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The Formation Mechanism and Cultivation Pathways of Digital Competence in College Students

Fenglin Zhang[1], Wenzhi Zhang[2]*

[1]Student, School of Education and Science, Baicheng Normal University, Baicheng 137000, Jilin, China

[2]Associate Professor, School of Continuing Education, Baicheng Normal University, Baicheng 137000, Jilin, China

**Author to whom correspondence should be addressed.*

Abstract: In the era where digital technology has deeply integrated into the entire educational process, college students as core participants in the future digital society have made the cultivation of their digital competence a key issue for higher education to address digital transformation. Based on theories related to digital competence and combined with students 'learning scenarios and developmental needs, this paper systematically analyzes the formation mechanism of digital competence from three dimensions: individual, environmental, and technological aspects. It proposes actionable cultivation pathways through five dimensions—curriculum system restructuring, practical platform construction, faculty team development, evaluation mechanism improvement, and collaborative ecosystem building—providing theoretical references and practical guidance for enhancing talent cultivation quality in higher education's digital transformation.

Keywords: digital era; college students; digital competence; generative mechanism; cultivation path

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1. Research Background

Amid the global wave of a new round of scientific and technological revolution and industrial transformation, a new generation of digital technologies such as 5G, artificial intelligence, big data, and blockchain is permeating all sectors of the social economy at an unprecedented speed and scale[1]. This is driving human society to leap from the "Information Age" to a "New Stage of Digital Civilization"[2]. This transformation is reflected not only in the intelligent upgrading of production methods—such as the popularization of industrial robots in smart manufacturing and the application of precision farming data systems in agriculture—but also in the profound reshaping of the public's lifestyle. Ranging from daily mobile payments and online medical services to remote work and virtual social interactions, digital technology has become a core link in maintaining social operation[3].

In this transition process, higher education, as the core hub for talent cultivation, is facing brand-new challenges and opportunities regarding its traditional talent cultivation goals and models. The former education model centered on "knowledge imparting" can no longer meet the demand of the digital age for interdisciplinary talents who "possess digital thinking, master digital skills, and adhere to digital ethics". How to integrate the cultivation of digital competence into the entire process of higher education has become a core issue in educational reform across various countries.

As early as in the "Global Framework of Digital Literacy" [4], the United Nations Educational, Scientific and Cultural Organization (UNESCO) clearly pointed out that digital competence has transcended the scope of "technical operation skills" and become an "essential core competence" for individuals to participate in modern social life and engage in lifelong learning. It is not only the foundation for individuals to adapt to the digital workplace and achieve career development, but also a key support for promoting social equity and digital inclusion.

As a "bridge group" connecting higher education and social development, the level of college students' digital competence is directly related to two core issues[5]. On one hand, from the national strategic perspective, the digital economy has become a core engine driving economic growth. The implementation of the innovation-driven strategy cannot do without a large number of high-quality talents with digital innovation capabilities. As the main force of the future digital industry, college students' digital competence directly determines the development quality and international competitiveness of a country's digital economy. On the other hand, from the perspective of the development of higher education itself, the in-depth integration of digital technology with education and teaching (such as blended teaching, virtual simulation experiments, and smart campus construction) also puts forward inherent requirements for college students' digital adaptability[6]. If college students lack basic digital competence, they will not only find it difficult to efficiently complete digital learning tasks, but also may fall into the "digital divide" in their future career development.

From the perspective of global research and practical progress, the current exploration of digital competence has formed a relatively mature theoretical framework and practical system, providing important references for the cultivation of college students' digital competence. At the international level, the "Digital Competence Framework (DigComp)" released by the European Union has wide influence[7]. Breaking through the single skill dimension, this framework systematically divides digital competence into five core domains. The first is "Information and Data Literacy", which emphasizes an individual's ability to acquire, screen, and manage digital information and data. The second is "Communication and Collaboration", focusing on cross-temporal and cross-cultural collaboration and communication skills in the digital environment. The third is "Digital Content Creation", covering the ability to edit, integrate, and innovatively produce digital resources. The fourth is "Safety", including safety awareness and skills such as digital identity protection and cyber risk prevention. The fifth is "Problem Solving", which focuses on the ability to analyze and solve complex real-world problems using digital technology. This framework not only provides a universal standard for EU member states to formulate digital education policies, but also serves as an important reference for many countries and regions around the world to design digital competence cultivation programs.

