Reframing Teacher Education for the Digital-Intelligence Era: An Empirical Study in Geography Education

Huirong Chen[1], Jianzhong Yang[2*], Zhen Guan[1]

[1] College of Resources and Environment, Beibu Gulf University, 535000 Qinzhou, China
[2] College of Electronic and Information Engineering, Beibu Gulf University, 535000 Qinzhou, China

* Correspondence: Jianzhong Yang (gxyjz@bbgu.edu.cn)

Citation: Chen, H. R., Yang, J. Z., & Guan, Z. (2025). Reframing teacher education for the digital-intelligence era: An empirical study in geography education. *Educ. Sci. Manag.*, *3*(3), 156–173. https://doi.org/10.56578/esm030302.

Abstract: With digital-intelligence technologies becoming increasingly embedded in educational practice, limitations in traditional teacher education have gradually emerged, particularly in terms of competency alignment, curriculum organization, and training models. In response to these challenges, this study addresses the professional development requirements of teachers in the digital-intelligence era by proposing a competency framework comprising Digital Literacy, Innovation Literacy, Subject Literacy, Humanistic Literacy, Educational Literacy, and Critical Thinking (DISHEL-CT), and by constructing an integrated training model grounded in technology empowerment, competency foundation, and practice-oriented innovation. Taking the geography teacher education program at Beibu Gulf University as an empirical case, the curriculum system was systematically reorganized into a structured model characterized by dual foundations, three extensions, four modules, and a central practice axis with two supporting wings. During instructional implementation, a double-helix nested case-based approach and a theme-based situational digital teaching model were adopted to integrate digital technologies across the entire teaching, learning, assessment, and instructional management process. Additionally, an evaluation scale grounded in the DISHEL-CT competency structure was developed to examine the outcomes of the training reform. Empirical analysis indicates that the reform measures were associated with observable progress in pre-service teachers' disciplinary understanding, educational practice awareness, humanistic orientation, and digital-instructional capability. The findings offer a practice-oriented reference for the reform of teacher education programs in the digital-intelligence era.

Keywords: Digital-intelligence era; Teacher education reform; Competency framework; Curriculum restructuring; Instructional practice

1. Introduction

1.1 Research Background and Problem Statement

1.1.1 Educational transformation in the digital-intelligence era

With the deep integration of digital-intelligence technologies such as artificial intelligence, big data, the metaverse, and blockchain, the operational mechanisms of educational systems, instructional forms, and modes of teacher–student interaction are undergoing profound restructuring (Záhorec et al., 2021). Intelligent instructional tools, represented by AI-based teaching assistants, are capable of conducting fine-grained learning diagnostics and providing individualized learning support based on learning behavior data. Immersive technologies such as virtual reality expand the temporal and spatial boundaries of instructional contexts, shifting classroom teaching from static presentation toward situational and experiential forms. Under these conditions, instructional activities increasingly display characteristics of data orientation, intelligent coordination, and contextual embedding, indicating a broader transformation of the educational ecology.

As digital-intelligence technologies continue to shape instructional practice, limitations have gradually emerged in traditional teacher competency structures centered on "disciplinary knowledge transmission plus pedagogical

skills training." On the one hand, knowledge systems organized around single disciplines are insufficient to support cross-disciplinary integration, complex problem-solving, and coordinated design across technology, content, and pedagogy in digital instructional environments. On the other hand, teachers' professional roles are shifting from knowledge transmitters toward learning designers, learning facilitators, and instructional decision-makers, with continuously expanding professional boundaries. This transformation calls for a shift in teacher education from a knowledge-oriented approach to a competency-oriented approach, placing greater emphasis on teachers' capacity to integrate technology, disciplinary understanding, and educational aims within digital contexts.

At the same time, digital-intelligence technologies have, to some extent, reduced geographical constraints in the allocation of educational resources, opening new possibilities for addressing educational inequality. Through online instructional platforms, digital resource-generation tools, and intelligent teaching-research systems, teachers in less-developed regions can access instructional resources that are more comparable to those available in developed areas. Meanwhile, local instructional cases and regional educational experiences can be systematically organized and shared through digital means, providing a practical foundation for the implementation of place-based teacher education models within digital environments.

1.1.2 Policy orientation and practical demands

At the level of educational development, advancing educational digitalization alongside teacher education reform has become an important strategic direction across many countries and regions. In alignment with broader educational modernization goals, a series of policy initiatives emphasizes the use of technology-driven approaches to reshape educational systems and to support teachers' adaptation to digital instructional environments. Relevant policy documents clearly state that emerging technologies such as artificial intelligence should be gradually introduced into basic education, thereby placing new demands on teachers' instructional understanding and technological application capacities (Chen, 2021; Gao et al., 2021).

In parallel, reform initiatives targeting teacher education consistently highlight the importance of strengthening teachers' information-related competencies and embedding information technologies throughout the entire teacher preparation process (Wang, 2018). Building teacher education models that integrate technology with pedagogy and disciplinary knowledge, and supporting future teachers in instructional design and classroom enactment within digital contexts, has become a central concern of contemporary teacher education reform (Ministry of Education of the People's Republic of China, 2018). These policy orientations provide both an institutional context and a practical rationale for re-examining the goals, curriculum structures, and training models of teacher education programs.

From a regional perspective, western and border regions continue to face multiple constraints in the process of educational digitalization. On the one hand, the supply of high-quality teachers remains relatively limited; on the other hand, the application foundation of digital-intelligence technologies in school instruction is still weak. Taking the Guangxi region as an example, graduates from some teacher education institutions are primarily employed in county-level and lower secondary schools, where future instructional environments differ considerably in terms of digital infrastructure and professional support. For instance, among pre-service teachers in the geography program at Beibu Gulf University, approximately 83% are expected to teach in county-level secondary schools. Internship feedback indicates that only 19% of these students are able to independently design geography lesson plans supported by artificial intelligence tools. This situation suggests that traditional teacher education models remain insufficient in addressing the demands of digital-intelligence-based instruction and require systematic reform.

1.2 Practical Challenges in Traditional Teacher Education

1.2.1 Misalignment between training objectives and era demands

For an extended period, teacher education has primarily focused on disciplinary knowledge transmission and basic instructional skills training. Its underlying logic has largely been aligned with conventional classroom teaching contexts, with limited attention to the comprehensive competencies required of teachers in the digital-intelligence era. In some local teacher education institutions, digital-intelligence-related competencies have not yet been incorporated into core training objectives. Taking the 2021 training scheme of a local geography teacher education program as an example, courses related to digital-intelligence competencies accounted for only 3.2% of total credits and were mostly offered as electives, making it difficult for them to provide systematic support within the overall training process. This lag at the level of training objectives often leaves pre-service teachers insufficiently prepared to respond to evolving role expectations and competency requirements once they enter digitally mediated instructional environments.

1.2.2 Structural imbalances in curriculum systems

Teacher education institutions in China commonly adopt curriculum structures organized around the sequence of "knowledge–ability–competency." While this structure has played a role in strengthening disciplinary foundations, its structural limitations have become increasingly evident in the context of the digital-intelligence

era. First, the supply of cross-disciplinary courses remains limited, with curricula still largely organized around single-discipline logics, restricting the development of integrated instructional perspectives. Second, courses emphasizing humanistic understanding and critical reflection occupy a relatively small proportion, constraining teachers' capacity for value judgment and reflective reasoning in complex instructional situations. Third, innovation-oriented practice courses are often positioned at lower levels, with practical training largely confined to simulated teaching activities and lacking opportunities for addressing complex problems in authentic instructional contexts. These structural shortcomings restrict the development of pre-service teachers' integrative disciplinary competencies and innovative capacities.

1.2.3 Disconnection between training models and technological application

At the level of training models, current teacher education programs remain dominated by theoretical coursework, with relatively limited proportions allocated to practice-based learning. Moreover, practical components are often distanced from authentic instructional contexts. Lecture-centered instructional approaches allow students to acquire theoretical knowledge, yet provide limited opportunities for systematically translating such knowledge into instructional action. At the same time, the application of digital-intelligence technologies within coursework lacks coherent design and is frequently treated as an auxiliary component, rather than being systematically aligned with instructional objectives, content, and assessment mechanisms.

More importantly, as digital-intelligence technologies increasingly intervene in instructional decision-making and evaluation processes, teacher education reform involves not only updates in methods and tools, but also the cultivation of professional judgment, value awareness, and reflective capacity (Browne & Jean-Marie, 2015; Picower & Love, 2021). Without adequate critical awareness, teachers may fall into forms of technological instrumentalism. Therefore, teacher education must guide future teachers toward developing critical understanding and rational adoption of technologies such as artificial intelligence, enabling a balanced relationship between technological application and educational purposes in practice (de Sousa Santos, 2018).

