-25	89	68.5%
	26-30	29	22.3%
	30 and above	12	9.2%
Academic qualification	Diploma	1	0.8%
	Postgraduate	118	90.8%
	Undergraduate	11	8.5%

Teaching experience	1-2 years	67	51.5%
	3-4 years	38	29.2%
	5 years and above	25	19.2%
Teaching certificate	Elementary school	80	61.5%
	Secondary school	26	20%
	High school	24	18.5%
Teaching grade	1-3 grade	55	42.3%
	4-6 grade	63	48.5%
	Secondary and above	12	9.2%

For the remaining sections of the questionnaire the researchers assessed teachers' STEM literacy in four separate dimensions: teachers' understanding of STEM, STEM disciplines and integration, STEM teaching ability and professional development, respectively (shown as appendices table 3,4,5, and 6). The specific analyses are as follows.

1. Teachers' understanding of STEM

The first dimension is to gain the data that teachers' self-assessment about the understanding of STEM education, which consisted of both understanding of STEM education (6 items) and understanding of STEM teaching targets (4 items). As shown in Table 2, The STEM education objectives were well understood by science teachers, who also performed well on issues pertaining to those objectives, such as the item "You have a good understanding of students' learning psychology, development psychology, cognitive laws, etc. (M=3.76, SD=0.88)". When it comes to STEM education related content such as teaching models, pedagogy, etc., the teachers performed poorly. The mean scores of the teachers were as follows, "You understand the philosophy of STEM education, the laws of pedagogy. (M=3.07, SD=0.97)", " You understand the teaching mode of STEM education. (M=3.08, SD=0.97).

Table 4

Understanding of STEM education

	Mean	SD
You can fully understand the student's personality, learning ability, life background and other aspects.	3.53	0.85
You have a good understanding of students' learning psychology, development psychology, cognitive laws, etc.	3.76	0.88
You understand the philosophy of STEM education, the laws of pedagogy.	3.07	0.97
You understand the characteristics and values of STEM.	3.07	0.97
You can deal with the relationship between STEM courses and related disciplines, practical activities.	3.32	0.88
You can excavate the values of disciplines you teach from STEM perspectives.	3.09	0.96
You understand the content and structure of the STEM literacy that are required of students.	3.22	0.91

You understand the value of STEM education to students' core literacy skills such as scientific literacy, innovation and practical skills.	3.64	0.86
You understand the position of STEM education in the school curriculum.	3.58	0.85
You understand the teaching mode of STEM education.	3.08	0.97

Short answer question 1

What do you think the students will gain through STEM courses?

In the short answer section, the researcher divided the respondents' responses into two categories by means of descriptive line analysis, one being 'knowledge' and the other being 'competence'. The majorities of the teachers' answers to the 'knowledge' question were centered on subject knowledge. For example, students can learn more than they can get from textbooks, deepen their understanding of science, and STEM programs provide students with access to cutting-edge science. However, the researcher found that most of the answers focused on science, with only three teachers mentioning improvements in engineering, technology and mathematics. This suggests that the current focus of STEM education is still on science and that teachers are neglecting the role of other subjects in STEM education.

Among the answers to the 'competencies', the most frequently mentioned competencies were creativity, problem identification and processing, thinking skills, hands-on skills and teamwork skills. However, only 10 teachers mentioned the interdisciplinary skills of their students as an interdisciplinary approach to teaching and learning, demonstrating the current lack of interdisciplinary awareness among science teachers who frequently ignore the significant role of interdisciplinary in STEM teaching and learning.

Analysis of the surveys found that science teachers' comprehension of STEM education was only marginally lacking, with pre-service and in-service training being cited as reasons why this was the case (Margot et al, 2019). When teachers lack expertise and comprehension, student learning is constrained (McMullin & Reeve, 2014). The results indicated that teachers do not recognize the importance of STEM instruction, which will have an impact on how they provide STEM teaching. According to Bell (2016), teachers' perspectives of STEM, their unique knowledge bases, and their comprehension involving those knowledge bases are inextricably tied to how well STEM is delivered in their own classroom practices. Additionally, there are differences between teachers' knowledge of STEM, their own expertise, and their understanding of this knowledge (Brown et al, 2011) and teachers' understanding of STEM education influences how they design STEM curricula, therefore this means that educational institutions need to align their understanding of teacher definitions and discuss how to implement STEM education. Another reason for the lack of understanding of STEM education among teachers may be that influenced by the traditional education model, China's general universities still follow the discipline-specific training model in terms of talent training, which is seriously contradictory to the concept of STEM education and cannot train teachers who can fully understand the science of STEM education. Making sure there is some alignment between the complexity of the integrated STEM context and the level of students' STEM understanding is essential for the effectiveness of integrated STEM approaches to learning (Nadelson & Seifert, 2017); it is commendable that teachers know enough about the STEM education objectives, which have a very positive impact on STEM teaching.