In the specific field of higher education, the "ISTE Standards for Students" released by the International Society for Technology in Education (ISTE) of the United States is more targeted[8]. Based on the learning and development needs of college students, this standard constructs a seven-dimensional performance system for digital competence. As "Learners", students need to be able to use digital technology to formulate personalized learning plans. As "Digital Citizens", they must adhere to digital ethics and safety norms. As "Knowledge Constructors", they need to integrate multi-source information and build knowledge systems through digital tools. As "Innovative Designers", they should carry out innovative practices and designs with the help of digital technology. As "Computational Thinkers", they need to have the ability to analyze problems using data thinking. As "Creative Communicators", they must express their views clearly and efficiently through digital media. As "Global Collaborators", they need to be able to carry out cross-cultural collaboration based on digital platforms. This standard closely combines digital competence with college students' academic learning and social practice, providing specific guidance for colleges and universities to carry out targeted cultivation.

In addition to theoretical frameworks, scholars at home and abroad have also conducted a large number of empirical studies on the measurement and improvement of college students' digital competence, resulting in rich practical achievements. Through a follow-up survey of multiple universities in the United States, Gilster (2022) found that there is a significant positive correlation between college students' digital learning ability and their academic performance. This correlation is particularly prominent in science and engineering majors. Further research also pointed out that "digital resource evaluation ability" is a key factor affecting learning effects—whether college students can critically identify

the authenticity, authority, and applicability of digital resources directly determines the efficiency and quality of their knowledge acquisition.

In addition, the research by Janssen et al. (2023) on the improvement path of college students' digital competence also has important practical value. The three-stage model of "Video Reflection - Collaborative Discussion - Practical Application" proposed by them follows a specific process: first, recording videos of college students' digital learning or practice processes to guide them in self-reflection; second, organizing interdisciplinary groups to conduct collaborative discussions around the video content and share experiences and shortcomings; finally, designing targeted practical tasks based on the discussion results to promote the transfer and application of digital skills. This model has been applied in digital education programs of many universities in the European Union, effectively improving college students' digital collaboration ability and problem-solving ability, and providing a reference practical paradigm for Chinese universities to carry out digital competence cultivation.

2. Definition of Key Terms

2.1. Digital Era

The digital era refers to a social development stage where digital technology serves as the core productive force, data acts as the key production factor, and technologies like the internet and artificial intelligence act as connecting bonds, achieving deep interconnection among "human-machine-thing"[9]. In this context, information dissemination methods, knowledge production models, and learning/work scenarios undergo fundamental transformations, placing higher demands on individuals 'digital literacy and capabilities.

2.2. Digital Competence of College Students

Based on the EU DigComp framework, ISTE student standards, and domestic academic research, combined with college students' core needs of "learning-practice-development", this paper defines digital competence of college students in the digital era as: comprehensive capabilities required to acquire, manage, evaluate, and create digital resources, conduct digital collaboration and communication, solve complex problems, and adhere to digital ethics and security norms in digital environments when completing academic studies, professional practices, and social participation. This represents an organic integration of "knowledge-competence-attitude".

2.3. Digital Competence of College Students

Considering students' learning scenarios and future career development needs, this paper categorizes digital competence into five core dimensions: digital ethics and security awareness, digital learning and innovation capabilities, digital collaboration and communication skills, digital resource management and evaluation capabilities, and digital problem-solving and critical thinking.

2.3.1. Digital Ethics and Security Awareness

As fundamental dimensions of digital competence for college students, digital ethics and security awareness encompass their understanding and adherence to ethical standards in digital environments, along with the ability to identify and mitigate digital security risks. This includes three key components: ethical awareness in digital contexts, practical measures for cybersecurity protection, and digital health management strategies.

2.3.2. Digital Learning and Innovation Capabilities

Digital learning and innovation capabilities constitute the core dimension of digital competence in college students, representing their ability to utilize digital technologies for self-directed learning, knowledge construction, and innovative practices. This includes three key aspects: application of digital learning tools, digital knowledge construction, and digital

innovation practices.

2.3.3. Digital Collaboration and Communication Competencies

These capabilities form the social dimension of digital competence, enabling students to collaborate effectively and communicate efficiently in digital environments. This encompasses three specific areas: utilization of digital collaboration platforms, digital communication techniques, and cross-cultural digital collaboration.

2.3.4. Digital Resource Management and Evaluation Capabilities

As the instrumental dimension, these competencies involve students 'abilities to acquire, screen, integrate, store, and evaluate digital resources. This includes four key components: digital resource acquisition, screening and evaluation, resource integration and storage.

2.3.5. Digital Problem Solving and Critical Thinking

Serving as the advanced dimension, these capabilities demonstrate students' capacity to analyze and resolve complex digital issues while critically reflecting on technology applications. This includes three specific aspects: digital problem analysis, problem-solving strategies, and critical thinking in digital contexts.

