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Literature Review on the Transformation Trend of Preservice Teachers' Competence in Smart Education

Journal of Electrical Systems

Abstract: Education is rapidly entering the era of smart education 4.0 supported by artificial intelligence. Teachers face challenges such as higher traditional knowledge literacy, skill literacy, and professional literacy. At present, whether it is the teacher admission standards in various countries or the academic research on the competence of pre-service teachers is relatively limited, most of the research on the competence of pre-service teachers relies on qualitative research such as literature reviews and hypotheses. Empirical research on its impact is scarce. We should pay attention to the logical starting point and realistic path of pre-service teachers' ability and quality under the background of smart education, and deeply analyze and discuss factors that affect pre-service teachers' ability, such as teachers' professional motivation, action investment, and learning outcomes, so as to provide a scientific basis for improving the level of teacher education.

Keywords: smart education, competence of pre-service teacher, Literature review

1. INTRODUCTION

In January 2016, the 46th World Economic Forum was held in Davos, Switzerland, with the theme "Mastering the Fourth Industrial Revolution." The concept of Industry 4.0 originated from the high-tech strategic project initiated by the German government to promote computerization in the manufacturing industry (Liu Huchen et al., 2023). The development of smart education in the era of Industry 4.0 is inseparable from intelligent information technologies, including artificial intelligence, and virtual reality, as well as information technologies such as big data and blockchain. These technologies collectively constitute the key driving force behind the advancement of smart education in the era of Industry 4.0. The traditional model of teacher education needs to undergo transformation to adapt to the needs of smart education in the era of Industry 4.0. From Industrial Revolution 1.0 to Industrial Revolution 4.0, the changing trend and direction of education have gradually adapted to the ever-changing social and technological environment.

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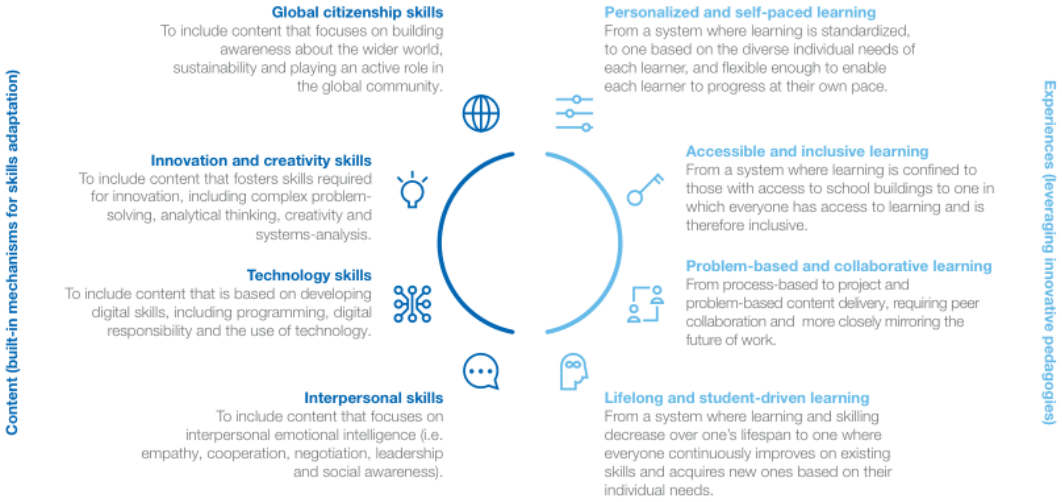


Figure 1. The World Economic Forum Education 4.0 Framework

Resources from: Schools of the Future: Defining New Educational Models for the Fourth Industrial Revolution, released by the World Economic Forum in January 2020.

Smart education advocates the concepts of "learner-centeredness" and "competence-based approach," as well as instructional innovation and personalized learning (Cai Baolai, 2019). Teachers face new challenges in the smart classroom, requiring innovative teaching methods to stimulate student interest and potential. In the context of the smart classroom, the core principles and concepts that should be adhered to are "teaching based on learning" and "teaching serving learning," where students complete learning tasks under the guidance, motivation, and instruction of teachers. This poses new requirements for teacher competence.

