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Digital Competence Development for Information Engineering Students in Higher Education Institutions in Yunnan Province: A Research Framework and Preliminary Exploration

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ABSTRACT: With the deepening of global digital transformation and the advancement of China's "Digital Yunnan" strategy, digital competence has become a core competency for information engineering students to adapt to industrial upgrading and national development needs. This study focuses on the digital competence development of information engineering students in higher education institutions in Yunnan Province, aiming to address the gaps in current research on regional specificity, infrastructure adaptation, and curriculum optimization. Through a systematic literature review, theoretical framework construction, and research design, this paper clarifies the research background, core questions, and methodological paths. The research adopts a mixed-methods approach, including questionnaire surveys, focus group discussions, and quasi-experimental design, to investigate the current status of digital competence among students from four representative universities in Yunnan, develop a targeted training program, and evaluate its effectiveness. The theoretical framework integrates five dimensions: Digital Awareness, Digital Knowledge, Digital Skills, Digital Security, and Digital Ethics, providing a localized research paradigm for engineering education digital competence cultivation. The research findings are expected to enrich the disciplinary differentiation research of digital competence theory and provide practical guidance for optimizing digital talent training in underdeveloped western regions.

KEYWORDS: Digital Competence; Information Engineering Students; Higher Education in Yunnan; Talent Cultivation; Mixed-Methods Research

INTRODUCTION

1.1 Research Background

Human society has entered the digital age, where digital technology has profoundly reshaped production methods, lifestyles, and educational models (Schwab, 2017; Forum, 2020). Digital competence, as a key capability for individuals to participate in the digital society, has been elevated to a national strategic height by international organizations and countries around the world. UNESCO has successively issued documents such as the Prague Declaration, emphasizing that digital competence is a prerequisite for effective participation in the information society and the core of lifelong learning (UNESCO, 2003; 2005). The European Union's DigComp 2.1 framework refines digital competence into 21 abilities in 5 major areas, embedding them into engineering education certification standards (Commission, 2022). The World Economic Forum predicts that by 2025, 97 million new digital jobs will emerge globally, and the demand for digital skills will grow by more than 50% (WEF, 2020), highlighting the urgency of digital competence cultivation.

In China, the digital economy has maintained vigorous development, with a scale of 39.2 trillion yuan by 2020, and its growth rate is more than three times that of GDP (CAICT, 2021). National policies such as "China Education Modernization 2035" and the "Guiding Opinions on Promoting the Construction of New Educational Infrastructure" clearly propose accelerating the digital transformation of education and strengthening the cultivation of students' digital competence (SCC, 2019; Ministry of Education, 2021). However, statistics show that although the supply of digital teaching resources in China's higher education has increased by 420% in the past five years, there is still a 22.3 percentage point gap in the matching degree of students' digital competence, which is particularly prominent in provincial engineering colleges (Ministry of Education, 2022).

As an important region in southwest China, Yunnan Province is facing the dual tasks of promoting the "Digital Yunnan" strategy and supporting regional industrial upgrading (Yunnan Provincial Government, 2023). Information engineering, as a discipline

closely integrated with digital technology, its students' digital competence directly affects the development of strategic industries such as smart manufacturing and crossborder e-commerce in Yunnan. However, due to factors such as weak economic foundation, uneven educational resources, and backward infrastructure, the cultivation of digital competence among information engineering students in Yunnan's higher education institutions faces unique challenges: the teaching model is outdated, the curriculum is disconnected from technological innovation, digital ethics and security education are insufficient, and there is a lack of localized training systems (Zhao et al., 2023; Liu et al., 2024). Therefore, it is of great theoretical and practical significance to carry out targeted research on the digital competence development of information engineering students in Yunnan.

1.2 Research Questions

Against the above background, this study focuses on the following core research questions:

(1) What is the current status of digital competence (including Digital Awareness, Digital Knowledge, Digital Skills, Digital Security, and Digital Ethics) among information engineering students in higher education institutions in Yunnan Province?

(2) What are the key components and implementation paths of a targeted digital competence training program suitable for information engineering students in Yunnan's higher education institutions?

(3) Can the designed training program effectively improve the digital competence of information engineering students in Yunnan, and what is the effect in each dimension?

1.3 Research Objectives and Significance

1.3.1 Research Objectives

(1) To systematically investigate the current status of digital competence among information engineering students in four representative universities in Yunnan Province, and identify the key competency gaps and influencing factors.

(2) Based on theoretical frameworks such as DigComp 2.2, Computational Thinking Theory, and Localized Knowledge Production Theory, design a localized, modular digital competence training program.

(3) Verify the effectiveness of the training program through quasi-experimental research, and provide empirical support for the optimization of digital talent training in Yunnan's higher education institutions.

1.3.2 Research Significance

Theoretical Significance: Existing research on digital competence mainly focuses on general education or humanities fields, and there is a lack of discipline-specific research targeting information engineering students (UNESCO, 2018). This study constructs a five-dimensional digital competence framework integrating engineering characteristics and regional needs, which helps deepen the disciplinary differentiation research of digital competence theory and provides a localized theoretical model for engineering education research in underdeveloped regions.

