

Research on STEM Teacher Education Strategies for Primary School in China

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Abstract

Over time, the requirements for scientific and technological talent have gradually increased. As a result, STEM education has attracted widespread attention from governments and educators worldwide. Research on STEM education showed that STEM teacher education is one of the critical factors in its development. This paper first analyses the current situation of STEM teacher education in China and other countries through CiteSpace software and finds that there is currently a lack of systematic research on STEM teacher education in China. Then, considering that STEM teacher education majors have not yet been established for primary school teachers in China's colleges and universities, this paper clarifies the goals of primary school STEM teacher education from three dimensions through the analysis of relevant national policies. Finally, combined with the current curriculum plan for cultivating primary school teachers in China and referring to the STEM teacher education curriculum of the University of Texas at Austin, this paper establishes a core curriculum system for primary school STEM teacher education. Based on these works, we also propose primary school STEM teacher education strategies in three stages: preservice education, induction education, and in-service education.

Keywords: STEM, Teacher Education, Primary School, strategies

Abstrak

Dengan berlalunya waktu, keperluan untuk bakat sains dan teknologi telah meningkat secara beransur-ansur. Akibatnya, pendidikan STEM telah menarik perhatian luas dari pemerintah dan pendidik di seluruh dunia. Penelitian tentang pendidikan STEM menunjukkan bahwa pendidikan guru STEM adalah salah satu faktor kritis dalam perkembangannya. Makalah ini pertama kali menganalisis situasi saat ini dari pendidikan guru STEM di Cina dan negara-negara lain melalui perangkat lunak CiteSpace dan menemukan bahwa saat ini masih kurangnya penelitian sistematis tentang pendidikan guru STEM di Cina. Kemudian, mengingat bahwa jurusan pendidikan guru STEM belum dibuat untuk guru sekolah dasar di perguruan tinggi dan universitas di Cina, makalah ini mengklarifikasi tujuan pendidikan guru STEM sekolah dasar dari tiga dimensi melalui analisis kebijakan nasional yang relevan. Akhirnya, dengan menggabungkan rencana kurikulum saat ini untuk menumbuhkan guru sekolah dasar di Cina dan merujuk pada kurikulum pendidikan guru STEM University of Texas di Austin, makalah ini membentuk sistem kurikulum inti untuk pendidikan guru STEM sekolah dasar. Berdasarkan karya-karya ini, kami juga mengusulkan strategi pendidikan guru STEM sekolah dasar dalam tiga tahap: pendidikan pra-layanan, pendidikan induksi, dan pendidikan dalam layanan..

Kata kunci: STEM, Pendidikan Guru, Sekolah Dasar, strategi

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1.0 INTRODUCTION

STEM originated in the United States in 1993 (Donahoe, 2013). After decades of development, STEM has been endowed with richer connotations. Countries are actively responding to economic challenges, while the demand for STEM skills is becoming increasingly urgent (Marginson et al., 2013). In addition, Industry 4.0 has become synonymous with the 21st century since it was proposed in Germany in 2013 (Lu, 2017). Its core concept is to improve the efficiency of human production and life through digitalization (Kurup et al., 2019) so that technology gradually penetrates every aspect of life (Mikulecky & Kirkley, 1998). Practitioners in technology-related occupations often require a certain level of scientific, engineering, and mathematical knowledge to have a practical understanding of how a particular device or system operates (Council, 2009). STEM education can shape students' abilities to face Industry 4.0, providing them skills such as critical thinking and engineering thinking (Hafni et al., 2020).

Since the 1990s, countries worldwide have successfully launched curriculum reforms based on the concept of STEM education. STEM education attempts to address the drawbacks of traditional subdiscipline teaching and emphasize the advantages of comprehensive and interdisciplinary teaching (Council, 2011). Looking at the whole process of teaching, STEM education can better cultivate students' ability to solve practical problems (Tan et al., 2023). Based on this goal, countries have explored STEM education models suitable for their

national conditions (Kennedy & Odell, 2014; Marginson et al., 2013). For example, in 2016, the U.S. Department of Education released “STEM 2026: A vision for innovation in STEM Education”, and in 2018, the White House and the Committee on STEM Education (CUSTOM) jointly released “Charting a Course for Success: America’s Strategy for STEM Education”; Canada’s “Let’s Talk Science” released the “Canada 2067 plan” in 2017, which formulated Canada’s STEM education action plan for the next 50 years (Johnson et al., 2020). The Australian Education Commission approved the “National STEM School Education Strategy 2016–2026” in 2015 (Timms et al., 2018). Building on this, states and territories have released their own STEM education strategies aimed at improving students’ STEM competencies. The Chinese government has recently issued related policies to promote the development of STEM education in the country, such as the “China STEM Education 2029 Innovation Action Plan” (China STEM Education Research Center, 2019), “China STEM Teacher Competency Level Standards (Trial)” (China STEM Education Research Center, 2018) and other essential documents. Governments of various countries have also provided policy guarantees for the development of STEM education. As an effective way to improve students’ skills in the 21st century, STEM education has received extensive attention and research in various countries’ educational and academic circles. However, the development of STEM education also faces several challenges.