1.3 Research Framework

Based on the above background analysis and problem identification, this study establishes an integrated reform concept for teacher education in the digital-intelligence era, structured around technology empowerment, competency foundation, and practice-oriented innovation (see Figure 1). This concept constructs a comprehensive framework for teacher education reform from the perspectives of driving mechanisms, training objectives, and implementation pathways.
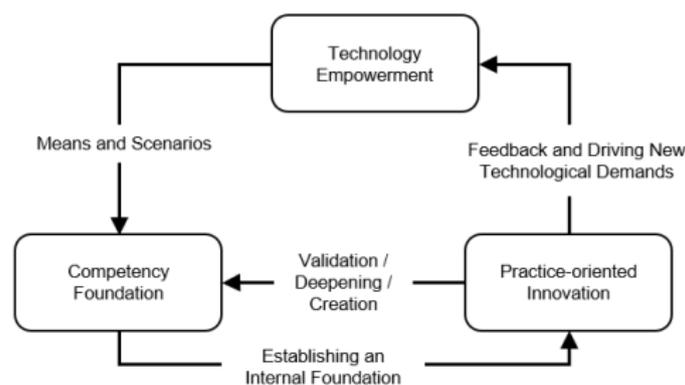

Figure 1. Framework of the proposed teacher education reform

Within this framework, technology empowerment is positioned as a key driving force of educational change. It emphasizes the proactive introduction of digital-intelligence technologies such as artificial intelligence and big data as functional tools for achieving educational aims. By constructing interactive relationships among teachers, students, and technologies, this dimension supports teachers in shifting away from repetitive, low-level instructional tasks and toward greater engagement in higher-order thinking development, affective interaction, and value-oriented guidance.

Competency foundation serves as the core pillar of teacher preparation, focusing on the essential competency structures required of future teachers. Anchored in the core competencies of teachers in the digital-intelligence era, this dimension systematically establishes a multi-dimensional competency base supported by technology, ensuring that pre-service teachers are not only capable of operating digital tools but are also able to integrate technology meaningfully into educational processes.

Practice-oriented innovation functions as a critical bridge for translating competencies into instructional action.

Through the design of challenging practice-based activities, this dimension guides pre-service teachers to apply technology and competencies in authentic or highly simulated instructional contexts to address complex teaching problems. In doing so, it facilitates the transition from theoretical learning to instructional practice and mitigates disconnections between learning and application.

Guided by this reform concept, the geography program at Beibu Gulf University has undertaken exploratory practices in preparing geography pre-service teachers for the digital-intelligence era. Building on the systematic construction of a six-dimensional teacher competency model, the program integrates pragmatist educational theory, the Artificial Intelligence–Geography–Technological Pedagogical Content Knowledge framework (AI-G-TPCK) model of geography teacher knowledge structure, the Outcome-Based Education (OBE) framework, and core practice theory to redesign and optimize curriculum structures and instructional implementation. This process has resulted in a new training paradigm for geography teacher education in the digital-intelligence era, the development of a theme-based situational digital teaching model and a double-helix nested instructional approach, and the construction of a curriculum system characterized as "dual foundations, four modules, one central axis, and two supporting wings" (see Figure 2). In parallel, an evaluation scale for geography pre-service teacher training grounded in the DISHEL-CT competency framework was developed, and comparative analysis across two cohorts before and after reform was conducted to examine the practical outcomes of the reform measures.
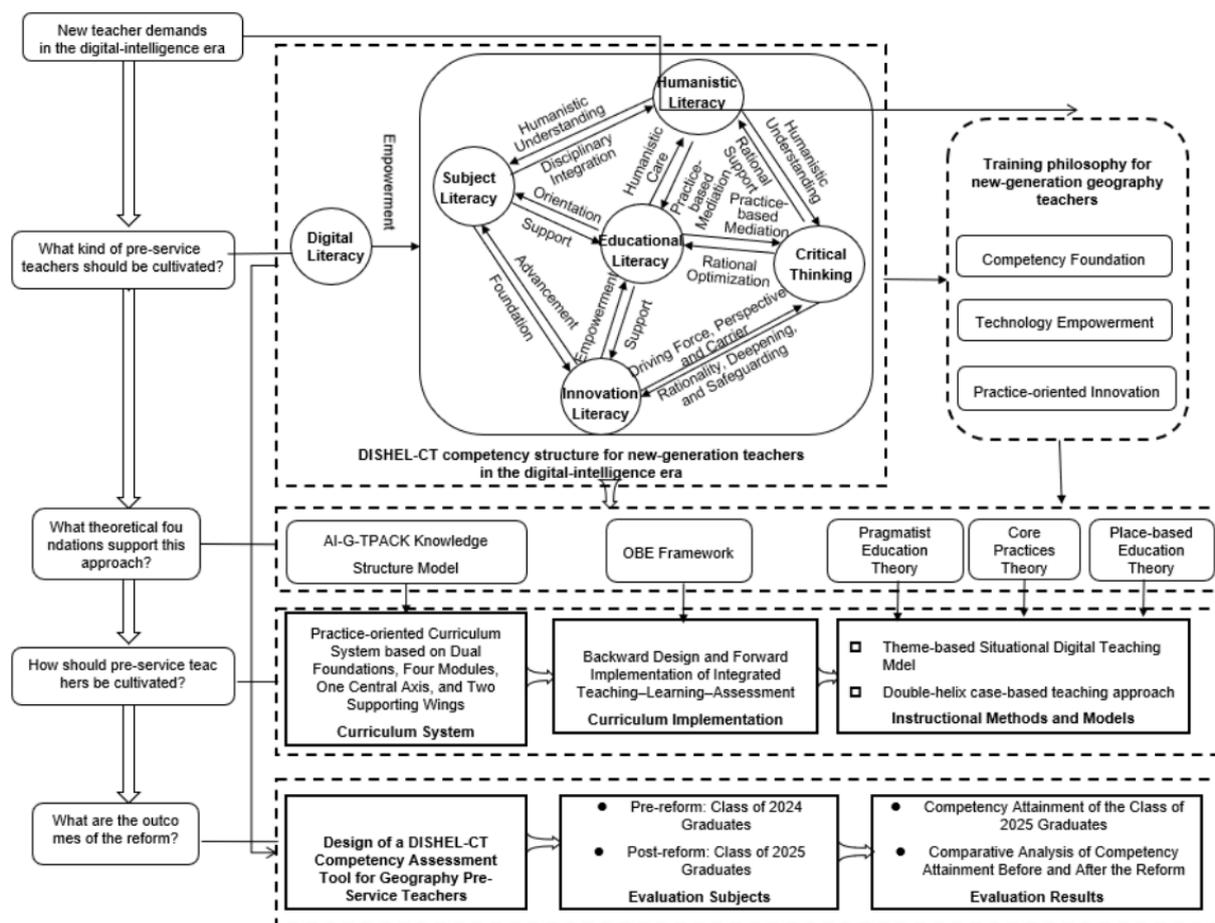

Figure 2. Geography teacher education reform framework

2. Theoretical Foundations

2.1 Definition of Core Concepts

2.1.1 New-generation pre-service teachers

With the continuous deepening of digital-intelligence-based educational environments, traditional training objectives centered on knowledge transmission and basic teaching skills are no longer sufficient to support the professional development needs of future teachers. In this study, new-generation pre-service teachers are defined as teacher education students who are able to adapt to digital-intelligence educational contexts, possess multiple core competencies, and carry out professional actions in complex instructional environments. Their competency

structure is no longer limited to single-discipline knowledge or isolated pedagogical techniques, but instead emphasizes the systematic integration and coordinated development of disciplinary competency, educational competency, humanistic competency, critical thinking, innovation competency, and digital-intelligence competency.

From the perspective of competency characteristics, new-generation pre-service teachers are primarily reflected in three aspects. First, cross-disciplinary integration capacity. New-generation pre-service teachers are able to move beyond traditional disciplinary boundaries and, based on an understanding of disciplinary logic, integrate cross-disciplinary knowledge and translate it into educational practice. This capacity includes embedding "artificial intelligence plus education/disciplinary understanding" into instructional design and implementation. Second, dynamic adaptability. In response to evolving instructional environments ranging from "AI-assisted teaching" to "metaverse-based situational instruction," new-generation pre-service teachers are able to understand the logic of technological change and transform digital tools into practical resources that support instructional work. Third, holistic integration of core competencies. New-generation pre-service teachers are expected to systematically develop the DISHEL-CT competency framework in order to meet the comprehensive professional demands placed on teachers in the digital-intelligence era.

