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Research on Teachers' Digital Competence in STEM of Higher Education in the Context of Digital Transformation

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Abstract

In the key points of the work of the Ministry of Education in 2022, it is proposed to implement the strategic action of education digitalization and promote the transformation of education digitalization. China is facing a critical period of digital transformation of education, which is an important node of education reform, and teachers' digital competence is an important factor in promoting digital transformation. STEM education aims to develop learners to comprehensively use the knowledge, skills, and methods of various disciplines to solve the integrated problems constantly raised by social life and to continuously improve their core competencies in the process of solving problems. By analyzing the European Framework for the Digital Competence of Educators (DigCompEdu), comparing it with China's "Teachers' Digital Literacy" framework and combining with the development characteristics of STEM education, this paper explores the digital competence framework of teachers in STEM education and provides optimization strategies for improving teachers' digital competence under the background of digital transformation of education.

Keywords

Digital Transformation of Education, Digital Competence, STEM Education, Optimization Strategy

1. Introduction

STEM education is a comprehensive educational method, which aims to promote students' study and comprehensive application in four disciplines: Science,

Technology, Engineering, and Mathematics. On November 9, 2023, the 42nd General Conference of the United Nations Educational, Scientific, and Cultural Organization adopted a resolution to establish the UNESCO International STEM Institute for Education in Shanghai, China (MOE, 2023b). STEM education emphasizes interdisciplinary integration, organically combines the knowledge and skills of different disciplines, and cultivates students' innovative thinking, problem-solving ability, and practical application skills. In the information age, with the rapid development of high technology, the demand for compound scientific and technological talents with high comprehensive quality and strong innovation ability is increasing rapidly, and education reform is facing new opportunities and challenges. STEM education came into being under this background and has become an important member of the world education system.

Under the background of digital transformation, China's industrial structure is facing major adjustment and transformation, which requires a large number of new scientific and technological talents. The digital transformation of education is also imminent. Teachers are the main body for cultivating talents, and their digital competence becomes the key to the new situation. The research on the concept and framework of digital competence for teachers in China is still in its early stages. Foreign research on digital competence for teachers is not solely focused on the capabilities of digital technology itself, but more on empowering students based on digital abilities and promoting the development of advanced abilities for students. STEM education is a new model of interdisciplinary comprehensive education, that can cultivate students' innovative ability and problem-solving ability. Teachers in STEM of higher education should actively adapt to the tide of digital transformation and play a leading role in demonstrating for teachers in other disciplines.

The purpose of this study is to construct the digital competency framework of STEM teachers in colleges under the background of digital transformation by analyzing the European Framework for the Digital Competence of Educators (DigCompEdu) and combining with the "Digital Literacy Framework of Teachers" (MOE, 2023a), and explore the strategies to improve the digital competency of STEM teachers in colleges, so as to promote the digital transformation and development of education from the teacher level.

2. Research on the Present Situation of STEM Education

With the digitalization of society and the rapid development of technology, STEM education makes it easier for students to adapt and participate in the society and economy in the digital age. It is very important to students' careers and lives. The Chinese government has always emphasized the importance of STEM education and invested a lot of resources to promote related development. At the national level, there are a series of policies and plans, including strengthening basic scientific research, improving the level of higher education, and promoting innovation and technological development. Many universities and research in-

stitutions have set up research centers in STEM education, which are committed to promoting STEM education research. These institutions have carried out a series of research projects covering STEM curriculum design, teaching methods, and teacher training.

STEM education involves many disciplines, and some researchers have conducted interdisciplinary research, paying attention to the intersection of different disciplines to improve the comprehensive effect of STEM education (Hebebci, 2023). Hu integrated art into STEM education and analyzed the significance of STEAM education to the construction of new engineering (Hu, 2017). Some studies focus on empirical research and evaluate the effectiveness and influencing factors of STEM education by collecting and analyzing data from actual educational scenarios. This helps guide the practice of STEM education more scientifically.

STEM teachers are the key to achieving STEM educational goals. From the research status at home and abroad, STEM courses can be divided into independent branches of science disciplines (such as science, mathematics, engineering, and technology), and can also be regarded as an interdisciplinary course. Interdisciplinary research is the main research in China, and Shan studies the performance evaluation of STEM teachers' teaching competence from the perspective of comprehensive disciplines (Shan, 2021).