2.0 LITERATURE REVIEW

To understand the current status of STEM education development, we performed a search for related articles in the Web of Science core library with the theme of “STEM education” or “STEAM education.” The number of articles published in public journals and the number of citations since 2011 is shown in Figure 1. Since 2011, the number of related studies on “STEM/STEAM education” has shown an increasing trend. Under the guidance of various government documents, the attention of the academic community to STEM education has also been increasing year by year in recent years, and the development of STEM education in various countries is in full swing.

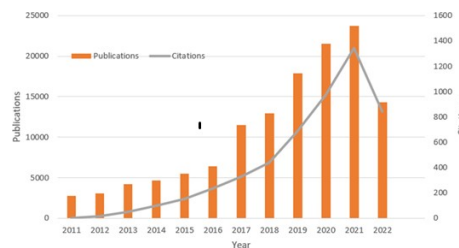


Figure 1. Number of papers published and citation rate of STEM-related papers (only before July 15 is retrieved in 2022; the number does not represent the whole year. Therefore, there is a trend of decreasing numbers in the figure in 2022)

However, while STEM education is developing rapidly, it also faces challenges. One of the challenges is that the academic community has not formed a unified understanding of the definition of the STEM education concept (Marginson et al., 2013). The main disagreement is whether STEM education emphasizes the critical factor of integration, that is, whether STEM education is taught as a single subject, including the four disciplines of S, T, E, and M, or whether it emphasizes comprehensiveness and treats STEM as comprehensive subject teaching. Sanders, M. (2009) described comprehensive STEM education as “exploring teaching and learning methods between two or more subject areas in S, T, E, M subjects, or between STEM subjects and other subjects” (Sanders, 2009). Moore et al. (2014) define comprehensive STEM education as “an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into a curriculum or in the unit.” (Moore et al., 2014). Kelley et al. (2016) define STEM integrative education as an approach to teaching two or more STEM content areas, constrained by STEM practices in a natural context, to connect these disciplines to improve student learning (Kelley & Knowles, 2016). In the “Science Curriculum Standards for Primary Schools” issued by the Ministry of Education of China in 2017, it was mentioned in the teaching implementation proposal that “Science, technology, engineering and mathematics, namely, STEM, is a project-based, problem-solving-oriented curriculum organization method, which organically integrates science, technology, engineering, and mathematics, and is conducive to the cultivation of students’ creative ability.” (Ministry of Education of China, 2020). It can be seen from this description that the Chinese government’s understanding of STEM is also interdisciplinary, emphasizing the organic integration of S, T, E, and M.

In addition, scholars from various countries have also mentioned other challenges faced by developing STEM education. Brown (2012) found that research on STEM education focused on K-12 students’ STEM learning while paying relatively little attention to teachers (Brown, 2012). Li et al. (2019) wrote, “China’s STEM education faces six significant problems and challenges, one of which is the lack of demonstration and guidance of national-level projects, including curriculum development, teacher training, and evaluation standards” (Li et al., 2019). Moreover, due to the ambiguity in the definition of STEM education, there are differences in the descriptions of STEM teachers. Teachers who have received traditional single-subject education still face specific problems in implementing STEM interdisciplinary teaching (Ayres, 2016; Holmlund et al., 2018; Marginson et al., 2013). It can be seen that STEM teacher education has become one of the main problems hindering the development of STEM education. In order to alleviate this serious challenge for STEM teachers, this article formulates the following research goals.

- 1) Determine the objectives of primary school STEM teacher education.
- 2) Develop a curriculum system for primary school STEM teacher education in China to achieve these objectives.
- 3) Propose specific strategies for implementing the curriculum system within the current teacher education model.

3.0 METHODOLOGY

This study first systematically reviews the development of STEM teacher education based on the application of CiteSpace software and in-depth system analysis. Secondly, based on the analysis of typical cases of STEM teacher education, combined with the current Chinese primary school teacher training model and curriculum system, a primary school STEM teacher education curriculum system was formulated, and specific strategies for implementing the curriculum system under the current teacher education model were proposed.

Current status of STEM teacher education

To understand the current status of international STEM/STEAM teacher education research, we search the Web of Science Core Collection with the subject headings “STEM Teacher Education” or “STEAM Teacher Education” or “STEM Teacher Training” or “STEAM Teacher Training,” with a retrieval time from 2010 to 2022, and with a document type of article. A total of 1999 pieces of data are retrieved. Invalid data are eliminated, and CiteSpace is used for data processing. After deduplication, there are 1876 pieces of data remaining. The results of keyword clustering analysis based on these data show modularity $Q=0.4653$ and mean silhouette $=0.7264$, which indicates that the significance of the clustering structure and clustering quality is credible (C. Chen, 2016). The top ten tags of keyword clustering analysis are STEM learning, physical education, higher education, science education, preservice teacher, educational robotics, teacher education, blended learning, STEM education, and elementary school. As shown in Figure 2, the smaller the label number, the more keywords it contains. The label “preservice teachers” ranks fifth in the keyword clustering, which shows that international research on STEM teacher education has begun to focus on the systematic training of teacher education.