Within the DISHEL-CT competency framework, digital-intelligence competency provides technical support for digitally mediated instruction and forms the basis for teachers' understanding and use of digital tools. Innovation competency supplies internal momentum for sustained professional development and supports continuous adjustment of instructional approaches and curriculum design. Disciplinary competency constitutes the knowledge foundation of educational work. Humanistic competency emphasizes value-oriented understanding and educational care centered on learners, helping to prevent educational practice from becoming dominated by purely human–machine interaction. Educational competency reflects teachers' ability to translate educational principles into instructional action. Critical thinking provides essential cognitive support for maintaining professional judgment and autonomy in digital-intelligence environments, a capacity that becomes particularly important in contexts where generative artificial intelligence is widely applied.

2.1.2 Geography new-generation pre-service teachers

Within the broader conceptual framework of new-generation pre-service teachers, geography new-generation pre-service teachers refer to teacher education students who respond to the demands of the digital-intelligence era by grounding their professional development in geography disciplinary core competencies while integrating educational competency, humanistic competency, critical thinking, innovation competency, and digital-intelligence competency. They are expected to adapt effectively to the digital transformation of geography education. The essential feature of this group lies in the organic combination of geography's disciplinary characteristics—regionality, integrative perspectives, and practical orientation—with digitally supported instructional capabilities, thereby supporting innovation in instructional forms and educational approaches.

Specifically, geography new-generation pre-service teachers are manifested in three main aspects.

(1) Cross-disciplinary integration capacity. On the one hand, they are able to transcend boundaries among subfields such as physical geography, human geography, and regional geography, using spatial and temporal perspectives as organizing principles to achieve systematic integration of interdisciplinary knowledge. On the other hand, they are capable of fostering integration between geography and the humanities as well as other related disciplines. By deeply combining artificial intelligence with geographic understanding, digital technologies are embedded into the development of core capacities such as geographic observation, geographic inquiry, and regional analysis. This process supports the educational translation of cross-disciplinary knowledge, including connections between geography and information technology, ecological studies, and historical–cultural perspectives, in order to meet the requirements of comprehensive geography instruction.

(2) Geography-oriented digital adaptability. New-generation pre-service teachers are able to understand and navigate technological developments ranging from "AI-assisted geography instruction" to "metaverse-based geographic scenario simulation," and to convert these technologies into practical tools that serve geography teaching. For example, GIS technologies and virtual simulation systems may be applied to support regional geographic inquiry, large-scale data analysis methods may be used to interpret complex geographic phenomena, and digital platforms may be employed to construct student-centered geography learning environments, thereby responding to the digital upgrading demands of practice-oriented and inquiry-based geography instruction.

(3) Integration of the DISHEL-CT competency framework with geography disciplinary characteristics. Within this framework, digital-intelligence competency provides technical support for geography instruction by facilitating the digitization of instructional contexts and the visualization of inquiry processes. Innovation competency supports ongoing adjustment of instructional approaches and curriculum design in geography education. Disciplinary competency, as the core of educational work, consolidates key geography competencies including regional cognition, integrative thinking, perspectives on human–environment relationships, and geographic practice capacity. Educational competency guides teachers in translating educational purposes into instructional processes grounded in geography's disciplinary characteristics. Humanistic competency, as a value-

oriented core, supports the communication of values such as human–environment coordination, regional equity, and ecological responsibility through geography instruction. Critical thinking provides cognitive support for rational analysis of geographic phenomena and dialectical understanding of human–environment relationships, thereby supporting professional competency in geography education positions in the digital-intelligence era.

2.2 Theoretical Foundations

2.2.1 The AI-G-TPACK framework

Research on teachers' instructional knowledge structures has evolved from Shulman's PCK model to the TPACK framework proposed by Koehler and Mishra in the context of educational technology (Ma & Ma, 2022; Shulman, 2004). The TPACK framework highlights the integration of technological knowledge, disciplinary content knowledge, and pedagogical knowledge, offering an important perspective for understanding technology integration in instruction. With the deep integration of artificial intelligence and educational practice, scholars have further proposed the AI-TPACK framework to address new requirements placed on instructional knowledge structures by intelligent technologies (Ning et al., 2024; Yan et al., 2020). On this basis, and in consideration of geography disciplinary characteristics, the AI-G-TPACK knowledge framework has been developed (see Figure 3).
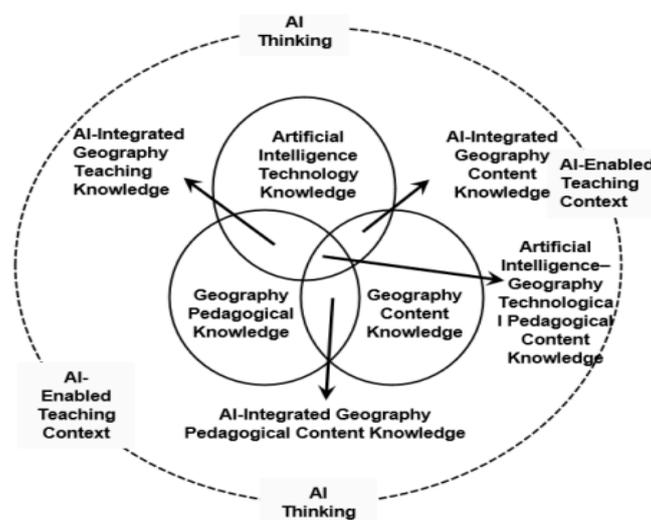

Figure 3. AI-G-TPACK framework for geography teachers (Zhang et al., 2024)

As a core knowledge–competency model for preparing geography new-generation pre-service teachers in the digital-intelligence era, the AI-G-TPACK framework forms a coupling relationship with the DISHEL-CT competency framework, characterized as "knowledge support–competency enactment." Each knowledge component corresponds to specific competency dimensions, jointly constructing a coordinated development logic integrating technology, discipline, and instruction.

Within this framework, artificial intelligence knowledge constitutes a foundational component of digital-intelligence competency and directly supports the development of pre-service teachers' digital tool application capacity and digital information competency. Geography content knowledge (GCK) consolidates disciplinary competency and serves as the core foundation for understanding disciplinary logic and conducting instructional practice. AI-integrated geography content knowledge (AI-GCK) deepens disciplinary understanding while activating innovation competency through technology-supported inquiry activities, supporting the parallel development of disciplinary and innovative capacities. AI-G-PCK, as a key linkage for competency enactment, translates educational competency and critical thinking into concrete instructional behaviors through intelligent instructional scenario design, while communicating humanistic values through place-based instructional cases. Technology-related geography instructional context knowledge provides practical scenarios for competency enactment, ultimately forming a dynamic mechanism in which knowledge components and competency dimensions mutually reinforce one another.

2.2.2 Outcome-Based Education (OBE)

OBE is an educational framework centered on learning outcomes, differing fundamentally from traditional models oriented toward content delivery or instructional time. OBE emphasizes what learners are able to do, understand, and demonstrate upon completion of learning activities, focusing on observable and measurable outcomes (Bhandurge & Suryawanshi, 2024). At the course level, the core logic of OBE lies in clarifying

assessment criteria and learning objectives through backward design, followed by the systematic design of instructional content, learning contexts, and learning activities, while maintaining alignment among teaching, learning, and assessment throughout course implementation. At the level of talent cultivation, OBE requires that operational and observable training objectives be defined in advance, and that curriculum systems, course syllabi, instructional implementation, and evaluation mechanisms be designed accordingly (Zhu et al., 2024).

2.2.3 Dewey's pragmatist educational theory

Pragmatist educational theory emphasizes the close connection between education and lived experience. Dewey proposed the principles of "education as lif" and "learning through doing," advocating the development of thinking capacity and innovative awareness through processes involving situation, problem, hypothesis, reasoning, and verification in authentic contexts (Jiang et al., 2019; Yang, 2003). From this theoretical perspective, teachers are not positioned as unilateral transmitters of knowledge, but as facilitators who guide learners' active participation in problem-solving processes. Introducing pragmatist educational theory into teacher preparation in the digital-intelligence era supports a stronger practice orientation by enabling pre-service teachers to translate theoretical knowledge into instructional action through authentic or simulated teaching contexts.