Although some achievements have been made in the research of STEM in China, there are still some challenges. Some schools may lack sufficient funds and teachers, which makes STEM education levels uneven in some areas. In addition, some teaching methods may be biased towards tradition, which requires more attention to practical application.

3. Research on Digital Competence

3.1. Research on the Difference between Digital Literacy and Digital Competence

To solidly promote the national digital education strategy and enhance teachers' awareness, ability, and responsibility to optimize, innovate, and transform educational and teaching activities using digital technology, the Ministry of Education issued the " Teachers' Digital Literacy " in 2022. Digital Literacy and Digital Competence are two related concepts with different focuses and meanings. Digital Literacy emphasizes an individual's ability to understand, use, and evaluate digital information. It includes basic technical operations such as using software and applications, as well as analyzing and evaluating digital information. Digital literacy mainly focuses on the understanding and application of digital information, including the basic ability to use the Internet, media, and other digital technologies. This includes the ability to identify and evaluate information, as well as using digital tools for basic tasks and communication. Digital competence has a broader meaning, covering the proficient use of digital tools, resources, and technologies to achieve more complex and advanced goals. It not

only includes the use of technology but also the ability to apply digital technology to practical problems in specific contexts and goals. Digital competence emphasizes the ability to use digital technology to solve problems in specific environments, including creatively using digital tools to achieve goals, participating in collaboration, and solving practical problems. It involves deeper levels of cognition and practice.

3.2. Analysis of European Framework for the Digital Competence of Educators (DigCompEdu)

The European Framework for the Digital Competence of Educators (DigCompEdu) is a comprehensive framework developed by the European Commission to guide educators in enhancing their digital competence (Redecker, 2022). It builds upon the general Digital Competence Framework for Citizens (DigComp) and is specifically tailored to the needs of educators.

DigCompEdu is organized into six areas of competence, each representing a key aspect of digital competence for educators: Professional Engagement, Digital Resources, Teaching and Learning, Assessment, Empowering Learners, and Facilitating Professional Development. Each area of competence is further divided into three competence levels: Foundation, Intermediate, and Advanced. These levels provide a progression to help educators assess and develop their skills.

The framework emphasizes the importance of continuous professional development for educators to keep up with evolving digital technologies. Member states are encouraged to integrate the DigCompEdu framework into national and regional education policies and strategies. The framework is designed to support educators in adapting to the digital transformation in education and in effectively using technology for teaching and learning.

The primary goal is to enhance the quality of teaching and learning through the effective integration of digital technologies. Preparation for the Digital Future: The framework aims to prepare educators and students for a future where digital skills are essential in various aspects of life and work.

The DigCompEdu provides a structured approach to help educators assess, develop, and enhance their digital competence. It plays a crucial role in supporting the integration of digital technologies in education. It also has a strong enlightening significance for the development of Chinese teachers' digital competence.

4. Research on Digital Competence Framework of Teachers in STEM

4.1. Research on the Characteristics of Teachers' Digital Competence in STEM

One of the key features of STEM teachers' digital competence is their depth of subject knowledge, enabling them to understand and seamlessly integrate concepts from science, technology, engineering, and mathematics. This encom-

passes not only an understanding of the subjects themselves but also the effective transmission of these concepts in a digital environment, allowing students to apply digital technology to solve real-world problems.

STEM teachers' digital competence highlights their adept use of various technological tools, including simulation software, programming tools, and virtual laboratories. This ability to fuse technology enables teachers to innovatively design teaching activities that encourage students to use digital technology in experiments and projects, fostering deeper and more practical learning experiences.

Digital competence for STEM teachers requires them to integrate knowledge from different disciplines, helping students understand the interconnectedness of these subjects. Through digital tools, teachers can create interdisciplinary teaching environments, nurturing students' holistic thinking and practical problem-solving skills. This involves the ability of teachers to break down disciplinary barriers in a digital environment, promoting cross-disciplinary learning.

STEM teachers' digital competence includes the analysis of real-time data to assess students' learning progress. Through digital technology, teachers can monitor students' performance more accurately, allowing for the personalized adjustment of teaching strategies to meet the diverse needs of students and facilitate a more effective learning experience.

DigcompEdu pays more attention to empowering students and the gradual development of teachers' digital competence. Teachers' digital competence in STEM should not only pay attention to the use of digital technology itself but also pay attention to the all-round development of comprehensive ability in the digital age. The digital competence of science teachers is higher than that of humanities teachers. Because science and other engineering teachers have been exposed to digital technology tools for a long time, they are more suitable for the transformation of the digital age than teachers in other disciplines (Wang & Chu, 2023). STEM education is a new model of interdisciplinary comprehensive education. Therefore, teachers in STEM can improve their digital competence and give full play to their advantage to help teachers in other disciplines improve their digital competence. This is also the significance of this study.