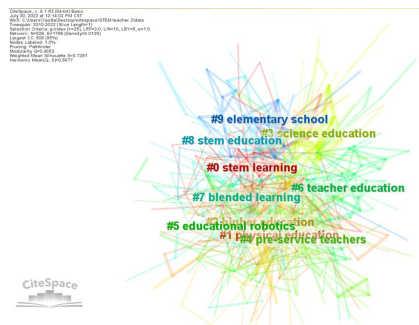


Figure 2. Clustering map of STEM/STEAM teacher education keyword

To further understand the changing trend of international STEM teacher education research over time, a Timeline View of keyword co-occurrence analysis was drawn, as shown in Figure 3. The keyword “teacher education” appeared in the research hotspots in 2010. Since the data of this study started in 2010, we hypothesize that STEM teacher education was included in international research before 2010. The emergence of “preservice teachers” in 2016 also shows that the international research field of STEM teacher education is further deepened and more specific. When using the same subject words “STEM Teacher Education” or “STEAM Teacher Education” or “STEM Teacher Training” or “STEAM Teacher Training,” we selected the same time interval to search the Chinese National Knowledge Infrastructure Database (CNKI) (<https://www.cnki.net/>), which includes Peking University Core, the Chinese Social Sciences Citation Index (CSSCI) and Chinese Science Citation Database (CSCD). Only 76 related studies were retrieved, and the clustering effect of CiteSpace keywords was not good, which shows that Chinese scholars’ research on STEM/STEAM teacher education has not yet formed the core content, nor has it made a sound contribution to the international academic community. Therefore, the Chinese academic community should pay attention to STEM teacher education.

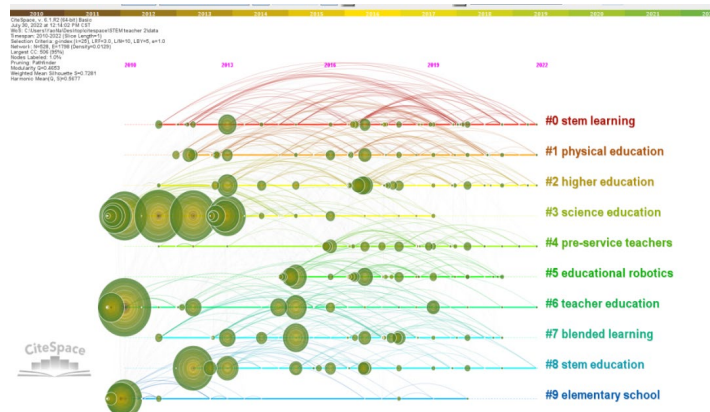


Figure 3. Timeline view of keyword co-occurrence of STEM/STEAM teacher education

To further understand the concern of Chinese scholars for STEM teachers in STEM education research, we search the Chinese CNKI database with the subject heading “STEM education” or “STEAM education.” The data source categories include Peking University Core, CSSCI, and CSCD, and the time is set from 2010 to 2022; a total of 766 pieces of data were retrieved, excluding 111 invalid data, such as meeting notices, micronews, calls for papers, advertisements, etc. CiteSpace is used to analyse the remaining 655 pieces of data visually, set the node type as “Keyword,” and draw a clustering map of STEM/STEAM education keywords. The result is shown in Figure 4.

In Figure 4, Modularity $Q = 0.764$, indicating that the clustering structure is significant, and Mean silhouette = 0.9341, indicating that the clustering quality is high (K. Chen et al., 2020). In the figure, the more frequently the keywords appear, the larger the node circle, and the smaller the cluster rank number, the more keywords are included in the cluster. The top 10 labels are artificial intelligence, the United States, Maker, Interdisciplinary, Science Education, Instructional Design, Engineering Design, Maker Space, Primary and Secondary Schools, and Teaching Models. There is no clear label related to “STEM/STEAM teacher education” in the hot keywords. Nevertheless, two hot keywords “teaching design” and “teaching model” indicate that Chinese scholars have paid attention to STEM education in their research. The appearance of the label “primary and secondary school” reflects that Chinese scholars are paying more attention to STEM education in primary and secondary schools, which show that relevant scholars agree that carrying out STEM education in primary and secondary schools is of great significance to children’s growth. The lack of STEM teacher education is at odds with the widespread focus on STEM in primary and secondary schools. In the research of STEM-related scholars (Cheng et al., 2022; Zhong et al., 2022), it has repeatedly appeared that “one of the factors hindering the development of STEM education in China is the lack of STEM teachers.”

