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A Study on the Pathway for Developing Pre-Service Primary School Teachers' Interdisciplinary Teaching Competence Based on Knowledge Anchors

Xiaobo Wang[1]*, Liping Wang[2]

[1]Department of Humanities and Arts, Xi'an Fanyi University, Xi'an 710105, Shaanxi, China
[2]Sipo Primary School, Xi'an 710102, Shaanxi, China

Corresponding author: Xiaobo Wang, 79141609@qq.com

Abstract: With the deepening of curriculum reforms in basic education, interdisciplinary teaching has gradually become an important means to enhance students' core competencies, and teachers' interdisciplinary teaching competence (ITC) has become a core element of the curriculum reform. Pre-service primary school teachers, as the future backbone of education, play a crucial role in the development of ITC. Knowledge anchors, as a framework that integrates subject knowledge and local cultural resources, provide a new perspective and approach to teacher competence development by linking real-world problems with disciplinary knowledge. Based on theories of ITC and knowledge integration, this paper proposes a pathway for developing pre-service primary school teachers' ITC from the perspectives of cognitive restructuring, curriculum design, instructional practice, and assessment mechanisms. The pathway is explored with the integration of Shaanxi's local cultural resources, with research findings indicating that this approach not only effectively promotes the enhancement of pre-service teachers' ITC but also provides feasible theoretical and practical support for educational reform.

Keywords: Knowledge anchors; Pre-service primary school teachers; Interdisciplinary teaching competence (ITC); Interdisciplinary education; Competence development pathways

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1. Introduction

1.1. Research background

As global educational reforms continue to deepen, interdisciplinary teaching has become one of the key approaches to enhancing students' core competencies. Interdisciplinary teaching not only helps students acquire knowledge but, more importantly, fosters their ability to solve complex problems, think critically, and innovate [1]. Recent educational reform research generally emphasizes student-centered learning approaches, advocating for

inquiry-based teaching strategies such as project-based learning to promote the development of 21st-century core skills in students. As a teaching model guided by real-world problems and contexts, project-based learning emphasizes interdisciplinary knowledge integration, which can effectively enhance students' critical thinking, creativity, and collaboration skills—key competencies that are highly valued in current educational evaluation systems [2]. Against this background, interdisciplinary teaching has become a core issue in basic education reform, and teachers' interdisciplinary teaching competence (ITC) has become an important component of educational practice and theoretical research.

Teachers' interdisciplinary competence requires them not only to master knowledge in a single discipline but also to have the ability to integrate content from different subjects effectively [3]. Developing this competence, especially during the pre-service teacher education phase, is crucial for the teaching quality of future frontline teachers. The cultivation of ITC is one of the key aspects of teacher education reform. It involves not only the techniques of knowledge integration but also how to design tasks, guide students in transferring interdisciplinary knowledge, and achieve effective integration across multiple disciplines [4].

However, many teacher training programs, both domestically and internationally, still prioritize disciplinary knowledge, with insufficient systematized interdisciplinary education design. The popularization of interdisciplinary teaching concepts and the enhancement of teachers' abilities still face significant challenges. Some teachers mistakenly view interdisciplinary teaching as a simple addition of subject content, neglecting the deeper integration and intrinsic connections between subjects, which makes effective implementation of interdisciplinary teaching in the classroom difficult [5]. Additionally, pre-service teachers still lack sufficient interdisciplinary competence in educational practice, with common issues such as a disconnect between teaching practice and theory, and an incomplete feedback mechanism in the process of ability development.

1.2. Research questions

The cultivation of interdisciplinary competence in pre-service primary school teachers still faces numerous challenges, primarily reflected in the following aspects:

(1) Structural issues in the education system: The pre-service teacher education curriculum still lacks comprehensive interdisciplinary courses. The curriculum mainly focuses on the one-dimensional transmission of subject knowledge, with insufficient effective interdisciplinary teaching design. Interdisciplinary teaching has not been organically integrated into the existing curriculum system, resulting in teachers' difficulty in integrating and applying knowledge from multiple disciplines in practice [6].

(2) Cognitive biases and disconnect with teaching practice: Some pre-service teachers have misconceptions about interdisciplinary teaching, limiting it to a simple addition of subjects, and lacking understanding of the deep logic of interdisciplinary integration. This cognitive bias restricts the development of teachers' competencies, making it difficult for them to design effective interdisciplinary tasks in actual teaching [7].

(3) Absence of teacher development pathways: Although some pre-service education programs have begun to introduce interdisciplinary teaching concepts, the current teacher development pathways are often limited to the strategy level, lacking deep instructional design and theoretical support. Teachers' mastery of ITC is often reliant on external training and teaching experience, lacking a systematic and sustainable development pathway [8].