However, research on the ability of pre-service teachers, a group of teachers just starting out in the field, is scarce. Existing research on Preservice teacher ability primarily relies on qualitative studies such as literature reviews and hypotheses (Li & Zhang, 2011; Wang, 2012; Wang et al., 2018), as well as individual empirical studies. These empirical studies primarily investigate their competency and professional traits, as well as the impact of demographic parameters (such as gender, grade, major, and so on) (Dong et al., 2016; Fan et al., 2022; Guo, 2020; Wang, 2012; Zhang, 2016). There is currently a scarcity of empirical studies on the generative mechanism and its influences. Therefore, this question intends to focus on the basic logic and realistic path of pre-service teachers' competence under the background of smart education.

2. Literature Review

2.1 Research on the Evolution of the Educational Field

Education is a complex system that has undergone significant transformations throughout history, especially in the context of rapid technological advancements. The emergence of smart education is accelerating the reconstruction of the educational field. Over the course of its long evolutionary process, education has experienced different eras of transformation, including the 1.0 era (relying on oral transmission for knowledge dissemination), the 2.0 era (where books became carriers of cultural inheritance), and the 3.0 era (with radio,

television, and the internet as channels for knowledge dissemination). However, with the continuous progress of artificial intelligence technology, education is rapidly entering the era of smart education 4.0, supported by artificial intelligence (Gao & Zhang, 2020). Artificial intelligence technology is gradually penetrating the field of smart education and demonstrating significant advantages in providing personalized teaching support and promoting innovative teaching models. As a result, it poses higher challenges to teachers' traditional knowledge literacy, skill literacy, and professional literacy (Zhao, 2018). The rise of smart education has brought about a profound transformation in the field of education, requiring teachers to not only possess traditional teaching methods and skills but also adapt and apply artificial intelligence technology to better address the challenges and needs of future education. Figure 2 below is a dynamic development diagram of the evolution of the field of smart education.

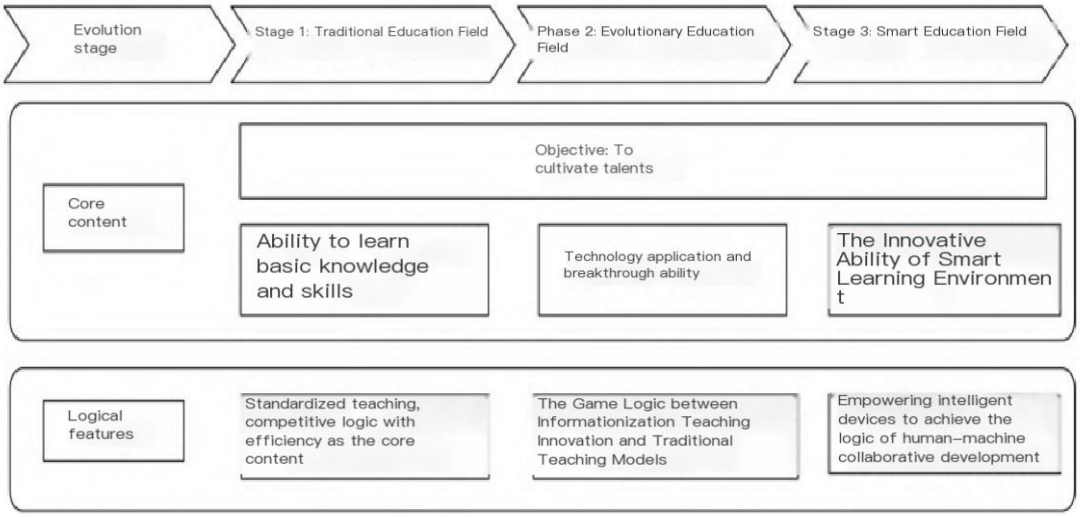


Figure 2. Dynamic development map of smart education field evolution

Resources from: 'What Makes a Teacher " in the Age of Education 4. 0--Consideration of Digital Literacy for Higher Education Teachers in the Smart Education Field', Zou Fang & Guo Xi, 2023.

2.2 Comparison of Teacher Competence Standards Policies

Teacher competency is a fundamental requirement for teachers engaged in educational work and serves as an important guide for improving their educational level. In-depth research on teacher competency is of great significance for promoting the comprehensive development of individual and collective teachers, driving educational and instructional reforms, and enhancing teaching quality and the cultivation of talent. This is particularly important for students trained in teacher education institutions, as they are the main force of the future teacher workforce and should receive special attention and emphasis. Various countries consider teacher competency standards as an integral part of their national education policies to ensure that teachers meet certain standards of professional literacy and competence. This, in turn, guarantees the improvement of educational quality and the effective implementation of talent cultivation.