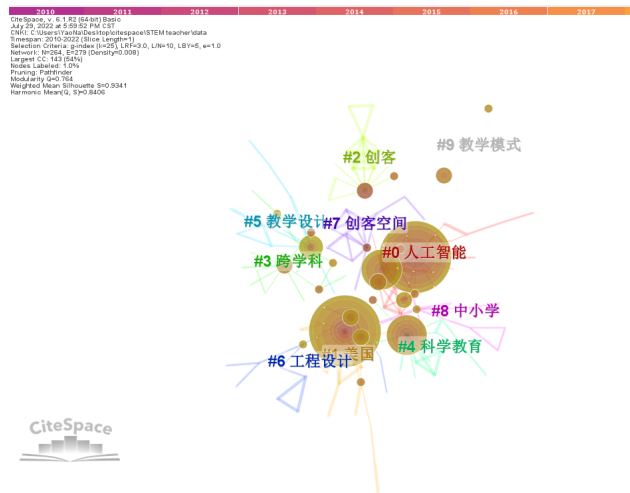


Figure 4. Clustering map of STEM/STEAM education keyword of Chinese papers.

In addition, Chen et al. (2019) used the Natural Language Processing and Information Retrieval (NLPIR) tool to conduct text mining on the “China STEM Education White Paper” jointly drafted by the Chinese Academy of Education Sciences and the STEM Research Center, and they compare the top 20 keywords of STEM education policy content texts in different countries, including the keyword “teacher”. It is mentioned in the content of STEM education policies in the United States, the United Kingdom, Finland, and China. The keyword “teacher” ranks 9th, 4th, 4th, and 14th in descending order of weight. Attention to STEM teachers in the context of China’s STEM education policy needs to be improved (CHEN et al., 2019). Dong et al. (2020) mentioned that China lacks a systematic new STEM teacher certification and admission system, and the training system has not yet been established (Dong et al., 2020).

In summary, one of the predicaments of carrying out STEM education in the primary education stage is the lack of STEM teachers. However, STEM teacher education has not attracted widespread attention from Chinese academic circles.

• STEM Teacher Education Courses

At the practical level, the teachers in China’s primary education are mainly college students with bachelor’s degrees. There are few majors and courses for training STEM teachers in China’s undergraduate-level education, which leads directly to the low quality of STEM education in the primary education stage and to the status quo where there are no professional teachers of STEM courses. Due to the lack of teachers in the STEM teaching reform in the primary education stage, an embarrassing situation in which the essential education reform forces the development of teacher education has gradually formed. Although in 2018, the STEM Education Research Center of the Chinese Academy of Education Sciences released the “STEM Teacher Competency Level Standards (Trial)” (hereafter referred to as “STEM Teacher Standards”), it did not mention how to train STEM teachers who can meet this standard under the background that there are no STEM education majors in Chinese universities at present, and there is no division of primary and secondary school learning stages for STEM teachers. Therefore, under the guidance of the national “STEM Teacher Standards,” how to train the STEM teachers needed by society has become a critical issue that urgently needs to be solved in the development of STEM education in China. In addition, China has not yet formed a curriculum system for STEM teacher training.

Starting from the ability requirements of STEM teachers in China’s “STEM Teacher Standards” and referring to Bloom’s classification of educational goals, this paper clarifies three-dimensional goals of STEM teacher education and sets up corresponding courses for the achievement of each dimension goal. Based on the curriculum system in Chinese existing primary education professional training programme and the curriculum plan of the excellent UTeach STEM teacher education programme in the United States, we explore the core curriculum categories of Chinese primary school STEM teacher education. The research ideas are described in Figure 5.

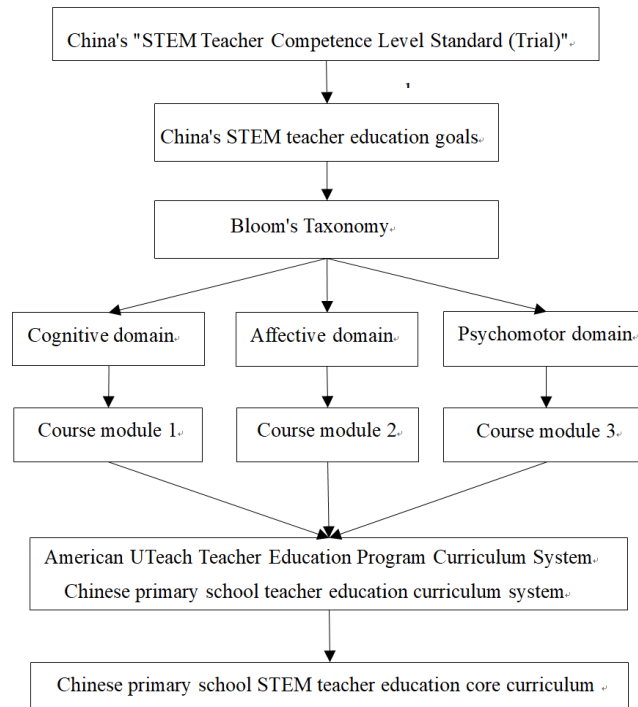


Figure 5. The framework of research ideas

4.0 RESULTS

Chinese STEM Teacher Education Goals

In 1956, American educational psychologist Bloom proposed the classification of educational objectives, which divides educational goals into three objective domains: the cognitive domain, affective domain, and psychomotor domain (Begam & Tholappan, 2018), which is still used as a basis for educators of all levels to formulate educational goals.