2.2.4 Core practice theory

Core practice theory emphasizes that teachers' professional capacities develop through engagement in high-leverage instructional practices. Grossman and colleagues argue that core practices consist of key instructional activities through which teachers exercise professional judgment to construct meaningful intellectual and social interactions, with particular attention to practices such as classroom questioning and learning analysis that demonstrate strong transferability (Zhu & Zhou, 2025). Through mechanisms including modeling, decomposition and simulation, and collaborative feedback, teachers are able to continuously refine instructional strategies in practice. Existing studies indicate that novice teacher preparation should prioritize the development of practical instructional capacity rather than remain confined to theoretical instruction (Ball & Forzani, 2009; Calabrese Barton et al., 2020). This perspective provides methodological support for teacher education reform in the digital-intelligence era.

2.2.5 Place-Based Education

Place-Based Education (PBE) emphasizes the use of learners' local communities and environments as starting points for interdisciplinary instructional activities, strengthening contextual relevance and real-world meaning in learning (Getting Smart, 2017; Sobel, 2004). Its core principle lies in reinforcing connections among individuals, schools, and local contexts, thereby increasing the authenticity and transferability of educational activities. Within digital instructional environments, PBE offers essential support for theme-based situational instructional models. On the one hand, local geographic resources provide concrete materials for instructional scenarios; on the other hand, place-based educational needs offer clear orientation for instructional design, ensuring that the preparation of geography new-generation pre-service teachers maintains practical grounding and contextual relevance (Wang & Wu, 2019).

3. Reform Practices in the Preparation of New-Generation Pre-Service Teachers

Based on the competency development requirements defined by the DISHEL-CT framework for geography new-generation pre-service teachers in the digital-intelligence era, the geography program at Beibu Gulf University has implemented systematic adjustments and continuous refinement of its teacher education curriculum since the 2021 cohort. Through this process, a curriculum structure integrating multiple core competencies has gradually been established, and a relatively stable implementation model has taken shape across the 2021–2025 cohorts. During this period, teaching reform measures such as theme-based situational digital instruction, the double-helix nested case-based approach, and higher-level process-oriented assessment were introduced in core courses, including *Chinese Geography*, to support the integrated development of geography pre-service teachers' core competencies.

3.1 Curriculum Structure Based on Dual Foundations, Three Extensions, and Four Modules

Within the context of digital-intelligence-based education, the professional capacity of geography pre-service teachers is not only reflected in their mastery of disciplinary knowledge, but also in the coordinated development of practical capability and digital-intelligence competency. On this basis, the reform adopts *technology empowerment–competency foundation–practice-oriented innovation* as the central axis and reconstructs the existing curriculum system through *dual foundational consolidation, three targeted extensions, and four modular alignments*. This process has gradually resulted in a new curriculum structure characterized by the integration of specialization and general education, as well as the convergence of disciplinary learning and digital-intelligence

applications (see Figure 4).
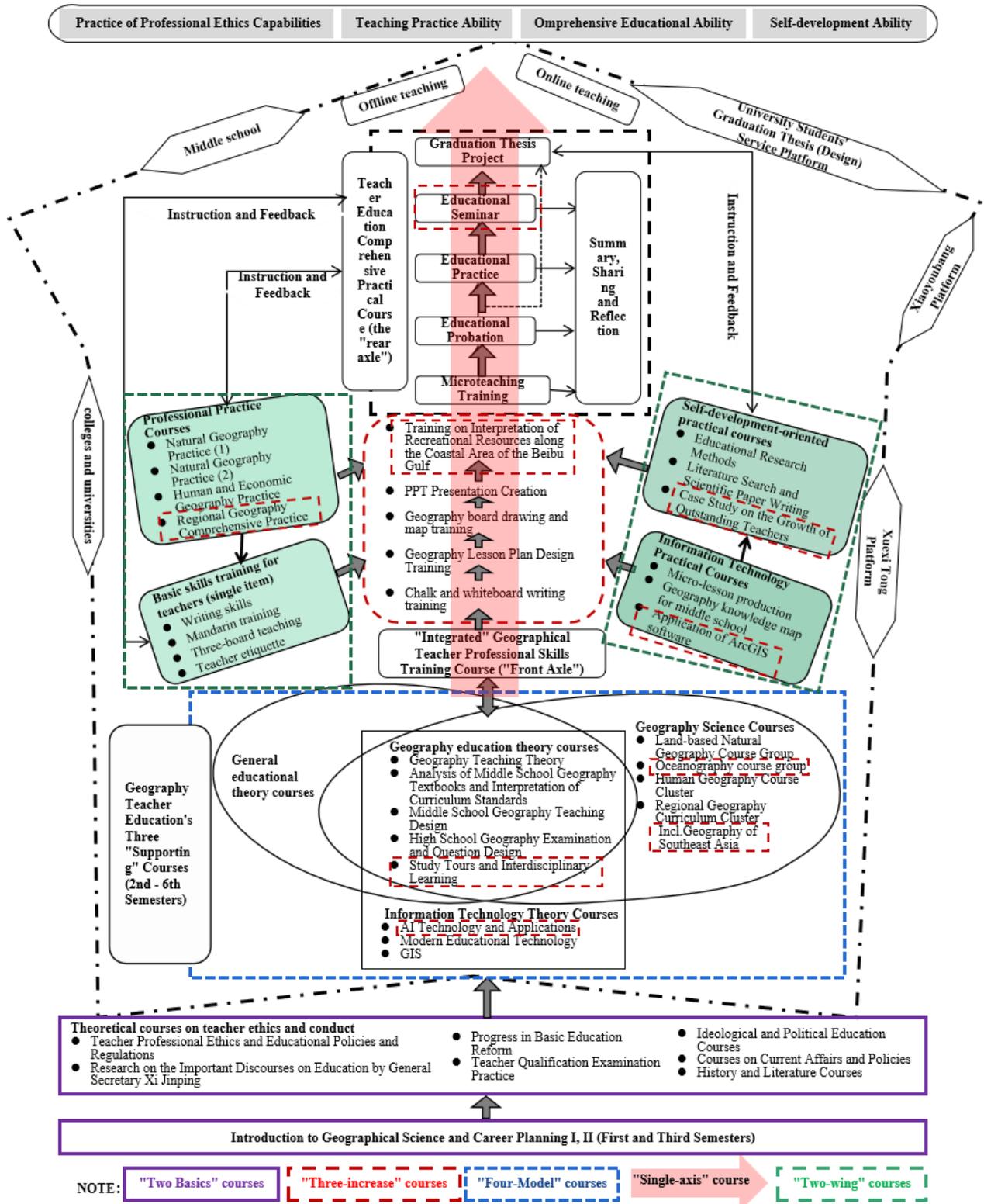
Figure 4. Curriculum framework based on dual foundations, three extensions, and four modules

3.2 Double-Helix and Situational Teaching Models

In alignment with the disciplinary characteristics and teacher education orientation of geography, the reform moves beyond traditional lecture-centered instructional approaches and constructs a teaching model driven by dual tracks of theory and practice, combined with situational generation. This model supports the integrated

development of theoretical learning, practical training, and digital intelligence application.