The following Table 1 is a comparative analysis of the establishment of teacher competency standards in major countries.

Table 1. Comparative analysis table for the development of teacher competence standards

Country	Policy Overview	Targets	Main Requirements
United States	In 1987, the Interstate New Teacher Assessment and Support Consortium (INTASC) established the entry standards for general teachers (new teachers) nationwide. The National Board for Professional Teaching Standards (NBPTS) developed the professional standards for in-service teachers (exemplary teachers). In 2001, the American Board for Certification of Teacher Excellence (ABCTE) formulated the standards for in-service teachers (outstanding teachers).	Entry standards (new teachers), In-service teachers (exemplary teachers), In-service teachers (outstanding teachers)	The four major standards focus on four dimensions: subject knowledge, teaching strategies, reflective ability, and understanding of students. These standards form the current integrated quality assurance system for Preservice, entry, and in-service teacher education in the United States, accompanying every teacher throughout their professional career. To meet the four major standards, teachers are required to engage in lifelong learning.
United Kingdom	In May 1998, the "Requirements for Initial Teacher Education Courses" were issued, followed by the publication of the "Qualified Teacher Status Standards and Requirements for Initial Teacher Training in England" in 2002. In 2007, new professional standards for teachers were introduced. On April 1, 2018, the induction guidelines for Newly Qualified Teachers (NQT) were published. On July 30, 2021, the Department for Education updated the teacher standards, setting minimum requirements for teachers' practices and behaviors.	Initial teachers	1. Teachers must set high expectations for students, motivating and challenging their potential. 2. Teachers must facilitate positive progress and achievements in students. 3. Teachers must demonstrate good subject and curriculum expertise. 4. Teachers must plan and deliver well-structured lessons. 5. Teachers must adjust their teaching to accommodate the strengths and needs of all students. 6. Teachers must use assessments accurately and effectively. 7. Teachers must

Country	Policy Overview	Targets	Main Requirements
			effectively manage student behavior to ensure a positive and safe learning environment. 8. Teachers must fulfill broader professional responsibilities.
Netherlands	In 1999, the first set of professional standards for teacher educators was introduced in the Netherlands. In 2003, the Dutch Association of Teacher Educators revised and supplemented the initial set of standards, forming the second set of professional standards. In 2007, further amendments were made, leading to the development of the third set of professional standards. In 2000, the Self-Assessment, Professional Development, and Registration (SPR) program was established, which is linked to the professional standards in what is known as the "standards-based professional development system."	All teachers	The abilities that teachers must possess are defined in terms of professional competence, professional knowledge, professional skills, professional attitudes, professional values, and professional qualities.
Australia	In February 2011, the Australian Federal Government commissioned the Australian Institute for Teaching and School Leadership (AITSL) to develop the National Professional Standards for Teachers (2011 edition), which drew upon international teacher professional standards. The standards were revised in October 2018.	Graduate Teachers , Proficient Teachers, Highly Teachers , Accomplished Teachers, Lead Teachers	Consists of seven dimensions across three domains: Professional Knowledge, Professional Practice, and Professional Engagement.
New Zealand	In 1989, New Zealand introduced the Education Act, the Teacher	Beginning Classroom	The three levels of teachers are described in terms of

Country	Policy Overview	Targets	Main Requirements
	Employment Regulations, and the New Zealand Curriculum for primary and secondary schools. In 1997, a mandatory Performance Management System (PMS) was implemented in all schools. In 1999, the Ministry of Education issued the "Professional Standards: Quality Teaching Standards - Secondary Teachers and School Owners" and "Professional Standards: Quality Teaching Standards - Primary Teachers and School Owners." In 2004, the "Kindergarten Teacher Professional Standards" were established. In 2007, the New Zealand Teachers Council announced the "New Zealand Teacher Education Graduate Standards."	Teachers, Registered Classroom Teachers, Experienced Classroom Teachers	professional knowledge, professional development, teaching skills, student management, student motivation, effective communication, collaboration and contribution, and "Māori education."
China	On February 10, 2012, the Ministry of Education issued the "Professional Standards for Kindergarten Teachers (Trial)," "Professional Standards for Primary School Teachers (Trial)," and "Professional Standards for Secondary School Teachers (Trial)." In 2021, the Ministry of Education issued five documents, including the "Professional Competence Standards for Secondary Education Preservice Teachers (Trial)", which explicitly defined the basic professional competencies for Preservice teachers in secondary education, primary education, early childhood education, vocational education, and special education.	The professional standards cover in-service kindergarten, primary school, and secondary school teachers. The professional competence standards for Preservice teachers cover graduates from teacher education programs specializing in kindergarten, primary school, and secondary	Each document presents four major competencies, namely professional ethics, teaching practice, comprehensive student development, and self-directed growth.