3. Mechanisms of Digital Competency Development in College Students

The development of digital competence among college students results from dynamic interactions and synergistic effects across three dimensions: individual, environmental, and technological factors. From a generative perspective, the core driving force lies in the "cognition-skill-attitude" synergy at the individual level[10]. The environmental support system comprising universities, families, and society serves as crucial safeguards, while the technological integration of tools, data, and scenarios forms the practical framework. These three elements collectively constitute the developmental system for digital competence.

3.1. Individual Dimension

As the primary agents in digital competency formation, college students internalize digital competence through a dynamic process of cognitive-emotional alignment. This process follows a progression: cognitive awakening → skill acquisition → attitude solidification → competence internalization.

Cognitive awakening refers to college students' formation of clear understanding regarding the importance, essence, and requirements of digital competence, serving as the starting point for its development. On one hand, through university courses on digital literacy and industry-leading seminars, students gain awareness of new competency demands in the digital era, recognize the impact of digital competence on academic advancement and career competitiveness, thereby stimulating intrinsic motivation for proactive cultivation. On the other hand, daily engagement with digital learning tasks (such as online research projects and digital course design) helps students identify gaps in their digital capabilities, creating a need for skill enhancement. Skill acquisition denotes the critical phase where students master specific digital competencies through study and practice. Attitude solidification involves developing positive attitudes toward digital technology—encompassing proactive learning, critical application, and ethical adherence—which ensures sustained growth of digital competence. A proactive digital attitude drives students to actively explore technological tools and continuously improve their skills. When cognition, skills, and attitude achieve dynamic synergy, digital competence becomes internalized, manifesting as flexible application of digital technologies to solve problems across scenarios and forming stable capability attributes.

3.2. Environmental Dimensions

The environment serves as the external foundation for developing digital competencies. Cultivating digital competence in college students requires collaborative support from three key dimensions: higher education institutions, families, and society, collectively forming an ecosystem for nurturing these skills. As the core educational institution, universities play a leading role in digital competency development by establishing curriculum systems, teaching models, and practical platforms to provide systematic support. Families, as crucial environments for student growth, profoundly influence digital competence through their digital atmosphere and educational philosophies. Society expands development opportunities for digital competence through policy guidance, industry participation, and cultural cultivation.

3.3. Technological Dimensions

Digital technology acts as the practical vehicle for developing digital competence. The deep integration of "tools, data, and scenarios" creates diversified practice fields that transform digital skills from passive learning to active application. Digital tools serve as the material foundation for students 'digital learning and practice, with their usability and functionality directly impacting skill development efficiency. With technological advancements, digital tools are trending toward intelligence, personalization, and collaboration. Digital data represents a critical production factor in the digital era. Students' abilities to acquire, analyze, and apply data not only demonstrate digital competence but also form its core components.

4. Cultivation Pathways for Digital Competence in College Students

4.1. Curriculum System Restructuring

The curriculum system serves as the core framework for developing digital competence in college students. Universities should break down traditional disciplinary barriers to establish a multi-tiered digital competency curriculum system integrating "general education + specialized training + advanced development"[11], achieving deep integration of digital literacy with professional education. Universal digital literacy general courses should be offered to all students, covering foundational topics such as digital ethics and security, application of digital learning tools, and digital resource management, helping build cognitive foundations for digital competence. Digital competency cultivation should be embedded into specialized course instruction by designing digital teaching content and tasks tailored to disciplinary characteristics, enabling synergistic enhancement of digital skills and professional knowledge. Advanced digital competency extension courses should be provided for interested students to access opportunities for advanced skill acquisition and foster innovative capabilities.

4.2. Practical Platform

Development Practice forms the critical component of digital competence development. Universities should integrate on-campus and off-campus resources to create diversified practical platforms through "on-campus + off-campus + online" approaches, offering abundant digital practice opportunities. Institutions should increase investment in digital infrastructure by establishing on-campus facilities including digital laboratories, maker spaces, and virtual simulation platforms to provide hardware and software support for student practice. Collaboration with enterprises, research institutions, and industry associations should be strengthened to establish off-campus digital practice bases, providing authentic real-world scenarios that align with industry demands for digital skills. Using online platforms to build online digital practice space, break through the time and space constraints, provide college students with flexible digital practice opportunities

4.3. Strengthening Faculty Development

As key guides in cultivating digital competencies among college students, universities should enhance faculty development by improving teachers 'digital pedagogical skills and practical guidance capabilities, thereby ensuring adequate faculty

support for digital competency development. Institutions should establish digital competency training programs to enhance teachers' application of digital technologies and digital teaching proficiency through diverse approaches[12]. Interdisciplinary digital teaching innovation teams should be formed to encourage collaborative digital teaching reforms and the development of digital educational resources. A scientific incentive mechanism for digital teaching should be implemented to motivate faculty participation in pedagogical reforms and elevate practical guidance standards.