3.2.1 Double-helix nested case-based teaching approach

Drawing on the structural logic of the DNA double helix, this approach nests a *theoretical knowledge helix* and a *practical competency helix* in parallel. Supported by a collaborative platform linking universities, local institutions, and partner organizations, a closed-loop training structure connecting learning, practice, and application is established (see Figure 5).
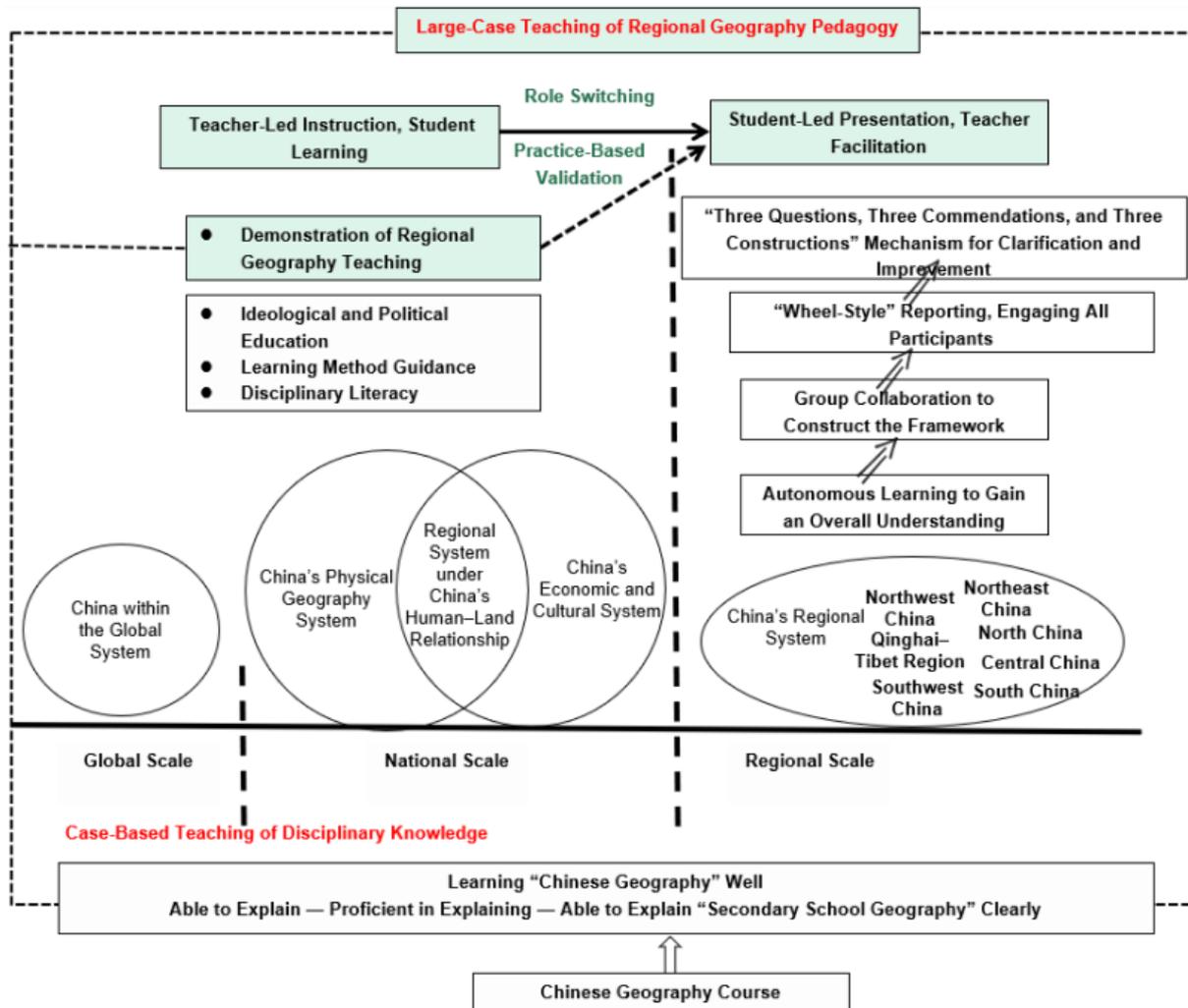

Figure 5. Double-helix nested case-based teaching approach

Within this approach, the theoretical knowledge helix takes disciplinary knowledge and digital-intelligence technologies as dual organizing threads and guides students through four instructional stages: situational introduction, problem decomposition, technology integration, and reflective reconstruction, thereby supporting the development of cross-boundary thinking. The practical competency helix focuses on transforming authentic instructional problems into case materials and organizing dual-scenario training through instructional demonstration and simulated classroom teaching, strengthening hands-on instructional capacity.

During implementation, two parallel trajectories gradually emerge: a teacher demonstration trajectory and a student generative trajectory. Teachers provide practical exemplars through demonstrations of geographic analysis methods, geography teaching strategies, and structured learning approaches. Students, in turn, engage in creative reconstruction through activities such as the *Hand-Drawn China* project, role-switching simulated classrooms, and structured learning notes. Through the parallel advancement of these two trajectories, the integration of disciplinary knowledge and the development of teaching competence proceed in coordination.

3.2.2 Theme-based situational digital teaching model

Grounded in situational learning theory, the reform employs digital-intelligence technologies to construct immersive instructional environments that integrate authentic problems, technological tools, and collaborative

inquiry, with the aim of cultivating students' capacity to address complex problems. Relying on the Learning Pass intelligent learning platform, a theme-based situational digital teaching model has been developed (see Figure 6), forming a six-stage instructional process consisting of learning analysis, situational initiation, situational entry, situational immersion, situational transition, and situational exit.
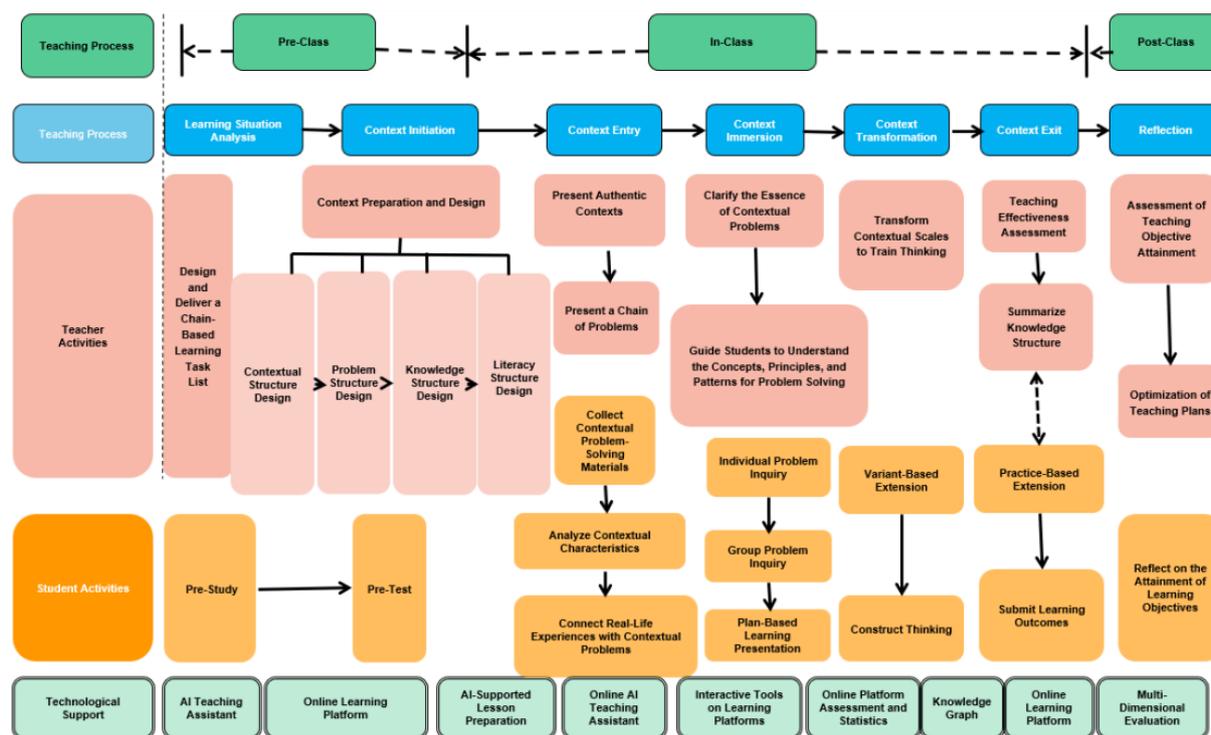

Figure 6. Theme-based situational digital teaching model

In practical implementation, chains of knowledge are embedded within authentic or highly simulated instructional contexts. Through task chains and problem chains, students are guided to identify problems, construct knowledge structures, and complete learning objectives through collaborative inquiry. This process provides cognitive scaffolding for the development of higher-order thinking and integrated competencies.

3.3 Digital Integration in Teaching, Learning, and Assessment

Guided by the AI-G-TPACK framework, the reform systematically integrates digital-intelligence technologies into instructional design, learning processes, assessment mechanisms, and instructional management, forming a closed-loop system characterized by precise instruction, intelligent assessment, and coordinated management.

On the instructional side, AI technologies are primarily applied to learning diagnostics, instructional resource generation, and immersive instructional support. On the learning side, digital tools assist students in analyzing disciplinary knowledge structures and increase engagement and immersion during the learning process. On the assessment side (see Table 1), a three-dimensional assessment system covering classroom learning, out-of-class practice, and outcome-based evaluation is constructed. This system combines self-assessment, peer assessment, instructor assessment, and AI-supported assessment (such as learning behavior data analysis), enabling alignment between process-oriented and outcome-oriented evaluation. On the management side, digital platforms support coordinated management of instructional resources, student assignments, and practice outputs.