1.3. Research significance

This study aims to explore the pathway for developing pre-service primary school teachers' ITC based on knowledge anchors, providing theoretical support and practical solutions for the cultivation of ITC in pre-service teacher education. Knowledge anchors, as the core support for connecting disciplinary knowledge with real-world problems, can help teachers break down barriers between subjects, offering a framework and pathway for integrating interdisciplinary knowledge [9]. By introducing the concept of knowledge anchors, this study will explore how to organically combine subject knowledge with local cultural resources in teacher education systems, promoting the overall enhancement of teachers' ITC.

Specifically, the significance of this research lies in the following aspects:

(1) Theoretical innovation: This study systematically introduces the concept of "knowledge anchors" into pre-service teacher education systems, providing a new perspective for the theoretical development of teachers' ITC by constructing a structural model for interdisciplinary capability.

(2) Practical value: By constructing a pathway for developing interdisciplinary teaching competence based on knowledge anchors and integrating Shaanxi's local cultural resources, this study provides an operational model for teacher education reform, effectively enhancing pre-service teachers' ITC and supporting local educational development.

(3) Educational reform: The proposed development pathway can provide educational administrators with a systematic teacher competence development plan, driving the reform and optimization of teacher education systems, particularly in cultivating ITC to meet the demands of future educational reforms.

1.4. Research goals and methods

The core goal of this study is to construct a pathway for developing pre-service primary school teachers' ITC based on knowledge anchors and to verify its effectiveness through empirical research. The specific goals include:

(1) Clarifying the components of pre-service primary school teachers' ITC and, in conjunction with knowledge anchor theory, defining its core dimensions and internal relationships.

(2) Constructing a model for developing ITC based on knowledge anchors, which includes cognitive restructuring, curriculum design, instructional practice, and assessment mechanisms.

(3) Empirically validating the effectiveness of the developed pathway and assessing its actual impact on enhancing teachers' ITC and professional development.

This study employed a mixed-methods research approach, beginning with a systematic literature review and theoretical analysis to construct a competency framework and theoretical model for the development pathway. Subsequently, data were collected through questionnaires, interviews, and teaching experiments, and the empirical data were analyzed using descriptive statistics and qualitative analysis methods to test the practicality and scalability of the pathway.

2. Theoretical framework

2.1. Interdisciplinary teaching competence theory

Interdisciplinary teaching competence theory focuses on how teachers can effectively integrate knowledge from multiple disciplines during the teaching process to help students transcend disciplinary boundaries and transfer their thinking and abilities when solving real-world problems. This theory advocates that ITC is not limited to the mastery of subject knowledge but emphasizes how teachers design and implement tasks that span multiple

disciplines to cultivate students' comprehensive abilities [10].

In interdisciplinary teaching, the teacher's role shifts from being a mere transmitter of knowledge to becoming a guide and facilitator of the learning process. Teachers need to address the following core elements in interdisciplinary teaching:

(1) Knowledge integration: Teachers need to effectively integrate knowledge from different disciplines to create teaching content that is logical and deep. By integrating knowledge from various fields, teachers can help students better understand the interdisciplinary connections of knowledge, thus fostering students' ability to think about problems from multiple perspectives.

(2) Task design: Teachers should design challenging tasks with interdisciplinary characteristics to stimulate students' interest in learning and innovative thinking. For example, through interdisciplinary project-based learning, students can apply knowledge from different subjects in solving real-world problems, thereby developing critical thinking and teamwork abilities.

(3) Disciplinary transfer: One of the core elements of ITC is disciplinary transfer. Teachers need to help students understand how to transfer knowledge from one discipline to another, thereby establishing an interdisciplinary knowledge system. This not only helps students flexibly apply knowledge from different disciplines in real-life situations but also enhances their ability to solve complex problems.

(4) Cultural integration: Interdisciplinary teaching should not only integrate subject knowledge but also consider the impact of cultural background. In a multicultural context, teachers should integrate local cultural resources with subject content to help students form a cultural identity in the globalized world and achieve cultural understanding and inheritance.

This theoretical framework is not only applicable to interdisciplinary education for senior students but also provides important theoretical support for pre-service teacher education. By cultivating pre-service teachers' interdisciplinary competence, teachers can better address the complex demands of modern education, especially in the context of education focused on core competencies, making this ability particularly important [11].