2. STEM subjects and integration

Dimension 2 is the teachers' self-reports which relates to the knowledge of four disciplines covered by STEM education - science, technology, engineering and mathematics, and the ability to integrate STEM.

From table 3, what can be seen, as science teachers, the teachers performed well on projects related to science, For instance, " You can explain, predict the phenomenon you watch using science knowledge (M=3.64, SD=0.86)", but in terms of other subject, teachers have insufficient knowledge, " In the class, you can guide students to use mathematical tools, look at the world through mathematical vision and think about the world through mathematical thinking (M=2.77, SD=1.14)." In the items relating to STEM integration, teachers scored an average of less than 3 in 2 items. "You can use multidisciplinary knowledge to solve the problems which cannot be addressed by a single discipline (M=2.69, SD=1.19)", "You can introduce multidisciplinary knowledge into your teaching (M=2.98, SD=1.01)". These examples show the difficulties teachers face integrating STEM, which is in line with Dimension 1's understanding of STEM education. Teachers' knowledge of STEM education is weak because they disregard its most crucial component - transdisciplinary learning.

Table 5

STEM disciplines and integration

	Mean	SD
You can understand the concepts, laws, theorems and theories found in science textbooks.	3.49	0.85
You can explain, predict the phenomenon you watch using science knowledge.	3.64	0.86
You possess the ability of science inquiry.	3.01	1.00
In class, you often analyze data using mathematical instrument.	3.78	0.89
In the class , you can guide students to use mathematical tools, look at the world through mathematical vision and think about the world through mathematical thinking.	2.77	1.14
You can integrate educational technology, information technology and multimedia with STEM teaching content.	3.10	0.95
You possess the awareness and ability to integrate engineering thinking throughout STEM classroom design, implementation, and reflective evaluation.	2.88	1.07
You can introduce multidisciplinary knowledge into your teaching.	2.98	1.01
You can use multidisciplinary knowledge to solve the problems which cannot be addressed by a single discipline.	2.69	1.19
You can learn about subjects other than science, technology, engineering and mathematics in line with the needs of STEM teaching.	3.70	0.87

Short Answer Question 2

How science lessons can be integrated with other lessons?

When asked how science lessons could be integrated with other curricula, the researchers found that the most frequently mentioned subjects in all the answers were mathematics, computing technology and the arts. A few teachers gave examples of lessons, for example, some teachers said that statistics and number tables could be taken to collect experimental data, and one teacher gave the example that she used multimedia technology to disguise the direction of current flow and that complex circuits would be easier to understand. Other teachers suggested ways to integrate other subjects with science lessons, for example, using the history of science as an introduction to the lesson and applying traditional Chinese stories as a backdrop for classroom instruction.

The findings show that teachers have a low level of knowledge of STEM subjects. The interdisciplinary nature of STEM education requires teachers who teach STEM to have knowledge of relevant subjects and to be able to integrate this knowledge to ensure that they can teach well across disciplines. there are three types of STEM interdisciplinary integration, namely 'subject knowledge integration orientation', 'lived experience integration orientation' and 'learner-centered integration orientation" (Zhou et al., 2021). Thus, in order to accomplish the objectives of STEM education, teachers cannot rely on the expertise of a single discipline and must instead integrate their curricula, erasing the barriers between disciplines. However, teachers' low STEM integration skills correspond to El-Deghaidy et al. 's (2017) study, where teachers did not have a clear understanding of how to integrate technology. They think that integrating two disciplines is feasible but combining four STEM disciplines presents challenges (El-Deghaidy et al., 2017). What's more, some studies indicate that teachers believe that STEM courses may be inflexible and that combining two inflexible lesson plans is very difficult (Bagiati & Evangelou 2015). Therefore, teachers engaged in STEM teaching need to have strong knowledge of relevant disciplines and skills in cross-curricular integration. However, in China, most science teachers are still unable to break out of their original professional backgrounds and are reluctant to break down disciplinary boundaries (Sai, 2019), believing that the domain-specific curriculum they have mastered (chemistry, physics, etc.) does not integrate well with other STEM disciplines.

3. Ability of teaching STEM

Dimension 3, concerning teachers' ability to teach STEM, was the dimension in which science teachers performed the weakest (Details seen in Table 4). Chinese scholars advocate teaching methods based on problems, research, or real-life scenarios (Huang et al., 2009), which is the same teaching model promoted by STEM education. The survey results show that most teachers indicated that they were able to deliver student-led lessons and to design lessons based on problems or real-life scenarios. For instance, “In the class, you can guide students to explore problems and solve them on their own (M=3.51, SD=0.85).” But when it came to STEM education, teachers performed poorly “You can develop STEM lessons in an interdisciplinary way around a theme, task, project or problem (M=2.76, SD=0.75) ”. “You can explore and integrate STEM teaching resources in line with STEM curriculum requirements and student development needs (M=2.77, SD=1.14).”