Country	Policy Overview	Targets	Main Requirements
		school.	

Resources from: Based on A review of standards of practice for beginning teaching (Ingvarson & Kleinhenz, 2003), Comparison of professional standards for teachers in developed countries and their implications (Jiang Xianghui & Wang Lili, 2012), Comparative study of professional standards for teachers and their implications - China and Australia as an example (Liu Songdi, 2021).

Table 2 below shows the main structure and dimensions of professional standards for teachers in some countries, which can be used as normative standards for prospective teachers.

Table 2. National Professional Standards for Teachers (partial)

Name of standard	The main content of standard
Standards established by the Interstate New Teacher Assessment and Support Consortium; the National Board for Professional Teaching Standards; and the California Standards for the Teaching Profession	Create curriculum and instruction; Support different learners; Use assessment to drive learning and teaching; Create a productive classroom atmosphere; Professional development
Standards of the Interstate New Teacher Assessment and Support Consortium; National Board for Professional Teaching Standards	promote student learning; understand learners; teach critical thinking skills; develop curriculum; assess student learning; develop professionalism
Standards established by the National Association for the Education of Young Children	knowledge of pedagogical subject; planning and preparing for instruction; classroom management; encouraging family involvement; professionalism
Guidance for the induction of Newly Qualified Teachers (NQTs) in England	Teachers must set high standards for their students, motivating and challenging them to realize their full potential. Teachers must encourage excellent student progress and outcomes; teachers must display topic and curriculum knowledge; A well-structured curriculum must be planned and taught by teachers. Teachers must adapt their teaching in a timely manner to accommodate all students' strengths and needs; teachers must use assessment accurately and effectively; teachers must

Name of standard	**The main content of standard**
	manage student behavior effectively to ensure a good and safe learning environment; and teachers must fulfill broader professional responsibilities.
Professional standards for teacher educators in the Netherlands	Six dimensions of professional competence: professional knowledge, professional skills, professional attitudes, professional values, and professional qualities
AITSL National Professional Standards for Teachers are developed by the Australian Institute of Teaching and School Leadership	Professional Knowledge; Professional Practice; Professional Engagement
China's five publications, including the Standards for Professional Competence of Teachers for Secondary Education Teacher Trainees (for Trial Implementation)	Each document proposes four major competencies in four parts, namely, the competence to practice teacher ethics, the competence to practice teaching, the competence to comprehensively educate people, and the competence to develop on one's own.

Resources from: Defining Teaching Quality around the world (Darling-Hammond, 2021); InTASC Model Core Teaching Standards: A Resource for State Dialogue; Trends of competencies in teacher education from 2015 to 2020: A Systematic Review Analysis (Galih Albarra Shidiq et al., 2022); The characteristics and evolution logic of the development of the professional quality structure of primary and secondary school teachers in my country—Based on the analysis of teacher education policy texts from 1980 to 2012 (Shi Yabing & Liu Junling, 2019).

Some scholars extracted keywords from the Chinese Ministry of Education's standards on teacher professional competence for teacher trainees in primary and secondary education to create a cloud diagram as follows in Figure 3:

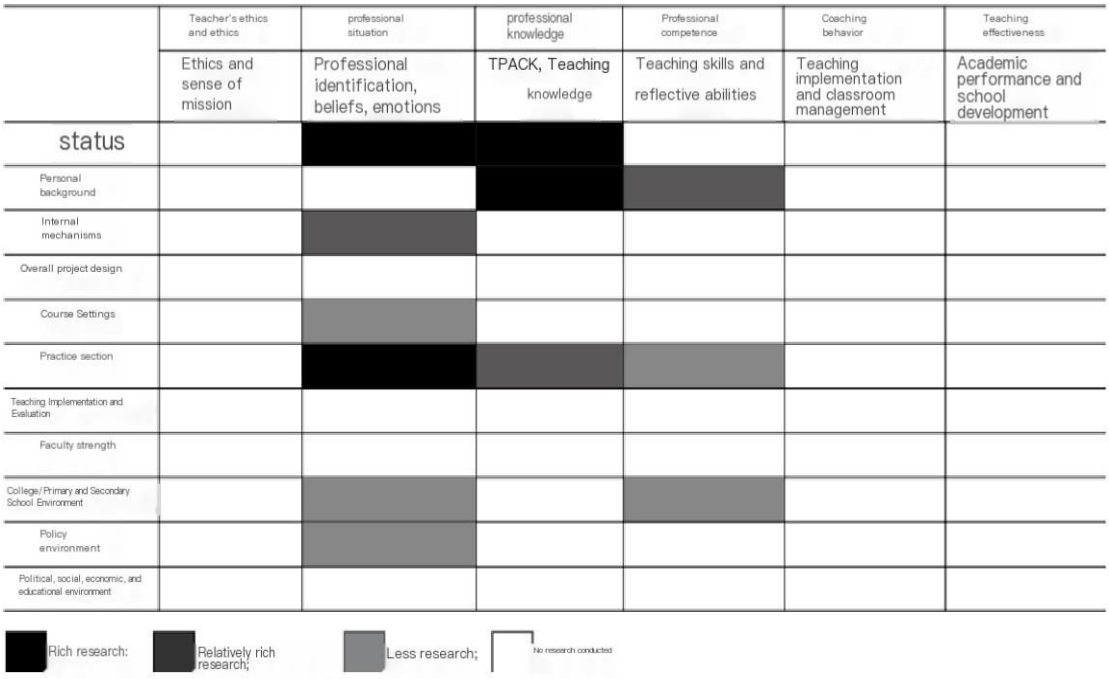
Figure3. Chinese Ministry of Education's Keyword Cloud Map on Teacher Professional Competence Standards for Preservice Teachers in Primary and Secondary Education

Resources from: The Ministry of Education of the People's Republic of China "Standards for Teachers' Professional Competence for Normal Students Majoring in Secondary Education (Trial Implementation)"; "Standards for Professional Competence of Teachers for Teachers Majoring in Primary Education (Trial Implementation)"; Five documents, including Professional Competence Standards for Teachers of Vocational Education Majors (Trial Implementation)" and "Professional Competence Standards for Teachers of Special Education Majors (Trial Implementation)", were produced by cite space.

2.3 Research on the Impact of Digital Technology on Teacher Education

Although there are predictions that teachers may be replaced by artificial intelligence, in fact, teachers are irreplaceable in cultivating students. The future of education will possess characteristics of human-machine collaboration (Gu Xiaoqing et al., 2023). However, future teachers will face many challenges, including crises in existing educational beliefs and concepts, misalignment between students' and self-perceived teacher identities, insufficient educational knowledge and skills, the construction of ever-changing educational environments, diverse educational assessments and measurements, information security and ethical risks, etc. Educational practitioners need to contemplate how to reshape teaching evaluation and management approaches, utilize artificial intelligence technology to uncover and unleash students' creative potential, cultivate students' problem-posing and innovative thinking abilities, and shape teaching capabilities related to critical thinking, problem-solving, creative thinking, independent learning, teamwork, flexibility, knowledge management, and digital skills relevant to knowledge creation. Simultaneously, they need to avoid the negative impacts brought about by technology (Zawacki-Richter et al., 2020). Figure 4. below shows the field distribution and gaps in academic research on teacher training.

Figure 4. Distribution of intensity of empirical research on teacher preparation and future directions



Resources from: A Systematic Literature Review of Empirical Research on Preservice Teacher Training (2015—2019), Song Yu et al., 2020.

2.4. Comparative Analysis of Digital Literacy Standards for Smart Education Teachers

In China, the Ministry of Education issued the "Standards for Information Technology Application Competencies of Primary and Secondary School Teachers (Trial)" in 2014. This standard includes five dimensions: technological literacy, planning and preparation, organization and management, assessment and diagnosis, and learning and development, covering a total of 25 specific indicators. In 2018, the Ministry of Education issued the "Standards for Preservice Teachers' Information Technology Teaching Competencies," which consists of three dimensions: basic technology literacy, technology-supported learning, and technology-supported teaching, with a total of nine specific indicators. On February 13, 2023, during the First World Conference on Digital Education, the Ministry of Education officially released the Industry Standard for "Teachers' Digital Literacy," which clearly defines the core connotation and indicator framework of teachers' digital literacyThis industry standard provides guidance for education management departments, schools, and educational institutions in developing teachers' digital literacy and serves as a basis for the construction of teacher training resources and the implementation of monitoring and evaluation. Table 3. below shows the content included in the digital literacy standards issued by typical countries or organizations.