This study establishes the training objectives of Chinese STEM teachers according to the “STEM Teacher Standards”. “STEM Teacher Standards” divides Chinese STEM teachers’ ability indicators into five dimensions: the understanding of STEM education value, basic knowledge in the STEM subject, STEM interdisciplinary understanding and practice, STEM curriculum development and integration, and STEM teaching implementation and evaluation. According to Bloom’s classification of educational goals, the five dimensions of STEM Teacher Standards are classified into three-dimensional educational purposes, as shown in Table 1. However, these “STEM Teacher Standards” did not differentiate by grade and failed to clarify the corresponding STEM teachers. Therefore, we believe this standard generally applies to current STEM teachers in China. As we known, the focus of teacher skills is different for each grade. The training of primary school STEM teachers is the responsibility of the primary school teacher education system. Primary school STEM teachers should have the essential qualities of primary school teachers. According to above analysis, the study establishes a curriculum system for primary school STEM teacher education based on the curriculum system of China’s existing primary teacher education programs.

Table 1. The three-dimensional educational goals corresponding to STEM Teachers Ability Level Standard (Trial) of China

Three dimensional objectives		STEM Teacher ability Classification
Cognitive domain	STEM subject foundation	Scientific literacy (SL)
		Mathematical literacy (ML)
Affective domain	Understanding the value of STEM education	Technical literacy (TL)
		STEM+
Psychomotor domain	STEM Interdisciplinary Understanding and Practice	STEM teachers understanding
		STEM Teaching Understanding
	STEM curriculum development and integration	Understanding of STEM Training Objects
		STEM Interdisciplinary Understanding and Practice
	STEM teaching implementation and evaluation	STEM curriculum development and integration
		STEM curriculum development and integration
		Creating a STEM education context
		Implementing STEM teaching
		Evaluation and Feedback
		Reflecting and improving

• Analysis Of Curriculum System Of Primary Education Major In China

At present, the source of primary school teachers in China is mainly graduates with a bachelor's degree from colleges and universities. In 2012, the Ministry of Education of China issued the "Professional Standards for Primary School Teachers (Trial)". Colleges and universities have also formulated their training programs for primary education majors based on the aforementioned Standards. This study uses the primary education major of Ankang College in Shaanxi Province as the main reference template. The primary education major of Ankang College was selected as a national first-class undergraduate prior construction site of the Ministry of Education of China in 2021 (Jiao Gao Office Letter [2022] No. 14). The College has also recently explored training primary school STEM teachers, so its talent training system has specific reference value.

The primary education major of Ankang College is at the undergraduate level. Its curriculum system mainly includes introductory public courses, professional compulsory courses, teacher education courses, and practical courses. The main courses offered by each grade are shown in Table 2. Since the curriculum system involves many courses, only the relevant core courses are listed in Table 2.

Table 2. Core curriculum system of primary education major in China

Grade	Course type	Core courses offered
Freshman	Basic public courses	College English, College Sports, College Information Technology Foundation, Innovative Thinking, etc.
Sophomore and Junior	Professional required courses Teacher education courses	Elementary Education, Advanced Mathematics, Elementary Psychology, Art Foundation, Music Foundation, Humanities, and Social Sciences Foundation, Natural Science Foundation, Elementary Science Curriculum and Teaching, Elementary Mathematics Curriculum and Teaching, Modern Educational Technology, Principles of Pedagogy, Principles of Psychology, History of Chinese and foreign education, comprehensive practice activities in primary schools, design of STEM practical activities in primary schools, etc.
Senior	Practical courses	Elementary education trainee, educational practice, normal student ability test, labour education practice, teacher education comprehensive skills training, etc.

The existing primary education curriculum system already contains some STEM-related content, such as primary school science curriculum and teaching, primary school mathematics curriculum and education, modern educational technology, and other courses, all of which reflect the relevant skill requirements in the educational goals of STEM teachers, including requirements for scientific literacy, mathematical literacy, technical literacy, etc. Based on these analyses, we established the correspondence between the core courses of primary education in Table 2 and the three-dimensional goals of STEM teacher education listed in Table 1. The results are shown in Table 3.