Table 6

The Ability of Teaching STEM

	Mean	SD
You can integrate the use of rich technological tools or teaching methods in the teaching process, focusing on learning methods such as research-based learning and problem-oriented learning.	3.03	0.98
You can explore and integrate STEM teaching resources in line with STEM curriculum requirements and student development needs.	2.77	1.14
You can design a class based on the questions or realistic scenarios.	3.38	0.86

You can develop STEM lessons in an interdisciplinary way around a theme, task, project or problem.	2.76	1.15
You can draw on cutting-edge technology and a variety of venues to create a STEM environment suitable for interdisciplinary learning.	2.88	1.07
You can lead students in various forms of discipline-integrated learning activities.	3.14	0.94
You can develop students' STEM literacy through project-based inquiry or projects.	3.18	0.92
You can develop the STEM class based on the textbooks.	3.07	0.97
In the class, you can guide students to explore problems and solve them on their own.	3.51	0.85
You can provide feedback and guidance on the implementation process and results of STEM education.	2.91	1.05

Short Answer Question 3

What are the ways in which STEM programs are implemented?

This question focused on teachers' STEM curriculum design skills and teaching abilities. In these answers, numerous teachers gave examples of outdoor activities they had organized for their students, such as observing the weather, visiting ancient buildings and observing minerals in the field. Project-based learning is also a hugely popular form of STEM education. One teacher expressed the project she had organized, called the 'Smart Waterwheel'. Students went outdoors to observe a waterwheel, learn how it works, then design and build a model of it using Lego. Project-based learning takes many forms and teachers' teaching is mostly based on a theme similar as the thematic activities mentioned by some interviewees. One teacher mentioned that she carried out activities based on the theme of the ocean, introducing students to marine life and its habitats, as well as the current state of the marine environment, thus creating awareness of the need to protect the ocean. Meanwhile, many teachers mentioned reverse dismantling, laser engraving, 3D printing, Lego, scratching and robotics.

STEM pedagogy requires them to make some basic changes in establishing the classroom environment and teaching (Margot et al., 2019), and These changes can be challenging for some teachers. For instance, STEM pedagogy calls for a change from teacher-led to student-led instruction (Park et al., 2017). On the context of curriculum reform, science teachers have encountered tremendous work pressure, and many have redoubled their efforts to keep up with the requirements of the new curriculum standards, but with disappointing results (Zhang, 2019). Teachers can mistakenly or unintentionally misunderstand the expectations of STEM developers (Bagiati & Evangelou, 2015) or fail to implement STEM concepts correctly in the classroom. When teachers tried to integrate different disciplines for authentic STEM teaching, they also mentioned issues with lesson development and a lack of control over instructional sequencing and session pacing (Herro & Quigley, 2017). More importantly, although most teachers were able to complete the teaching tasks scheduled in the materials, there were few resources available (Zhang, 2017), making it almost impossible for teachers to expand and supplement the content. The researcher also found it interesting that respondents scored worse on items involving STEM than on items omitting the term STEM, suggesting that instructors' teaching effectiveness may have decreased because of their teachers' lack of confidence in their abilities to teach STEM (Bagiati &

Evangelou, 2015). Therefore, Margot et al. (2019) propose that enhance the efficacy of STEM education and give instructors learning opportunities to enhance their capacity to successfully incorporate STEM content into the curriculum.

4. Professional development

The final section tested the professional development of science teachers, who have good prospects for STEM development (details seen in Table 5). Although few teachers are currently able to take the initiative to learn about STEM, the majority of teachers expressed a desire to improve their STEM skills. The respondents would not read extra-curricular books on physics, chemistry and geospatial sciences (M=2.60, SD=1.26), but rather books related to the subjects they teach. This suggests that most competent teachers are proactive in learning about science-related topics, but they rarely cover other subjects, which explains the weak STEM subject literacy of teachers, which is align with results of dimension 2. And teachers have shown positive attitudes in projects related to learning STEM education, for example, “You are willing to participate in STEM training (M=4.07, SD=1.01)”. “You will be proactive in learning and updating your pedagogical knowledge because of the need for STEM teaching (M=3.70, SD=0.87)”.