4.4. Refining Evaluation Systems

A scientific evaluation framework serves as a crucial guide for cultivating digital competencies in students. Universities should move beyond traditional single-dimensional knowledge assessment models to build a multi-faceted digital competency evaluation system encompassing "process + outcome + feedback" to comprehensively assess students 'proficiency levels[13]. Emphasis should be placed on process-oriented evaluations that track developmental trajectories, integrating these assessments throughout the entire digital competency cultivation process. This includes documenting learning and practice progress through digital platforms to evaluate capability development comprehensively. Outcome-based evaluations should be conducted via digital achievement showcases, skill certifications, and competition performances to assess the practical effectiveness of students' digital competencies. Establish Feedback-Based Evaluation to Drive Continuous Improvement. Develop a multi-stakeholder, multi-channel feedback evaluation mechanism to provide timely feedback on assessment outcomes, helping both students and universities continuously improve digital competency development.

4.5. Building a Collaborative Ecosystem

Cultivating digital competencies in college students requires multi-party collaboration. Universities should partner with families, society, and enterprises to establish a coordinated training mechanism, forming a "four-in-one" ecosystem for digital competency development. Institutions should create regular communication channels with families to engage them in nurturing students' digital skills, fostering a collaborative education-family partnership. Universities should actively integrate social resources to expand training opportunities through external partnerships. Long-term stable collaborations between universities and enterprises will ensure precise alignment between digital competency development and industry demands.

5. Conclusions and outlook

5.1. Research conclusions

Based on the background of digital transformation of higher education in the digital era, this paper systematically discusses the connotation, generation mechanism and cultivation path of college students' digital competence, and draws the following main conclusions:

In the digital era, college students 'digital competence constitutes an organic integration of "knowledge, skills, and attitudes," encompassing five dimensions: digital ethics and security awareness, digital learning and innovation capabilities, digital collaboration and communication skills, digital resource management and evaluation abilities, and digital problem-solving with critical thinking. These dimensions address the core needs of students' academic, practical, and developmental growth.

The development of digital competence in college students results from dynamic interactions across three levels: individual, environmental, and technological dimensions. At the individual level, internalization occurs through the dynamic coupling of "cognition, skills, and attitude." At the environmental level, a cultivation ecosystem is built through collaborative support from "universities, families, and society." Technologically, deep integration of "tools, data, and scenarios" provides practical implementation environments. Together, these three elements form the generative system of digital competence.

Cultivating digital competence requires systematic approaches across five dimensions: curriculum, practice, faculty, assessment, and ecosystem. This includes strengthening foundational capabilities through a "general + specialized + extended" curriculum system, providing practical opportunities via "on-campus + off-campus + online" platforms, ensuring quality assurance through enhanced digital competencies among faculty, guiding capability development through a "process + outcome + feedback" evaluation system, and forming synergistic cultivation forces through collaborative ecosystems involving "universities, families, society, and enterprises."

5.2. Research Outlook

With the continuous development of digital technology and the deepening of digital transformation in higher education, the cultivation of digital competence of college students still needs further exploration in the following aspects:

Theoretical research will be deepened. In the future, the development of emerging digital technologies such as artificial intelligence and metaverse can be combined to expand the connotation and dimension of digital competence of college students, such as adding new dimensions such as "metaverse collaboration ability" and "AI ethical judgment ability" to improve the theoretical framework of digital competence.

Empirical research should be strengthened. In the future, large-scale questionnaire surveys and follow-up studies can be conducted to analyze the differences and development laws of digital competence among college students of different majors and grades, verify the effectiveness of cultivation paths, and provide empirical basis for the optimization of cultivation programs.

International comparative research. Carry out comparative research on the cultivation of digital competence among Chinese and foreign university students, draw lessons from advanced foreign experiences (such as the digital literacy certification system of American universities and the application practice of the EU DigComp framework), optimize the cultivation path based on China's national conditions, and enhance the international level of cultivation.

The cultivation of digital competence among college students in the digital era is a systematic project that requires joint efforts from universities, families, society, and enterprises. Only by establishing a scientific theoretical framework, a comprehensive cultivation system, and a collaborative cultivation ecosystem can we continuously enhance the level of digital competence among college students, thereby cultivating more high-quality digital talents with innovative spirit and practical capabilities for the development of Digital China.

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