2.2. Knowledge integration theory

Knowledge integration theory explores how teachers can effectively integrate knowledge from different disciplines and transform it into content that can be taught effectively. The focus of this theory is on how to enhance students' comprehensive abilities through the fusion and integration of knowledge, rather than relying solely on the individual knowledge points of a single discipline. The task of the teacher is to identify the connections between disciplines and, by designing integrative learning tasks, help students apply knowledge from different disciplines flexibly when solving problems [12].

In interdisciplinary teaching, teachers not only need to deeply understand the knowledge of each discipline but also need to be able to identify the connections between disciplines and base their teaching content on these links. The key to integration lies in how teachers discover the intersection points between disciplines and use these points to design effective teaching, allowing students to establish an organic knowledge network through multi-disciplinary learning.

In the process of knowledge integration, teachers also need to focus on the issue of knowledge transfer between disciplines. By designing interdisciplinary tasks, teachers can help students apply the learning outcomes from one subject to a new discipline. This transfer not only helps students establish an interdisciplinary knowledge system but also enhances their ability to solve real-world problems.

Knowledge integration theory not only focuses on the integration of subject knowledge but also emphasizes cultural integration. In the context of globalization and multiculturalism, teachers should consider

local cultural elements in interdisciplinary teaching and integrate them with subject content, thereby enhancing students' cultural identity and multicultural understanding [13]. This cultural integration not only helps students better understand interdisciplinary content but also helps them better integrate and develop in a multicultural society.

The significance of knowledge integration theory for teacher education lies in the fact that it not only requires teachers to have the ability to integrate knowledge from different disciplines but also emphasizes how teachers design tasks to promote students' transfer of learned knowledge and effectively apply it to real-world problems. This theory provides a solid theoretical foundation for interdisciplinary education and offers a clear path for pre-service teacher education [14].

2.3. Knowledge anchors

The knowledge anchors theory, as a new teaching framework, primarily explores how to integrate knowledge with real-world problems to help teachers better consolidate multidisciplinary knowledge in their teaching. Knowledge anchors, as the core support points connecting disciplinary knowledge with real-world issues, can help teachers establish a stable teaching framework in interdisciplinary teaching, thus enhancing teachers' ITC [15].

As an important tool in interdisciplinary teaching, knowledge anchors help teachers link subject knowledge with real-world contexts, thereby improving the practicality and interactivity of teaching. Through knowledge anchors, teachers can pose specific questions in their teaching and guide students to explore and solve these problems from various disciplinary perspectives.

One notable feature of knowledge anchors is their ability to integrate disciplinary knowledge with local cultural resources. For instance, Shaanxi's Qin culture, intangible cultural heritage, and other local resources can serve as carriers of knowledge anchors. In this way, teachers not only help students understand subject knowledge but also enable them to perceive the diversity and richness of culture. Through such integration, teachers can design teaching content that is locally distinctive and interdisciplinary, enhancing students' cultural literacy and interdisciplinary thinking abilities [16].

In pre-service teacher education, knowledge anchors can help teachers understand the essence of interdisciplinary teaching. By designing tasks centered around knowledge anchors, teachers can organically combine subject knowledge with real-world problems, thereby improving students' comprehensive abilities. Knowledge anchors not only aid in the organization and integration of teaching content but also enhance teachers' teaching efficiency and quality in the classroom [17].

By combining interdisciplinary teaching competence theory, knowledge integration theory, and the knowledge anchors theory, this research provides a solid theoretical framework for developing pre-service primary school teachers' ITC. These theories emphasize not only the integration and transfer of knowledge but also the fusion and application of local cultural resources, which promotes the comprehensive enhancement of teachers' interdisciplinary teaching abilities. By introducing knowledge anchors as a teaching tool, teachers can effectively design and implement interdisciplinary tasks, providing students with a richer learning experience, thus offering both theoretical and practical support for educational reform in basic education.

3. Literature review

Interdisciplinary teaching competence refers to a teacher's ability to integrate knowledge and methods from multiple disciplines to design and implement interdisciplinary teaching activities in real-world problems and complex situations. It also involves guiding students to achieve knowledge transfer, ability development, and

value identification as part of their comprehensive literacy [18]. In recent years, interdisciplinary teaching has gradually shifted from being a conceptual idea to classroom practice. However, studies generally indicate that whether interdisciplinary teaching can be effectively implemented depends on whether teachers possess structured ITC and whether teacher education programs have developed systematic, replicable training mechanisms [19]. Therefore, it is necessary to examine domestic and international research from three dimensions: "current situation diagnosis–strategy comparison–theoretical progress," to lay a theoretical and empirical foundation for constructing the "knowledge anchor-based pathway model for developing pre-service primary school teachers' interdisciplinary teaching competence."