Table 3. Correspondence between the core curriculum of primary education major and the threedimensional

Educational goals		Corresponding courses
Cognitive domain	STEM subject foundation	(SL) Elementary Science Curriculum and Instruction, Humanities and Social Sciences, Natural Sciences
		(ML) Basic Mathematics, Advanced Mathematics, Primary Mathematics Curriculum and Teaching
		(EL) none
		(TL) Fundamentals of modern educational technology, university information technology
Affective domain	Understanding of STEM teachers	(STEM+) Art foundation, music foundation, elementary school comprehensive, practice activities
		none
		Elementary Education
		Elementary School Psychology
Psychomotor domain	STEM Interdisciplinary Understanding and Practice	Elementary school STEM practice activity design
		STEM curriculum development and integration
		none
		STEM teaching implementation and evaluation

As seen from Table 3, except for engineering literacy (E.L.), all subject bases involved in the cognitive domain of primary school STEM teachers' educational goals are involved in the existing primary education professional curriculum system. This is consistent with the research results of the general lack of engineering literacy among current STEM teachers in China (Guzey et al., 2014), which also provides a basis for expanding STEM-related courses based on existing primary education majors. In the affective domain, the existing primary education majors have relatively few courses on the educational goals of STEM teachers. This is also consistent with the lack of overall and comprehensive understanding of STEM education by existing STEM teachers. In the psychomotor domain, "Primary School STEM Practice Activity Design" is a newly established course exploring STEM teacher training at the primary education stage, effectively improving STEM teachers' interdisciplinary understanding and practical STEM skills. However, STEM curriculum development and integration, teaching implementation and evaluation skills still do not have special courses.

To improve the STEM teacher education curriculum system in Chinese primary schools, based on Table 3, we analyse and draw lessons from some of the curriculum content of the UTeach STEM teacher education programme in the United States.

• Analysis of the Curriculum Scheme Of The Uteach Project

In 1997, the University of Texas at Austin started a STEM teacher training programme called the UTeach programme. Implementing the UTeach programme has led to a dramatic increase in the number of professionals earning teaching credentials in STEM subjects. Cade et al. mentioned that "it is estimated that by 2023, 46 UTeach programs across the country will graduate more than 8,000 teachers" (Cade et al., 2019). In this study, the UTeach project curriculum plan is analysed to provide a reference for China to establish a curriculum system for primary STEM teacher education. The researchers obtained the UTeach Course Sequence from the official website of the University of Texas at Austin (<https://uteach.utexas.edu/courses>), as shown in Figure 6.

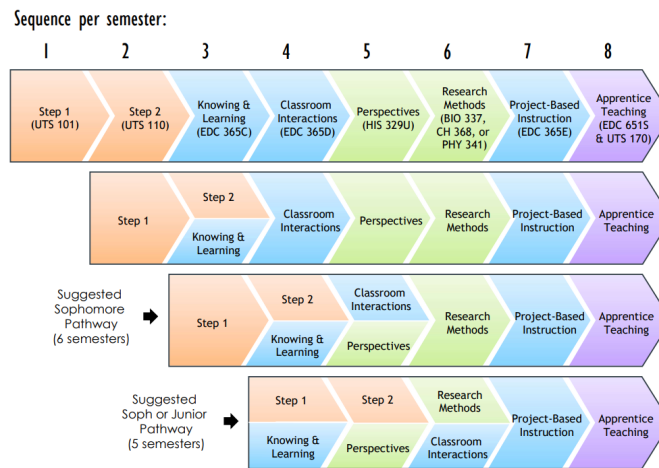


Figure 6. Overview of UTeach Course of Study

• Develop a Curriculum System For Primary School STEM Teacher Education In China

According to Figure 6, the course arrangement sequence is in an inverted trapezoid shape, is appropriate for students of different semesters, stages, or types to enter the programme. The 8-semester curriculum effectively achieves the goal of STEM teacher education, which is also one of the reasons why the UTeach programme is generally recognized. Among them, step 1 and step 2 include introductory courses to guide students to understand STEM education, let students understand the inquiry-based curriculum design of STEM teaching, and stimulate students' interest in learning STEM. It should be noted that although the course programme is distributed over eight semesters, students do not need to complete these courses over the entire eight semesters. This project aims to help people interested in STEM complete the UTeach project course and then obtain teacher qualification certification in the STEM field, which also provides a reference for solving the current shortage of STEM teachers in China. The STEM teacher education courses of the UTeach project are summarized and sorted in Table 4.

Table 4. UTeach Program STEM Teacher Education Programs at The University of Texas at Austin

Grade	Core courses/content offered	
Freshman	UTS101	Inquiry-based lessons, Inquiry-based STEM curriculum design
Freshman	UTS110	Inquiry-based curriculum implementation, 5E curriculum planning, emphasizing how to develop and manage preassessment and postassessment tools
Sophomore	EDC365C	Knowing & Learning in Mathematics and Science
	EDC365D	Classroom Interaction (Understand how the theories explored in knowledge and learning work in the classroom, with an emphasis on designing and implementing instructional activities)

Junior	HIS329U/PHL 329U	Perspectives on Science and Mathematics (The history or philosophy department introduces students to the historical, social, and philosophical implications of the STEM field through an investigation of five important events in the history of science)
	BIO 337-1/CH 368-1/PHY 341-7	Research Methods (Conduct four independent investigations and learn to combine skills from STEM fields to solve research questions)
Senior	EDC 365E	Project-Based Instruction (Master new techniques for conducting question-based investigations in a live STEM classroom with a 3-day inquiry session)
	EDC 651S	Final field experience and seminar