Table 3. Comparison of Typical Digital Literacy Standards

Dimension	**Dig Comp Edu (2022)**	**Chinese Digital Literacy (2022)**	**UNESCO ICT-CFT (2018)**	**Chinese ICT Application Competency (2014)**	**Japanese Digital Literacy for Teachers**	**Chinese Normal Student ICT Teaching**

					(2018)	**Competency (2018)**
Information and Data Literacy	+	+	+	+	+	+
Digital Resource Development	+	+	+	+	+	+
Digital Teaching	+	+	+	+	+	+
Teaching Research	+	+	+		+	
Digital Security	+	+				+
Digital Communication and Collaboration	+	+				
Digital Assessment	+	+	+	+		+
Promoting Learners' Digital Learning	+	+	+	+	+	
Digital Problem-Solving	+	+	+	+	+	
Digital Professional Development	+	+	+	+	+	+
Digital Management	+	+	+			
Digital Citizenship	+	+	+		+	
Teacher Leadership			+			

Resources from: According to the European Framework for the Digital Competence of Educators, Education Industry Standard of the People's Republic of China: Teachers' Digital Literacy, Standard of Information Technology Application Competence for Primary and Secondary School Teachers (Trial), Interpretation of

Standard of Informatisation Teaching Competence for Teacher Trainees (Ren Youqun et al., 2018), Research on Teachers' Digital Literacy and Its Cultivation Path (Yan Guangfen & Liu Li, 2022), and Characteristics of Competency Standards for Elementary and Middle School Teachers' Digital Literacy in the Digital Transformation Period in Japan and Its Implications for China (Hu Qihui et al., 2023), etc., are collated.

2.5. Research on Factors Influencing Preservice Teachers' Competence

Currently, there are several issues in the education and competency development of Preservice teachers in China. Due to the relatively low salary for basic education teachers, many students choose to pursue teacher education programs to obtain relatively stable employment, not necessarily out of passion or recognition for the teaching profession. In addition, many high-achieving high school students do not prioritize enrolling in teacher education institutions or majoring in education. If students achieve high scores in the national college entrance examination (gaokao) and have the opportunity to attend a better university or choose a profession that may offer higher salaries in the future, they generally do not consider teacher education institutions or majors. Consequently, teacher education institutions currently exhibit two typical characteristics: low admission scores for education majors and a female student majority comprising 3/2 of the total student population. According to the survey conducted by Zhang Fenzi and Zheng Gaojie on the sense of professional identity among Preservice teachers, only 35.6% express a clear willingness to become teachers, with a prevalent attitude of seeing the teaching profession as "impoverished" (Zhang & Zheng, 2007).

The author used "professional identity," "digital literacy," "learning inputs," "learning outcomes," "teacher competence," and "teacher competence of normal students" as keywords for literature retrieval in the CNKI and SCOPUS databases. The CNKI search spanned from 2003 to 2023, while the SCOPUS search spanned from 2000 to 2023. The results are as follows in Table 4 and ***Figure 5-6:***