Table 7

Professional development

	Mean	**SD**
You pay strong attention to the latest developments in the theory and practice of STEM teaching, both nationally and internationally.	2.76	1.15
You can reflect on and optimize the implementation of your STEM curriculum.	2.63	1.24
You will be proactive in learning and updating your pedagogical knowledge because of the need for STEM teaching.	3.70	0.87
You regularly read extra-curricular books on physics, chemistry and geo space science.	2.60	1.26
You are willing to participate in STEM training.	4.07	1.01
You can improve your STEM teaching in response to problems in your lessons.	3.82	0.90
You can learn from excellent STEM cases.	4.07	1.00
You regularly discuss with other teachers or experts about STEM education.	2.59	1.27
You are willing to study the laws of STEM pedagogy.	2.87	0.92
You can develop your professional emotions and enhance your professionalism constantly in STEM education through STEM-related knowledge and teaching practice.	3.78	0.87

Short Answer Question 4

For front-line teachers, what suggestions you will give to science teachers candidates who are learning STEM now?

The last question was set up to encourage teachers to give advice to STEM teacher candidates based on their own professional development experiences. The teachers made tons of useful suggestions for the candidates, which were grouped by the researcher into categories. One of aspects is about knowledge. Teacher candidates should broaden their knowledge beyond the subject they teach and learn about other subjects as well, such as physics, biology, geography and astronomy to improve their knowledge base. Another one is about teaching practice. It is important to pay as much attention as possible to every student during the lecture. The class should be student centered and the teacher is only responsible for guiding. Good examples of STEM teaching and learning can be drawn on as appropriate when developing a STEM curriculum, but they should not be copy and teachers should adapt them to suit their students. Some teachers stressed that STEM content should be taught from real-life problems and focus on practicality. Personal skills are also a point of emphasis for many teachers, so teacher candidates should concentrate on improving their own literacy skills, such as hands-on, problem-solving skills, as only a highly educated teacher can be better equipped to provide students assistance. Many teachers gave some suggestions to candidates in terms of personal skills.

An emphasis on improving teachers' content knowledge and STEM experience can be achieved through effective professional development, which can give instructors the time and structure they need to investigate methods to incorporate STEM into their curriculum. Also, methods such as 'working with peers' and 'reflective practice' have been promoted in recent years. Few teachers are capable of active reflection, according to research; yet "reflective practice" enables teachers to examine and assess their own practices, fostering a greater understanding of effective teaching (Yee et al., 2022). The lack of quality assessment tools is also a major impediment to teachers' professional development, as Nadelson and Seifert (2013) state that teachers and many others believe that ineffective classrooms result from a lack of standardized assessments that can be used in STEM courses. Following the Chinese curriculum reform, schools are asking science teachers to shift their focus to STEM courses, thus increasing the amount of work that teachers must do in order to plan with other content areas and get ahead on materials for students. Lack of time is one of the obstacles teachers face while implementing STEM lessons (Bagiati & Evangelou 2015). In addition to this, Herro and Quigley (2017) stated that a collaborative culture would increase the feasibility of STEM projects, however, the findings show that teachers hardly interact with STEM teachers or specialists. Collaboration with other STEM teachers and specialists is very important in STEM teaching, not only for the exchange of experiences and to enhance STEM curriculum preparation, but also to establish a teamwork culture for students, therefore an integrated team approach is required for STEM design and execution (Asghar et al., 2012).

However, it is exciting to note that teachers have shown a good willingness to improve their STEM literacy, which is crucial for future STEM teacher development, and therefore STEM teacher professional development deserves more attention to improve teachers' STEM literacy levels.

CONCLUSION

Teacher literacy is a crucial factor in promoting the development of students' literacy and skills. Teachers with excellent STEM literacy will encourage students to learn more independently and actively, helping them to acquire the knowledge, skills, and attitudes they need (Le et al., 2021). This study was dedicated to investigating the level of STEM literacy among elementary school science teachers in China. The findings show that teachers' understanding of STEM concepts is incomplete and their STEM knowledge and teaching skills need to be improved, but most teachers have a positive attitude towards improving their STEM literacy, so the prospects for professional development in STEM education in China are good in the long term.

Although only 130 teachers were surveyed in this study, the results obtained could serve as a reference for future research. In future research, researchers can propose STEM training strategies suitable for Chinese teachers in response to the current status of science teachers' STEM literacy and explore in depth the factors affecting teachers' STEM literacy from different dimensions. In order to better absorb the advanced STEM education concepts of different countries, a comparative study of STEM teachers in different countries and regions can be conducted. This study has repeatedly highlighted the important role of STEM education in contemporary development, and if STEM education can be implemented nationwide, it will create a generation of well-qualified citizens and contribute to national development. Therefore, governments and educational institutions should recognize the important impact of STEM education, provide funding and policy support for teachers to improve their literacy, promote professional learning communities among teachers, and offer activities to promote and optimize STEM teacher competencies. Finally, there is a hope that STEM education will receive more attention by stakeholders so that both teachers and students can benefit from it.

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