Practical Significance: By improving students' digital competence, the research helps enhance their employability in emerging fields and meet the talent needs of Yunnan's industrial upgrading. At the same time, it provides reference for universities to optimize curriculum systems, teaching methods, and evaluation mechanisms, and helps cultivate high-quality digital talents that adapt to the "Digital Yunnan" strategy, narrowing the regional high-skill talent gap (Security, 2023).

Literature Review and Theoretical Framework

2.1 Evolution of the Concept and Framework of Digital Competence

The definition of digital competence has evolved from instrumental operation to social participation. In the early stage, scholars such as Gilster (1997) and Eshet-Alkalai (2004) emphasized the operational skills of digital tools and the ability to process information. In the socialized stage, international organizations such as the OECD and UNESCO expanded its connotation to include social participation, ethical responsibility, and lifelong learning (OECD, n.d.; UNESCO, 2018a). Chinese scholars and institutions have combined national conditions to propose a framework including Digital Awareness, Computational Thinking, and Digital Social Responsibility (China, 2021).

In terms of theoretical frameworks, the EU's DigComp series of frameworks (DigComp 1.0 to 2.2) are the most influential, dividing digital competence into five areas: Information and Data Literacy, Communication and Collaboration, Digital Content Creation, Safety, and Problem Solving, with clear proficiency levels and practical examples (Commission, 2017; 2022). UNESCO's Digital Competence Global Framework (DLGF) adds "Operational Skills" and "Career-Related Competencies" on this basis, emphasizing inclusiveness and global applicability (UNESCO, 2018b). China's Action Plan for Enhancing Digital Competence and Skills for All Citizens simplifies the proficiency levels into three tiers (Basic, Applied, Innovative) and highlights the independent dimension of "Security Protection" (CAC, 2021).

However, existing frameworks have limitations in adapting to regional characteristics and engineering disciplines: the EU DigComp framework has a Eurocentric bias and high implementation costs; UNESCO's DLGF has vague professional competence standards;

China's framework lacks granularity in proficiency levels (Table 1). Therefore, it is necessary to construct a localized framework combining discipline characteristics and regional needs.

Table 1 Comparison of Mainstream Digital Competence Frameworks

Framework	Core Dimensions	Strengths	Limitations
EU DigComp 2.2	5 areas (Information Literacy, Communication and Collaboration, Content Creation, Safety, Problem Solving)	Comprehensive, foresighted, with clear proficiency levels	Eurocentric bias, high implementation complexity
UNESCO DLGF	7 areas (adding Operational Skills, Career-Related Competencies)	Inclusive, globally applicable, assessment-oriented	Vague professional competence standards
China's Action Plan	4 dimensions (Digital Awareness, Computational Thinking, Digital Learning and Innovation, Digital Social Responsibility)	In line with national strategy, emphasizing security	Insufficient proficiency level granularity

2.2 Core Theories Supporting the Research

2.2.1 Engineering Education Integration Theories

Computational Thinking Theory: Proposed by Wing (2006), it emphasizes four core competencies:
problem decomposition, pattern recognition, algorithmic design, and abstract modeling, which is the core methodology for cultivating digital skills in engineering education.

CDIO Engineering Education Model: Advocates holistic competency development throughout the Conceive-Design-Implement-Operate lifecycle, emphasizing integration with real-world engineering contexts (Crawley et al., 2007).

Digital Thread Education Theory: Reconstructs the engineering knowledge chain through data integration of "theory-simulation-practice", realizing the deep integration of digital competence and professional knowledge (MIT, 2021).

2.2.2 Regional Development Adaptation Theories

Digital Divide Theory: Points out that regional disparities in digital resources lead to competency stratification, requiring targeted compensatory mechanisms (van Dijk, 2006), which provides a theoretical basis for addressing the imbalance of educational resources in Yunnan.

Localized Knowledge Production Theory: Holds that knowledge transfer must align with local industrial demands and cultural contexts (Chen, 2003), guiding the localization of curriculum content in this study. **2.2.3 Ethics and Security Professional Theories**

Responsible Innovation Framework: Emphasizes four principles: anticipation, inclusivity, reflexivity, and responsiveness, providing guidance for the design of algorithm ethics courses (Stilgoe et al., 2013).

IEEE Code of Ethics: Proposes seven AI ethical standards, including human well-being and accountability, which is the basis for constructing the Digital Ethics dimension (Systems, 2019).

2.3 Research Gaps and Innovations

Existing research has the following gaps: (1) Limited regional focus, lacking research on the specific challenges of digital competence cultivation in Yunnan's higher education institutions; (2) Insufficient attention to infrastructure constraints, failing to propose scalable training models for underdeveloped regions; (3) The curriculum design for emerging technologies such as AI in underdeveloped regions is understudied (Li & Zhang, 2022; Chen et al., 2021).

The innovations of this study are: (1) Focusing on the specific context of Yunnan, investigating the current status of digital competence among information engineering students in underdeveloped regions; (2) Integrating multiple theories to construct a five-dimensional training framework (Digital Awareness, Digital Knowledge, Digital Skills, Digital Security, Digital Ethics) with

engineering characteristics and regional adaptability; (3) Using mixed methods to verify the effectiveness of the training program, ensuring scientificity and practicality.