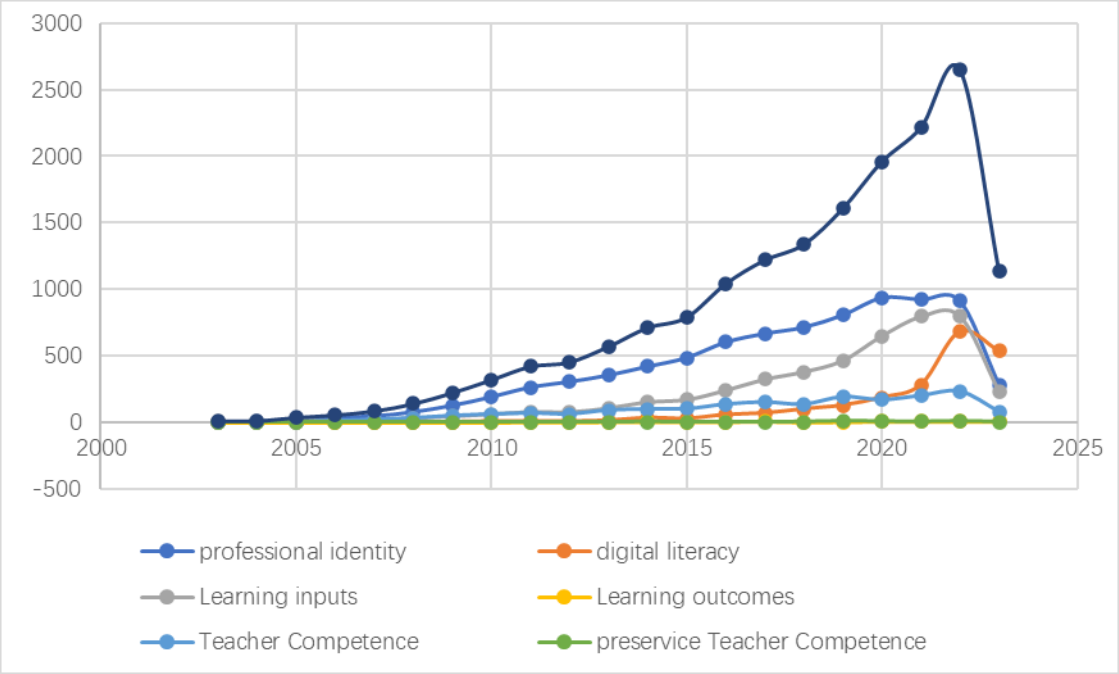
Table 4. Number of literature searched by major keywords

NO	**Keywords**	**CNKI (2003-2023)**	**SCOPUS (2000-2023)**
1	professional identity	8185	31135
2	digital literacy	2140	14973
3	Learning inputs	4660	147733
4	Learning outcomes	61	175633
5	Teacher Competence	1897	24367
6	Pre-service Teacher Competence	61	477
7	Identity + digital literacy (competence) + teacher competence	21	42
8	professional identity+ digital literacy	0	0

	(competence) + teacher competence		

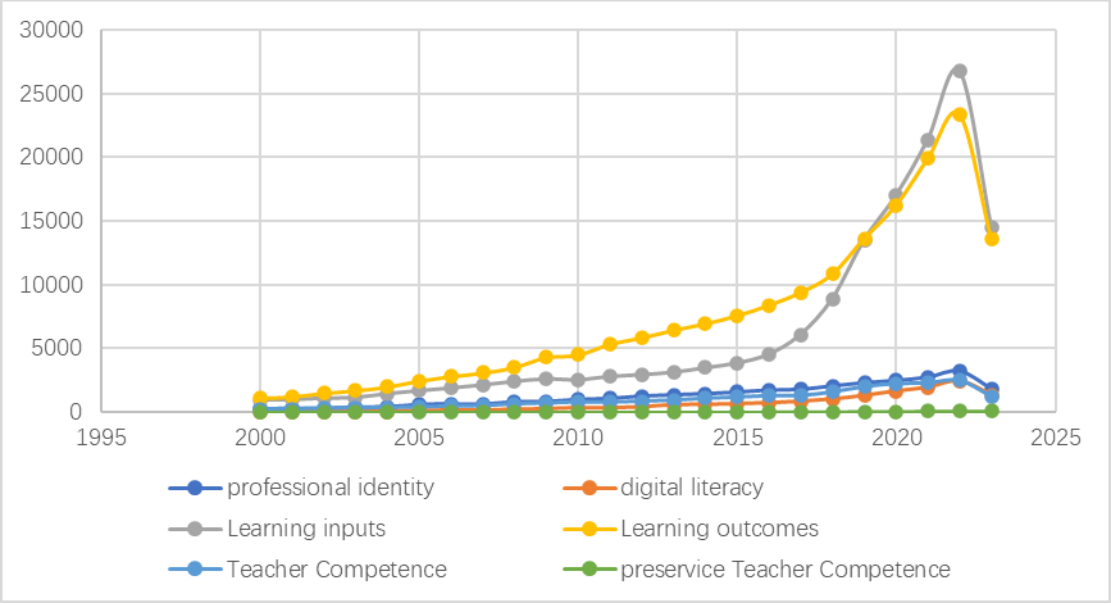
Resources from: According to CNKI and SCOPUS query data collation.