After matching the relevant courses in the UTeach project to the training goals of STEM teachers in Chinese primary schools, we found that some courses can supply the courses that are lacking for training STEM teachers based on the original Chinese primary education major, which are shown in bold italics in Table 5. At the same time, there are also some courses in the UTeach project is similar to courses offered by the original Chinese primary education major, such as EDC365C (Knowing Learning in Mathematics and Science) has some duplicate content with the primary science curriculum and teaching, humanities and social sciences, basics of nature science, basic mathematics, advanced mathematics, and elementary school mathematics curriculum, which are no longer reflected in Table 5.

Table 5. Core curriculum system for STEM teacher education in primary schools in China

Educational goals		Courses to achieve goals
Cognitive domain	STEM subject foundation	(SL) Elementary School Science Curriculum and Teaching, Humanities and Social Sciences Foundation, Natural Science Foundation (ML) Basic Mathematics, Advanced Mathematics, Primary Mathematics Curriculum and Teaching (EL) <i>EDC 365E</i> (TL) Fundamentals of modern educational technology, university information technology (STEM+) Art foundation, music foundation, elementary school comprehensive, practice activities
	Understanding of STEM teachers	<i>HIS329U or PHL 329U</i>
Affective domain	Understanding of STEM Teaching	Elementary Education
	Understanding of STEM Training Objects	Elementary School Psychology
	STEM Interdisciplinary Understanding and Practice	Elementary school STEM practice activity design
	STEM curriculum development and integration	<i>UTS110, BIO 337-1 or CH 368-1 or PHY 341-7</i>
Psychomotor domain	STEM teaching implementation and evaluation	

In addition, the engineering literacy (EL) matching course in Table 5 is project-based instruction. Although there is no obvious engineering practice course in the entire UTeach project curriculum system, the ideas of engineering and project-based instruction is the same as engineering practice. Mills et al. (2003) mentioned that “projects need to raise students’ awareness of the social, environmental, economic and legal issues that are part of modern engineering practice and that implementing project-based learning is a logical extension of engineering design education”(Mills & Treagust, 2003). Therefore, we match project-based instruction courses to engineering literacy metrics. In summary, the contents of Table 3 and Table 4 are integrated, and the core curriculum system for STEM teacher training in Chinese primary schools is shown in Table 5.

It can be seen that, as a student majoring in primary education, only after minor study and completion of the following five courses included in the major of primary STEM education one can apply to be certified as a primary school STEM teacher. The five courses include Project-Based Instruction, Perspectives on Science and Mathematics, planning and teaching three inquiry-based lessons, writing high-quality 5E lesson plans, and Research Methods.

■5.0 DISCUSSION AND RECOMMENDATION

To date, no majors specialize in cultivating primary school STEM teachers at the undergraduate level of Chinese universities. Moreover, under the guidance of national policies and scholars, there has been a robust establishment of primary school STEM education, forcing STEM teacher education reform. However, establishing new majors requires comprehensive demonstration in teacher education and takes

a long time. To effectively train primary school STEM teachers at the current stage, we have established a minor course module based on existing primary education majors for STEM teachers. Using different strategies in the three stages of preservice education, teacher induction, and in-service education to “supplement” these minor courses for STEM teachers can effectively improve the professional quality of primary school STEM teachers.

Preservice education is the main stage of teacher education, so it is also an essential link to ensuring the quality of primary school STEM teachers. In this study, we design a framework in which students majoring in primary education can obtain two certifications. They can obtain primary school teacher qualification certification after completing primary education courses. Based on this certification, they can obtain primary school STEM teacher certification again after completing the core courses of STEM teacher education as a minor course of study. To prevent students from blindly applying for a minor course of study and causing excessive academic burdens, the minor course of study adopts two different schemes.

The first scheme is as follows. The minor courses are carried out in parallel with the original studies of the primary education major, and the STEM teacher education minor core courses are completed in the 2nd-4th grade of the university. Chinese colleges and universities have about 30 days of winter and summer vacation each academic year, called the third semester. Students who are interested in minoring in STEM teacher education courses can apply to the school for a minor at the end of the first year of college. After the school's unified assessment, selected students can take a few STEM teacher education courses in the third semester of each academic year. If they pass the strict assessment in the fourth grade, they can obtain the qualification of primary school STEM teachers. It should be clear that they must be selected to enter the STEM teacher minor course because they will receive dual teacher qualification certification in four years of college. Students' academic burdens will be relatively heavy in order to get dual certification. Therefore, only students with spare capacity are selected to participate in this program.