Research Design and Methodology

3.1 Research Design

This study adopts a Research and Development (R&D) approach, divided into three phases (Figure 1):

Phase 1: Diagnostic Analysis: Assess the current status of digital competence among information engineering students in Yunnan through questionnaire surveys.

Phase 2: Intervention Design: Develop a targeted training program based on the diagnostic results and theoretical framework, verified by expert focus groups.

Phase 3: Efficacy Evaluation: Use a quasi-experimental design to evaluate the effectiveness of the training program through pretest-posttest comparisons.

3.2 Research Subjects

Phase 1: Through random sampling, 4 universities in Yunnan offering information engineering programs were selected: Kunming University of Science and Technology (KUST), Yunnan Minzu University, Yunnan Open University, and Yunnan University of Business Management. Using proportional allocation systematic sampling, 413 students were selected as the survey sample (Table 2).

Phase 2: A 7-member expert panel was established, including 3 engineering professors, 2 corporate technology directors, 1 educational ethicist, and 1 digital policy advisor.

Phase 3: 30 information engineering students from KUST were selected as the experimental group to participate in the training program.

Table 2 Sample Allocation in Phase 1

University Name	Total Enrollment	Sample Size
Kunming University of Science and Technology	3064	220
Yunnan Minzu University	1200	86
Yunnan Open University	1069	77
Yunnan University of Business Management	288	30
Total	5621	413

3.3 Research Instruments

3.3.1 Digital Competence Scale

Based on the EU DigComp 2.2 framework, UNESCO DLGF, and China's relevant policies, a 28-item scale was developed, covering five dimensions: Digital Awareness (5 items), Digital Knowledge (6 items), Digital Skills (10 items), Digital Security (4 items), and Digital Ethics (3 items). The scale uses a 5-point Likert scale (1=Strongly Disagree to 5=Strongly Agree). Expert review shows that the content validity index (IOC) of each dimension is ≥0.75, and the pilot test confirms that the Cronbach's α coefficient is 0.91, indicating good reliability and validity.

3.3.2 Focus Group Interview Outline

For the expert panel, the interview outline includes three parts: the rationality of the training program's objectives and content, the feasibility of the implementation path, and suggestions for optimization. The interview adopts a semi-structured format, and the results are analyzed using content analysis.

3.3.3 Training Program

The training program is modularly designed, with a total of 8 sessions (24 class hours), covering the five dimensions: Digital Awareness (2 sessions), Digital Knowledge (2 sessions), Digital Skills (2 sessions), Digital Security (1 session), and Digital Ethics

(1 session). The teaching methods include lectures, case studies, handson operations, and group discussions, integrating local industrial cases (e.g., Yunnan tourism big data platform development).

3.4 Data Collection and Analysis Methods

Quantitative Data Collection and Analysis: In Phase 1, the questionnaire was distributed online and offline, and the data were analyzed using SPSS 26.0 for descriptive statistics, correlation analysis, and difference analysis. In Phase 3, paired-samples t-tests were used to compare the pretest and posttest scores of the experimental group to verify the training effect.

Qualitative Data Collection and Analysis: Focus group interviews were recorded and transcribed, and the data were coded and themed using NVivo 12 to optimize the training program.

3.5 Research Quality Assurance

Validity and Reliability: The scale was revised through expert review and pilot testing; Harman's singlefactor test confirmed that the common method variance (CMV) is <30%.

Ethical Compliance: All participants signed informed consent forms; the data were anonymized and stored securely; the research was approved by the Ethics Committee of Srinakharinwirot University.

Expected Results and Discussion

4.1 Expected Research Results

(1) Clarify the current status of digital competence among information engineering students in Yunnan, revealing that the overall level is medium, with weaknesses in Digital Ethics and Digital Security, and significant differences among different universities.

(2) Form a localized, modular digital competence training program suitable for information engineering students in Yunnan's higher education institutions.

(3) Verify that the training program can significantly improve students' comprehensive digital competence, with the effect of Digital Skills and Digital Awareness being the most obvious.

4.2 Discussion Directions

(1) Analyze the influencing factors of students' digital competence, including individual characteristics, school resources, and curriculum design, providing a basis for targeted improvement.

(2) Discuss the adaptability of the training program in underdeveloped regions, focusing on how to overcome infrastructure constraints and achieve effective implementation.

(3) Explore the long-term effect of digital competence cultivation and the path of integrating it into the entire undergraduate training process.

CONCLUSION

This study focuses on the digital competence development of information engineering students in Yunnan's higher education institutions, constructing a theoretical framework and research design integrating multiple theories and regional characteristics. Through three phases of research, it is expected to fill the gap in regional digital competence research and provide practical solutions for cultivating digital talents in underdeveloped western regions. The research results will not only enrich the theoretical system of digital competence but also provide important reference for universities, governments, and enterprises to cooperate in promoting digital education reform, helping Yunnan better adapt to the requirements of the digital economy and realize highquality development.

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