Figure 5. Annual Trends in Literature Published on Related Topics of CNKI (2003-2023)



Resources from: According to CNKI and SCOPUS query data collation.

Figure 6. Annual Trends in Literature Published on Related Topics of SCOPUS (2003-2023)



Resources from: According to CNKI and SCOPUS query data collation.

From the search results, it can be observed that the Chinese academic community has shown the most interest in professional identity, followed by learning inputs, teacher competence, and digital literacy. Foreign scholars, on the other hand, have focused more on research related to learning inputs and learning outcomes, followed by professional identity, teacher competence, and digital literacy. In recent years, there has been a rapid growth in research on digital literacy and learning inputs, indicating that these two aspects are currently hot topics in academic research.

2.6 Cluster Analysis

The author conducted searches using the keywords "professional identity, digital literacy, teacher competence" in databases such as CNKI and SCOPUS. In CNKI, 21 relevant articles were retrieved, while in SCOPUS, 42 articles were retrieved. These articles were selected as the focus for detailed analysis in accordance with the research objectives. Keyword cluster analysis was performed using CiteSpace. The results indicate that professional identity, digital literacy, and teacher competence are the prominent thematic clusters in the research literature, See Figure 7 below for details:

Figure 7. CNKI and SCOPUS Keyword Word Cloud Analysis

Resources from: The author made it with cite space.

3. Research Gap

In summary, the current academic research on teacher competence covers both macro and micro levels, forming a theoretical framework centered around teacher competence and achieving fruitful research outcomes. Scholars' in-depth examination of teacher competency has provided insights into the study of Preservice teachers' competence, laying the groundwork for this research. From a research standpoint, the study of teacher competence encompasses a wide range of subjects, including early childhood educators, primary and secondary school teachers, special education teachers, and university teachers, as well as subject-specific teachers such as language arts, music, mathematics, and computer science teachers. It also includes rural teachers and county-level teachers. In terms of research content, the research focus mainly centers on literature reviews of teacher competence, conceptual definitions, model construction, current status evaluation, and issues and

improvement strategies. In terms of research methods, studies have gradually evolved from conceptual research to quantitative empirical research. Some scholars use literature review to determine the measurement dimensions of teacher competence and utilize well-established questionnaires for survey research. Others employ the Delphi method to reach consensus and establish measurement models through expert panel evaluations after multiple rounds of assessment of teacher competence dimensions. In recent years, there has been a gradual shift in research trends from in-service and exemplary teachers to Preservice teachers and teacher candidates.

3.1 Lack of scrutiny research starting from the logical starting point of preservice teacher competence formation

As members of the professional group responsible for "educating and enlightening," teachers require Preservice teachers (i.e., future teachers) to possess a clear "self-perception as a teacher" concept. This concept should be fully recognized and reflected in their consciousness, emotions, and behaviors, enabling teacher candidates to have a clear understanding and cognition of the teacher education profession and the teaching profession and demonstrate positive emotional tendencies (Wang Ping, 2021). This helps teacher candidates exhibit positive emotional states during the learning stage, invest in their studies, and consciously engage in psychological adjustment when encountering learning obstacles, thereby maintaining enthusiasm for learning inputs and ultimately influencing their academic performance and level of teacher competence.

4. Conclusion

With the continuous advancement of artificial intelligence technology, education is rapidly entering the era of smart education 4.0 supported by artificial intelligence. Teachers face challenges such as higher traditional knowledge literacy, skill literacy, and professional literacy. Teachers need to explore new teaching methods, adopt innovative teaching methods, allow students to participate in personalized and interactive learning experiences, and stimulate students' interest and potential in smart classrooms. They should be able to effectively integrate information technology into teaching practice, be open to change, and be willing to try different strategies to meet the changing needs of students in the digital age. However, at present, both national teacher admission standards and academic research on pre-service teacher competency are relatively limited. Most studies on pre-service teacher competency rely on qualitative research such as literature review and assumptions. There are few empirical studies on the generation mechanism and its impact. We should pay attention to the logical starting point and realistic path of pre-service teachers' ability and quality under the background of smart education, and deeply analyze and discuss factors that affect pre-service teachers' ability, such as teachers' professional motivation, action investment, and learning outcomes, so as to provide a scientific basis for improving the level of teacher education.

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