3.4 Value-Oriented Teaching Through Human–Environment Relationships

In geography instruction, human–environment relationships constitute a central thread for understanding regional development and sustainability issues. Taking the evolution of human–environment relationships as the organizing framework, the reform integrates value-oriented instructional aims throughout the digital teaching process and constructs a three-stage instructional pathway of *understanding history, analyzing the present, and orienting toward the future* (see Table 2). By guiding students to examine historical experiences of human–environment interaction, analyze contemporary regional issues, and reflect on future development directions, this pathway supports the development of systemic thinking, public responsibility awareness, and global perspectives.

Table 1. AI-supported multi-agent assessment system across three dimensions

Assessment Dimension	Assessment Focus	Weight	Implementation Tools
Classroom learning	Proficiency in digital tools, group collaboration, and classroom interaction quality	20%	Learning Pass interaction data, AI-based behavior analysis
Out-of-class practice	Place-based project outputs, AI-supported instructional design products	20%	Internship mentor evaluation, AI-based product quality analysis
Outcome evaluation	Comprehensive competency assessment based on authentic tasks	60%	Double-blind review by university and secondary school teachers

Table 2. Three-stage value-oriented instructional implementation in the *Chinese Geography* course

Stage	Instructional Focus	Example
Understanding history	Analysis of historical cases of human–environment interaction	The *Yellow River Basin ecological conservation* unit, combining AI-generated historical imagery for comparative analysis
Analyzing the present	Investigation of regional development challenges	In the place-based *Mangrove Ecosystem Conservation* module, students use large-scale data analysis to examine drivers of ecological degradation and propose solutions
Orienting toward the future	Simulation of decision-making processes	AI-based simulation of the impacts of carbon reduction policies on Guangxi industries, followed by policy recommendation reports submitted to local authorities

3.5 Process-Oriented and Higher-Order Course Assessment

The reform establishes a multi-dimensional course assessment system organized around classroom learning, out-of-class learning, and learning outcomes. During classroom learning, student engagement, interaction patterns, and operational behaviors are used to dynamically capture learning status. In out-of-class learning and simulated teaching activities, learning reports and role-switching instructional tasks are combined with self-assessment, peer assessment, and instructor assessment to comprehensively examine students' instructional design and implementation capacities. In outcome-based evaluation, authentic instructional tasks serve as the primary reference, with a focus on students' integrative thinking and the quality of proposed instructional solutions.

4. Practical Outcomes

4.1 DISHEL-CT Competency Assessment Design

Following the implementation of the above reform measures, the Geography Science teacher education program at Beibu Gulf University completed the training of the Class of 2025 graduates. To examine the actual effects of the reform in cultivating new-generation geography teachers, this study developed a competency assessment scale grounded in the DISHEL-CT framework (see Table 3).

Given the abstract nature of competency constructs, the scale operationalized each competency dimension into observable and measurable indicators. Specific behavioral descriptors and performance-based anchors were used to support consistent interpretation and statistical analysis. This design aimed to strengthen the alignment between competency measurement and instructional practices implemented during the training process.

Specifically, educational literacy was assessed through indicators including career commitment, moral knowledge–ability–orientation, subject-based value education, instructional design, instructional implementation, and student management. Humanistic literacy comprised humanistic knowledge, humanistic concern, and cultural grounding. Subject literacy included intra-disciplinary integration, interdisciplinary integration, and professional development. Innovation literacy was measured through subject research, instructional research, and collaborative capacity. Critical thinking was evaluated through analytical judgment and reflective capacity. Digital intelligence literacy consisted of digital tool application, digital information literacy, intelligent instructional design, and digital innovation practice.

Together, these indicators covered knowledge, capability, and disposition dimensions, while maintaining correspondence with the curriculum structure and instructional activities of the training program, thereby supporting internal coherence between cultivation and evaluation.

A Likert-scale questionnaire was administered to graduates of the Class of 2024 (pre-reform) and the Class of 2025 (post-reform). A total of 176 valid responses were collected from the Class of 2025, representing 87.5% of graduates (Cronbach's α = 0.975; KMO = 0.916, p = 0.00). For the Class of 2024, 183 valid responses were collected, accounting for 88.83% of graduates (Cronbach's α = 0.974; KMO = 0.918, p = 0.00). These results indicate satisfactory internal consistency and structural adequacy, meeting the requirements for subsequent

comparative analysis.

Table 3. DISHEL-CT competency assessment scale

Competency Dimension	Indicator	Description
Educational Literacy	Career Commitment	Recognition of the educational value of secondary geography teaching, understanding of professional responsibilities, formation of appropriate human–environment perspectives, and willingness to undertake educational responsibilities.
	Moral Knowledge	Familiarity with educational laws and regulations and compliance with teaching and management practices.
	Moral Ability	Ability to design and conduct value-oriented activities aligned with students' developmental characteristics and integrate them into geography teaching and class management.
	Moral Orientation	Adherence to professional ethics and consistent regulation of professional conduct in educational practice.
	Subject-Based Value Education	Understanding the value-oriented role of geography and the integration of holistic educational goals into teaching design and implementation.
	Instructional Design	Learner-centered geography lesson design aligned with curriculum standards, application of disciplinary knowledge and educational technologies, and diagnostic use of assessment.
	Instructional Implementation	Effective use of subject knowledge, general teaching skills, and instructional strategies in classroom teaching and field-based activities.
	Student Management	Competence in classroom organization, guidance, and participation in moral and psychological support activities.
Humanistic Literacy	Humanistic Knowledge	Understanding of the educational meaning of school culture and the integration of humanistic values into campus activities.
	Humanistic Concern	Respect for student individuality, responsibility, patience, and care in instructional interaction.
	Cultural Grounding	Awareness of geographical aesthetics and regional cultural contexts.
Subject Literacy	Intra-disciplinary Integration	Systematic understanding of physical geography, human geography, and geospatial technologies and application of geographical thinking patterns.
	Interdisciplinary Integration	Understanding of connections between geography and related disciplines, including natural sciences and social sciences.
	Professional Development	Commitment to lifelong learning and continuous improvement in geography education.
Innovation Literacy	Subject Research	Ability to analyze geographical issues using disciplinary methods.
	Instructional Research	Capacity to conduct instructional inquiry and produce research-based outcomes.
	Collaboration	Participation in professional learning communities and collaborative teaching practices.
Critical Thinking	Analytical Judgment	Rational examination of geographical phenomena and instructional issues.
	Reflective Capacity	Use of reflection to revise instructional strategies based on evidence.
Digital-Intelligence Literacy	Digital Tool Application	Proficient use of GIS, remote sensing, navigation systems, and online teaching platforms.
	Digital Information Literacy	Ability to process digital instructional resources and manage information risks.
	Intelligent Instructional Design	Integration of artificial intelligence and data technologies into lesson design for learning analysis.
	Digital Innovation Practice	Application of digital technologies in inquiry-based learning and research activities.

4.2 Analysis of DISHEL-CT Competency Attainment Among the Class of 2025

Overall, graduates of the Class of 2025 demonstrated high levels of attainment in educational literacy, subject literacy, and humanistic literacy, with critical thinking reaching a generally satisfactory level. In contrast, innovation literacy and digital-intelligence literacy showed greater room for further development (Figure 7).

This pattern corresponds to the structural characteristics of the training process. Foundational disciplinary knowledge and classroom teaching skills have long been emphasized in teacher education, contributing to stable