4.2. Fundamentals of Research Theory

4.2.1. Iceberg Model

Harvard University professor David McClelland used the iceberg model as a metaphor to show that what things show on the surface is only a small part of their reality, while more complex and profound levels are hidden underneath (McClelland, 1973). When exploring the influencing factors of teachers' digital competence in STEM, these factors can be divided into surface factors and deep factors. Surface factors include subject professional knowledge, technical ability and digital literacy, teaching experience, and subject integration ability, which can be observed and measured and directly affect teachers' digital competence. The evaluation of teachers' digital competence should not only pay attention to

surface factors such as knowledge and skills but also pay attention to potential deep characteristics, which include intrinsic motivation, values, attitudes, personal characteristics, and self-efficacy. These competence characteristics are also the key factors to judge whether teachers are competent or not. Wang and Chu found that self-efficacy is an important factor in teachers' digital competence, and teachers with doctoral degrees have higher digital competence than master's and bachelor's degrees (Wang & Chu, 2023).

4.2.2. Onion Model

Based on the iceberg model, Richard abstracts the three-layer "onion model" according to the difficulty of cultivation (Boyatzis, 1991). The outermost layer of this model is the surface ability that is easy to observe and evaluate, including knowledge and skills, which is the most basic and universal ability, and can be improved through training. The middle layer includes values, self-concept, attitude, and social role, which can also be developed and promoted through planned long-term accumulation or long-term training. The innermost part includes motivation and traits, which are not easy to acquire and often difficult to change, and have a key influence on work efficiency. The onion model is more detailed than the iceberg model and extracts deeper parts. The onion model vividly represents the difficulty of individual ability training which is also an important theoretical basis for competence research. Tian improved the onion model and put forward a dual-core onion model of the future teacher ability structure and analyzed the relationship and operation mode among the four abilities in the digital transformation period: man-machine cooperation ability, self-growth ability, effective moral education ability, and curriculum teaching ability (Tian, 2023).

4.3. Model Building

According to the deep internal influencing factors proposed by the iceberg model and onion model, combined with DigcompEdu Framework, compared with the framework of "teachers' digital literacy" in China, this paper analyzes teachers' digital competence in STEM, focusing not only on basic digital literacy but also on deep self-efficacy and other factors. Teachers in STEM have high digital ability, so their digital competence is a comprehensive high-level ability, which is a deep-level cognition and practice. More emphasis should be placed on the level that teachers empower learners and promote their development, in which learners include both students and teachers of other disciplines. Teachers' digital competence in STEM can be constructed as a four-dimensional model, including self-efficacy, digital professional ability, discipline depth and digital integration, and empowering learners. Each dimension is progressive and developing continuously. Self-efficacy is divided into five levels: Motivation for Learning, Challenging Tasks, Self-Reflection, Social Support, and Achievement Motivation. Digital expertise is divided into five levels: Digital Literacy, Data Analysis and Statistics, Innovative Thinking, Project Management, and Continuous Learning.

Subject depth and digital integration can be divided into five levels: Disciplinary Foundation, Digital Research Methods, Digital Innovation and Application, Interdisciplinary Integration, Disciplinary Innovation, and Frontier Research. Empowering learners can be divided into five levels: inspiring education, Self-directed Learning, Creative Thinking, Continuous Reflection, and Sense of Social Responsibility. Finally, the digital competence model of teachers in STEM education is formed, as shown in Figure 1.