Of course, to ensure that all primary education students have the opportunity to qualify as STEM teachers, in addition to adopting this minor course in parallel with the original curriculum of the primary education major, a second scheme can be adopted. After students majoring in primary education have obtained a professional degree in primary education and obtained the qualification of primary school teachers, we can provide concentrated STEM teacher education learning opportunities for students who are willing to participate in STEM teacher education. Students can complete the STEM teacher education courses in one year, and then can be recognized as primary school STEM teachers after passing the assessment. Compared with the first one, this scheme relieves the pressure brought by major courses and minor course, but in terms of time, needs an increase of one year from the former.

STEM teacher qualification is the second qualification alongside the major of primary education. The traditional Chinese concept “Skill is no burden” can improve students' enthusiasm for learning STEM teacher education courses. The school provides two ways to help students complete the core courses in STEM teacher education. Students can choose any plan according to their own learning situation and their plans for their future learning and employment, which fully guarantees that STEM teacher education programme can be accepted by more people.

Teacher induction education is regarded as the second stage of teacher professional development. At this stage, the improvement of teachers' ability is reflected in the extension from subject content in preservice education to the application of pedagogy in actual teaching situations. Wojnowski et al. mentioned that “effective induction training programs can successfully alleviate the stress faced by beginning teachers” (Wojnowski, 2003). The importance of teacher induction education has received widespread attention, but the requirements for teacher induction education vary significantly from country to country (Tekir, 2022). For example, the United States requires teachers to participate in induction training programs. Most states require new teachers to participate in induction training for one year (Goldrick et al., 2012). The English government stipulates that new teachers who have obtained “qualified teacher status” on or after May 7, 1999, must complete a three-semester induction education programme and pass the assessment before they can genuinely obtain teaching qualifications (Yan & Lin, 2016).

In 2011, the Ministry of Education of China promulgated the “Opinions on Vigorously Strengthening the Training of Primary and Secondary School Teachers”, which emphasized prejob training for new teachers: “Prejob adaptive training is conducted for all new teachers to help them as soon as possible to adapt to education and teaching work, stipulating that the training time is not less than 120 hours.” The promulgation of this document shows that China imposes great importance on the induction training of new teachers. Since STEM education is different from single-subject teaching and emphasizes interdisciplinarity, induction education for STEM teachers must be combined with the characteristics of STEM education and induction training that is different from single-subject teaching. Research shows that project-based learning (PBL) is an effective way to deliver STEM education by providing participants with the contextualized, authentic experiences necessary for students to scaffold learning and build meaningfully powerful science, technology, engineering, and mathematics concepts (Capraro et al., 2013). This kind of authentic experience can enable new teachers to comprehend interdisciplinary teaching design and to prepare for entry and subsequent on-the-job continuing education.

How can the project-based learning method play an advantage in the induction training of new teachers? First, the problem of project design must be solved. Due to the small number of STEM teachers and the uneven regional distribution in China, educational authorities can first build bridges and establish workshops for STEM teachers led by famous teachers in schools or districts. Studies have shown that participating in induction training programs, such as cooperation with mentors in the same field and collaboration with teachers in the same discipline, can improve the willingness of new teachers to stay in teaching positions in the domain (Arends & Rigazio-DiGilio, 2000). According to the local teaching practice, the workshop can develop a library of primary school STEM education projects. The induction education of new STEM teachers is mainly based on participating in the STEM teacher workshop.

In-service education is the last stage of educational professional development and is also a link that accompanies teachers' life-long development. Therefore, a long-term mechanism should be formed at this stage to provide teachers with stable resources. For the in-service education of STEM teachers, one of the methods is to continue the workshop participation plan of teacher induction education to form a stable “mentor system,” and the mentor can provide long-term guidance for STEM teachers in on-the-job education. The other method is to set up a virtual teaching and research room for STEM teachers at the primary education stage led by STEM teachers in colleges and universities. In July 2021, the Higher Education Department of the Chinese Ministry of Education issued a notice on the pilot construction of virtual teaching and research rooms. It is mentioned that the “virtual teaching and research room is an important exploration in the construction of new grass-roots teaching organizations in the information age.” Although this initiative is currently only for higher

education, primary education can also learn from its ideas and experience, relying on colleges and universities with expertise and excellent teachers to establish a virtual teaching and research room for primary education STEM teachers.

6.0 CONCLUSION

This research is based on the current situation in which Chinese colleges and universities have not established an independent primary school STEM teacher education major. Based on the professional quality that STEM teachers should have mentioned in the “STEM Teacher Ability Level Standard (Trial),” relying on the professional curriculum system of the existing Primary school education in Chinese colleges and drawing on the excellent international STEM teacher education projects, we design the core curriculum of primary school STEM teacher education and propose specific strategies to improve the literacy of primary school STEM teachers from the three stages of preservice education, teacher induction and in-service education. With the continuous development of educational science, STEM teacher education strategies will also continue to be iterated and updated. China will also form a systematic and complete STEM teacher education system.

Except for primary education majors, at present, there is no way for students of other majors to obtain STEM teacher qualification. We will continue to explore and improve the curriculum system, expand the professional coverage of STEM teacher education, and provide students of different majors with opportunities to participate in STEM teacher education courses.

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