performance in these areas. By contrast, advanced research capabilities and deep technology–discipline integration typically depend on sustained, iterative practice, resulting in relatively weaker performance at the point of graduation.
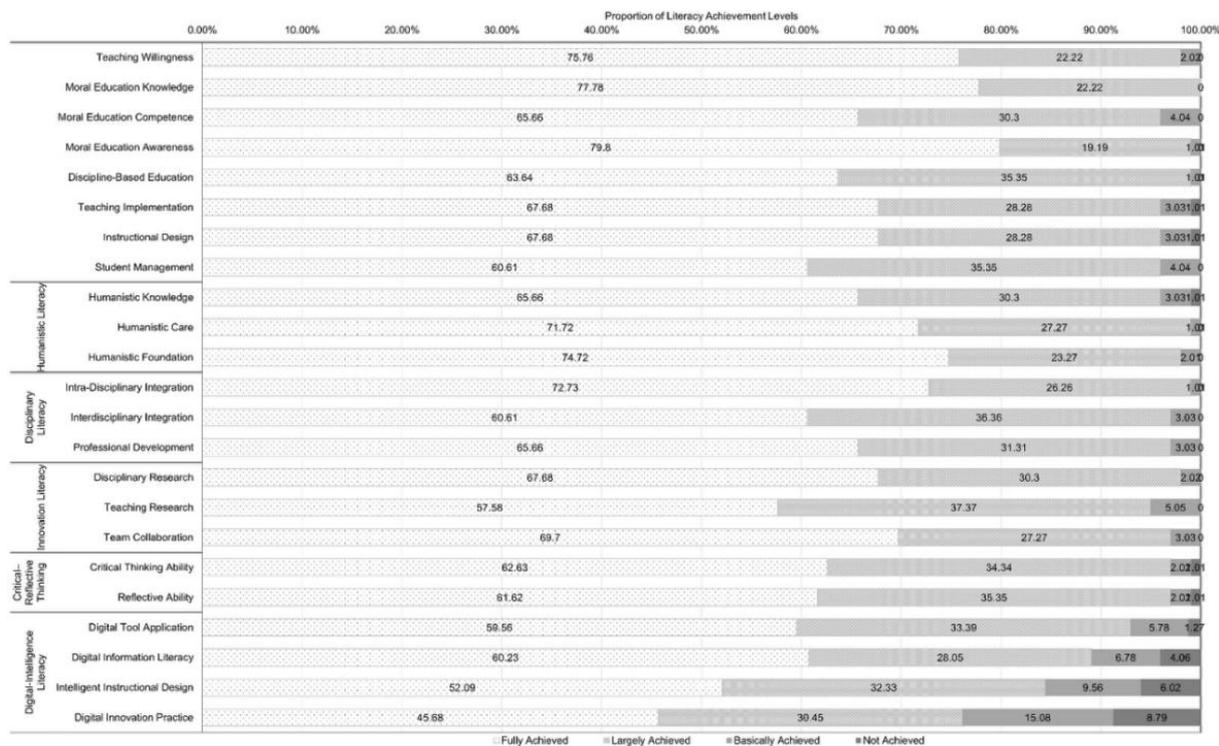
Proportion of Literacy Achievement Levels

Indicator	Fully Achieved	Largely Achieved	Basically Achieved	Not Achieved
Teaching Willingness	75.76	22.22	2.02	
Moral Education Knowledge	77.78	22.22	0	
Moral Education Competence	65.66	30.3	4.04	0
Moral Education Awareness	79.8	19.19	1.01	
Discipline-Based Education	63.64	35.35	1.01	
Teaching Implementation	67.68	28.28	3.03	1.01
Instructional Design	67.68	28.28	3.03	1.01
Student Management	60.61	35.35	4.04	0
Humanistic Knowledge	65.66	30.3	3.03	1.01
Humanistic Care	71.72	27.27	1.01	
Humanistic Foundation	74.72	23.27	2.01	
Intra-Disciplinary Integration	72.73	26.26	1.01	
Interdisciplinary Integration	60.61	36.36	3.03	
Professional Development	65.66	31.31	3.03	
Disciplinary Research	67.68	30.3	2.02	
Teaching Research	57.58	37.37	5.05	
Team Collaboration	69.7	27.27	3.03	
Critical Thinking Ability	62.63	34.34	2.02	1.01
Reflective Ability	61.62	35.35	2.02	1.01
Digital Tool Application	59.56	33.39	5.78	1.27
Digital Information Literacy	60.23	28.05	6.78	4.06
Intelligent Instructional Design	52.09	32.33	9.56	6.02
Digital Innovation Practice	45.68	30.45	15.08	8.79

Figure 7. Competency attainment of geography pre-service teachers after reform (Class of 2025)

4.2.1 Educational literacy

Career commitment and rule awareness were strong overall. The combined proportion of "fully achieved" and "well achieved" exceeded 95% for most indicators. However, instructional design and instructional implementation each showed a small proportion (1.01%) of non-attainment, indicating the need for further reinforcement of practical classroom organization and instructional execution.

4.2.2 Subject literacy

Intra-disciplinary integration showed a very high attainment rate (99.03%), while interdisciplinary integration remained a relative weakness, with a "fully achieved" rate of 60.61%. This suggests the need for more demanding interdisciplinary instructional tasks.

4.2.3 Humanistic literacy

Graduates demonstrated solid cultural grounding, though translating humanistic understanding into observable classroom care and student support behaviors requires further strengthening.

4.2.4 Innovation literacy

Collaborative capacity was strong, whereas instructional research—particularly research design and application—remained the weakest component within this dimension.

4.2.5 Critical thinking

Overall attainment was satisfactory, though higher-level analytical judgment and structured reflection warrant continued attention.

4.2.6 Digital-intelligence literacy

Basic digital tool use was stable, while intelligent instructional design and digital innovation practice showed lower attainment, indicating limited ability to embed digital technologies into instructional problem-solving.

4.3 Comparative Analysis of Pre- and Post-Reform Outcomes

Across all six competency dimensions, the Class of 2025 demonstrated higher average attainment than the Class of 2024 (Figure 8). Educational literacy and subject literacy remained consistently strong across cohorts, while digital-intelligence literacy showed improvement but remained comparatively weaker.
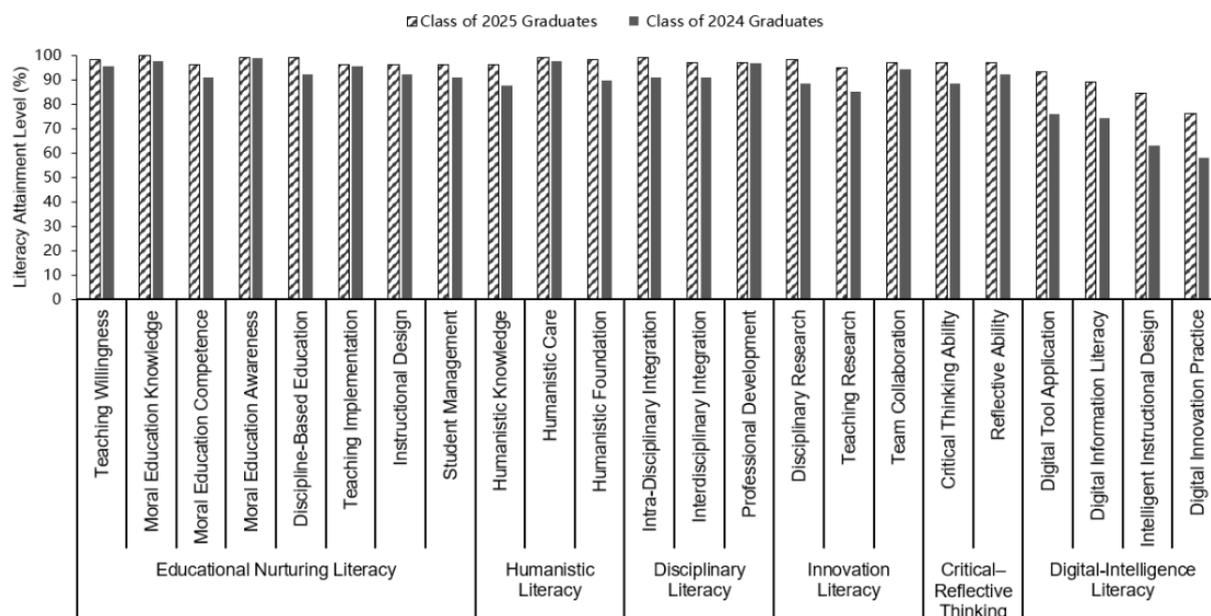

Figure 8. Comparison of competency attainment before and after reform

These findings indicate that the reform measures contributed to observable progress across competency dimensions, while also highlighting the need for sustained attention to advanced digital integration and instructional innovation.

4.4 Research Design and Methods

This study employed a mixed methodological approach combining design-based research with quasi-experimental comparison to examine the implementation process and outcomes of geography teacher education reform in the digital-intelligence era. The Geography Science teacher education program at Beibu Gulf University served as the empirical context.

Graduates from the Class of 2024 were designated as the pre-reform comparison group, while the Class of 2025 constituted the post-reform group. The two cohorts shared comparable admission backgrounds, training objectives, and graduation requirements, supporting the validity of comparative analysis.

Data were collected through an anonymous questionnaire administered prior to graduation. The DISHEL-CT-based competency assessment scale was used to measure attainment across six dimensions. Reliability and validity were examined using Cronbach's alpha and KMO tests, confirming satisfactory internal consistency and structural adequacy. Descriptive statistical analysis was conducted to compare competency attainment between cohorts, providing empirical support for evaluating reform outcomes in authentic educational settings.