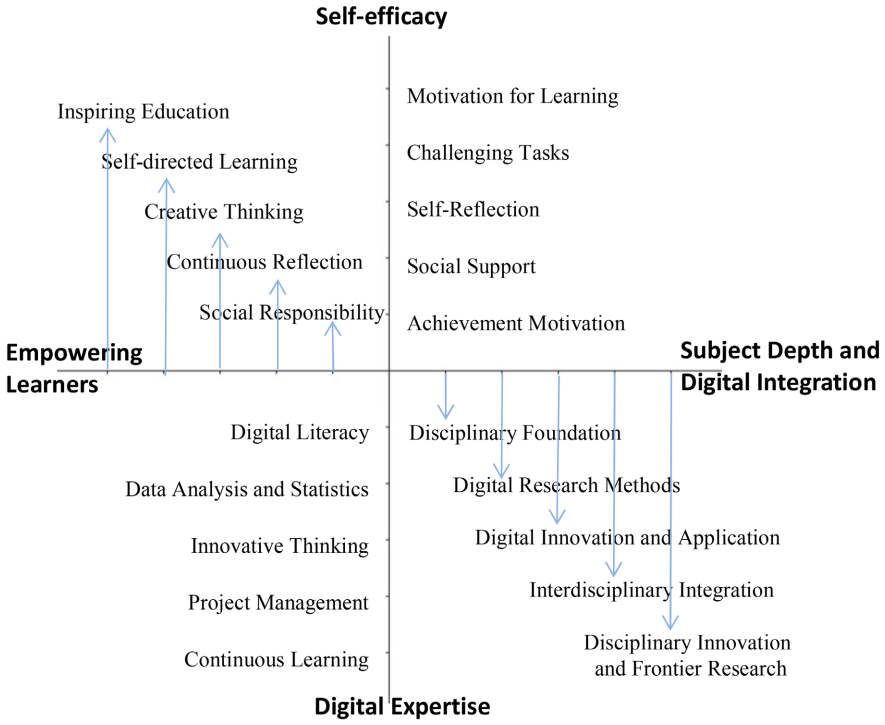

Figure 1. Digital competence model of STEM teachers.

4.4. Research on the Path of Improving Teachers' Digital Competence in STEM

4.4.1. Carry out Professional Advanced Development Training

Under the background of digital transformation, STEM teachers need to clarify their personal digital competence needs and understand the latest application trend of digital technology in STEM education, to make a clear development plan. Pay attention to practical STEM projects and experience, deepen the understanding of digital education, and improve operational skills by personally participating in the application of digital technology in practical teaching. Actively participate in expert lectures and seminars in professional fields, deeply understand the innovative application of digital technology in STEM education, and move closer to frontier development in professional fields. Participate in digital education seminars, research groups, or academic conferences specifically for the STEM field, and deeply understand the current research results, best practices, and future development direction of digital teaching. Participate in local or global STEM education professional community, and communicate,

share, and discuss with other teachers online and offline, which is helpful to gain practical teaching experience and teaching resources. Participate in workshops and training courses organized by professional institutions or universities, especially those covering the topics of digital education in STEM, which usually provide practical cases and operational guidance.

4.4.2. Innovating and Integrating STEM Educational Resources

STEM education is a new model of comprehensive discipline education, which needs to integrate and innovate multiple disciplines, and then provide rich digital resources for STEM education, including online teaching materials, simulation experiments, and teaching applications. With the help of virtual experiments and simulation tools, students' practical experience can be expanded, and teachers can make better use of digital means for experimental teaching. In this way, students' interest in learning can be stimulated and empowered, which can not only cultivate students' professional skills but also improve students' digital literacy. Through the integration and innovation of multiple disciplines, teachers are encouraged to participate in the sharing and innovation of digital educational resources, promote the renewal and optimization of teachers' teaching methods in STEM, empower teachers, and enhance the digital competence of multidisciplinary teachers.

4.4.3. Empowering Learners and Establishing Multidisciplinary Support System and Group Network

The introduction of interdisciplinary cooperation enables STEM teachers to establish contact with technical experts and industry practitioners, to improve their comprehensive quality and better adapt to the requirements of digital transformation. Promote communication and cooperation among teachers in the STEM field, establish group networks, and share successful experiences, teaching resources, and best practices. Establish a support system for digital transformation, including technical support, and instructional design consultation, to ensure that teachers can carry out teaching activities smoothly in the digital environment. Teachers in non-STEM fields can actively participate in communication, empower teachers in this field, and improve their digital ability. Through this group network, we can explore a new model of multidisciplinary comprehensive development.

5. Conclusion

Digital transformation promotes the digital reform of education and has an impact on the traditional education model. Higher education teachers should actively change their thinking, enhance their digital competence, and adapt to the tide of digital transformation. Digital transformation makes cross-regional and interdisciplinary cooperation more convenient. STEM teachers should actively make good use of their digital competence to promote multidisciplinary comprehensive research and educational innovation. By establishing a comprehen-

sive discipline system, we can cultivate compound innovative talents, empower teachers and students in other disciplines, and jointly improve the digital competence of teachers and students.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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