5. Conclusions and Discussion

5.1 Conclusions

In response to the reform demands of teacher education in the digital-intelligence era, this study focuses on the professional competence and long-term development of geography pre-service teachers. It argues that new-generation geography teachers should develop a coordinated competency structure encompassing digital-intelligence literacy, humanistic literacy, innovation literacy, critical thinking, subject literacy, and educational literacy. On this basis, the study proposes the DISHEL-CT competency framework to address the core question of what kind of teachers should be cultivated in contemporary teacher education.

Building on this framework, a three-dimensional teacher education model—technology empowerment, competency foundation, and practice-oriented innovation—is constructed. Within this model, technology

empowerment functions as the driving mechanism by providing systematic support across the teaching process; competency foundation serves as the structural core by organizing multidimensional professional competencies; and practice-oriented innovation operates as a key bridge that facilitates the transformation of disciplinary knowledge into professional teaching competence through authentic or highly simulated tasks.

Using the Geography Education program at Beibu Gulf University as a pilot case, the study reorganizes the curriculum around geography teaching practice as the central axis. Through the coordinated restructuring strategy of dual foundations, three extensions, and four modules, a curriculum structure aligned with the DISHEL-CT competency framework is established. At the instructional level, a double-helix case-based teaching approach is introduced to integrate disciplinary knowledge and teaching practice, alongside a theme-based situational digital-intelligence teaching model supported by digital platforms. Together, these approaches move beyond one-way lecture-centered instruction and support the combined development of digital integration and place-based teaching practices.

The study further formulates a practice model that integrates digital-intelligence support with place-based educational approaches. From the digital perspective, intelligent technologies are embedded throughout teaching, learning, assessment, and instructional management. Specifically, instructional processes incorporate learning diagnostics and immersive support; learning processes are guided by technology-assisted analysis of disciplinary logic and learning pathways; assessment adopts a multi-agent, three-dimensional structure combining classroom learning, out-of-class practice, and outcome-based evaluation; and instructional management relies on coordinated digital platforms for resources, assignments, and practice outputs. From the place-based perspective, regional resources in Guangxi are incorporated into curriculum design and instructional cases. Through a value-oriented pathway that emphasizes understanding historical contexts, analyzing current regional challenges, and considering future development, issues such as regional development, ecological protection, and public responsibility are embedded into geography teaching tasks. This approach supports the development of professional responsibility, regional awareness, and a global perspective, while offering a feasible pathway for addressing challenges related to limited teacher supply and constrained educational resources in underdeveloped regions.

To evaluate the effectiveness of the reform, a DISHEL-CT–based competency assessment scale was developed and applied to compare two cohorts of graduates before and after the reform. The results indicate that curriculum restructuring and instructional innovation are associated with clear improvements in overall competency development, while also revealing existing strengths and limitations. Educational literacy and subject literacy remain consistently strong and represent relative advantages. Digital-intelligence literacy, interdisciplinary integration, and teaching research competence show noticeable progress compared with the pre-reform cohort, but continue to constrain further quality improvement. Across both cohorts, educational literacy and subject literacy demonstrate attainment levels above 0.9, with teaching commitment ranking highest among all indicators, reflecting strong professional identification. Subject literacy is characterized by solid disciplinary integration, while humanistic literacy is supported by a stable cultural foundation. At the same time, digital-intelligence competencies remain uneven, particularly in intelligent lesson design and digital innovation practice; interdisciplinary integration shows limited transfer to instructional implementation; and advanced teaching research abilities related to project design and result transformation require further development.

5.2 Discussion

Although the integrated framework of technology empowerment, competency foundation, and practice-oriented innovation implemented in the Geography Education program at Beibu Gulf University has yielded observable progress in multidimensional competency development and teaching readiness, several challenges and constraints remain when considering sustainability, long-term adaptability, and contextual alignment. These limitations point to key directions for future refinement.

5.2.1 Deep-seated constraints in digital-intelligence competency development

Digital-intelligence competency development has progressed from a lack of systematic training to the establishment of basic operational capacity; however, limitations persist in both depth and scope. The post-reform cohort continues to exhibit lower overall attainment in this dimension compared with other competencies, with particular weaknesses in intelligent instructional design and digital innovation practice. This pattern suggests that while pre-service teachers are able to operate basic digital tools, they face difficulties in integrating technologies such as artificial intelligence and data-driven methods into subject-specific teaching practices.

This challenge reflects the need for continuous training sequences that link technological understanding, instructional design, classroom implementation, learning evidence, and assessment feedback. Two structural factors contribute to this constraint. First, limitations in faculty interdisciplinary capacity reduce opportunities for high-quality modeling. Approximately 90% of faculty members have single-discipline backgrounds, only 10% possess combined expertise in geography and information technology, and 85% have not received systematic training in educational technology applications. As a result, instructional demonstrations often emphasize tool use

rather than deep pedagogical integration. Second, the technological readiness of practice settings constrains transfer. Despite the establishment of teaching practicum sites, many county-level schools exhibit limited use of smart classroom systems, and some lack access to intelligent instructional tools. This gap restricts opportunities for authentic digital-intelligence teaching practice and contributes to misalignment between university preparation and workplace demands.

5.2.2 Practical barriers to interdisciplinary integration

Although the reform highlights the importance of interdisciplinary integration, translating this principle into instructional practice remains challenging. Assessment results show that while disciplinary integration within geography achieves consistently high attainment, interdisciplinary integration lags. This contrast indicates that pre-service teachers demonstrate stable strengths in organizing geography knowledge but encounter difficulties when addressing tasks that require cross-disciplinary transfer and contextual application.

Two primary constraints account for this pattern. On the curriculum level, interdisciplinary components are often introduced through elective courses or thematic lectures rather than through structured modules organized around real-world geographic problems supported by multiple disciplinary perspectives. In addition, the absence of a sustainable interdisciplinary case repository limits opportunities for repeated practice. On the instructional level, although core practice theory emphasizes high-leverage teaching activities, existing training primarily targets general skills such as classroom management and questioning strategies, rather than systematic preparation for interdisciplinary lesson design and evaluation.

5.2.3 Limitations of the assessment system for capturing higher-order competencies

The multi-agent, three-dimensional assessment system developed in this study marks a shift from outcome-focused evaluation to a combined process-and-outcome approach. Nevertheless, challenges remain in indicator precision, tool alignment, and dynamic adjustment mechanisms. Current assessment indicators provide limited evidence for higher-order competencies. For example, critical thinking is often evaluated through classroom interaction measures or questionnaire items, which insufficiently capture evidence-based analysis, instructional revision, or data-supported reasoning.

Furthermore, although learning behavior data are incorporated into formative assessment, intelligent assessment technologies are not yet fully utilized to construct comprehensive competency profiles. Implicit competencies such as value-oriented instruction and humanistic concern remain difficult to capture through automated or multi-source evidence, leading to continued reliance on subjective judgment. Future improvements require clearer alignment between evidence types, intelligent assessment tools, and feedback mechanisms that directly inform instructional refinement.

5.3 Limitations and Implications

5.3.1 Limitations

Several limitations of this study should be acknowledged. First, the sample is drawn from a single institution and a single disciplinary program. Although the pre- and post-reform cohorts are comparable, the generalizability of the findings to other regions or types of teacher education institutions requires further validation through multi-site or multi-sample studies. Second, the assessment relies primarily on self-reported questionnaire data. Despite acceptable reliability and validity, such data may be influenced by social desirability effects, and additional evidence sources—such as classroom observation, teaching artifact analysis, or third-party evaluation—were not systematically incorporated. Third, the evaluation focuses on outcomes at the point of graduation, without longitudinal tracking of graduates' instructional practices or professional development after entering the workforce. The sustainability and transfer of reform outcomes therefore remain to be examined.

5.3.2 Implications

Despite these limitations, the study offers several implications for teacher education reform in the digital-intelligence era. First, the findings suggest that expanding technology-related coursework alone is insufficient for developing higher-level digital-intelligence competencies. Greater emphasis should be placed on continuous training sequences that connect technology use with instructional design, learning evidence, and assessment feedback through authentic teaching tasks. Second, interdisciplinary competency development may benefit from a shift from additive course arrangements to problem-driven instructional modules organized around real geographic issues supported by multiple disciplinary approaches. Third, assessment systems would benefit from further integration of intelligent tools and multi-source evidence to improve the identification and feedback of higher-order and implicit competencies.

From a broader perspective, the proposed technology empowerment–competency foundation–practice-oriented innovation framework and the DISHEL-CT competency structure provide a feasible reference for teacher education reform in contexts with constrained educational resources. The findings contribute to ongoing

discussions on how regional teacher education programs can respond to the demands of digital-intelligence transformation while maintaining disciplinary depth and educational responsibility.

Funding

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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