3.1. Current status and issues of pre-service teachers' interdisciplinary teaching competence

Existing research generally finds that the development of pre-service teachers' ITC shows a pattern of "high conceptual recognition, insufficient ability, and weak practical preparation" [4]. Especially in the context of primary education, where interdisciplinary teaching emphasizes comprehensiveness, real-life applicability, and inquiry-based learning, pre-service teachers often struggle to make the transition from "understanding the concept of interdisciplinary teaching" to "developing interdisciplinary teaching design competence." The main challenges lie in the cognitive, ability, resource, and mechanism levels.

(1) Cognitive level: Interdisciplinary understanding tends to remain at the "mosaic-style addition" level

While some pre-service teachers recognize the importance of interdisciplinary teaching, they often lack the ability to discern its deeper meanings and tend to misinterpret the "presence of multiple disciplines" as "complete interdisciplinary integration." This leads to fragmented and superficial lessons in the classroom [20]. This cognitive bias directly weakens the authenticity and problem orientation of interdisciplinary tasks, making it difficult to form a deep structure of "disciplinary integration–cognitive enhancement–ability generation" in the classroom.

(2) Ability level: Insufficient knowledge integration and task design abilities

The core of interdisciplinary teaching is not about adding more content to lessons, but about reconstructing the knowledge structure around real-world problems, thereby forming a comprehensive task and learning activity chain. However, research indicates that pre-service teachers commonly lack the ability to organize multidisciplinary knowledge, generate problem tasks, and design effective teaching assessments. In actual lesson planning, this often manifests as overly broad topic selection, forced disciplinary integration, and a lack of progression in learning tasks, making it difficult to achieve the goals of interdisciplinary teaching [21].

(3) Resource level: Lack of stable, supportive contextual and cultural resource conversion mechanisms

Interdisciplinary teaching requires rich, real, and sustainable contextual resources. Studies have shown that pre-service teachers often rely on online materials or extended textbooks for interdisciplinary resources, lacking the ability to develop local cultural and life resources educationally [22]. The lack of resources further results in interdisciplinary teaching designs lacking authenticity and local relevance, which also weakens students' cultural understanding and emotional engagement.

(4) Mechanism level: Fragmented curriculum structure, weak evaluation, and feedback mechanisms

Research indicates that the development of pre-service teachers' interdisciplinary competence still faces issues such as "fragmented curriculum modules," "insufficient practical mechanisms," and "lack of evaluation tools" [23]. The formation of ITC requires continuous training, reflection, and iterative improvement. However, many training programs remain limited to short-term activities or single

training sessions, lacking formative evaluation and diagnostic support, making it difficult to form a progression in competencies.

To clearly present the research conclusions, the main issues in the development of pre-service teachers' ITC are summarized in **Table 1**.

Table 1. Summary of current issues in the development of pre-service primary school teachers' interdisciplinary teaching competence

Issue dimension	Main manifestation	Typical outcome	Supporting research
Cognitive level	Understanding interdisciplinary teaching as a "subject platter" or "activity addition"	Teaching integration remains superficial, lacking a problem chain	[24]
Ability level	Weak knowledge integration, weak task design, weak transfer support	Fragmentation and superficiality of interdisciplinary teaching	[25]
Resource level	Insufficient contextual resources, difficulty in converting local cultural resources	Lack of real tasks and cultural support	[26]
Mechanism level	Scattered development pathways, absence of evaluation and feedback	Difficulty in sustaining and optimizing competence	[27]

3.2. Comparison of domestic and international training models and strategies

From an international research perspective, the cultivation of ITC is typically placed within the framework of teacher professional development, with the main pathways being "curriculum integration–real-world tasks–collaborative co-construction–evidence-based evaluation," emphasizing the systemic and sustainable nature of the training mechanism [28]. In comparison, while domestic pre-service teacher training has gradually gained more attention in recent years, it is still in the exploratory stage regarding curriculum systems, practical environments, and evaluation mechanisms [29].

(1) International research: Emphasizing interdisciplinary course organization and task-driven learning mechanisms

More developed international training models often use approaches such as project-based learning, inquiry-based learning, and STEM-integrated curricula to train interdisciplinary competencies. These models allow pre-service teachers to learn how to integrate knowledge within tasks and form an evidence chain for evaluation through classroom performance, project outcomes, and reflective logs, thereby promoting the iterative development of competencies [30]. A common characteristic of this research is the emphasis on real-world contexts, the logic of disciplinary integration, and the feedback loop of practical evidence and evaluation.

(2) Domestic research: Emphasizing conceptual guidance, but lacking systematic training and evaluation tools

Domestic research on pre-service teacher interdisciplinary training mostly focuses on the explanation of interdisciplinary concepts, the construction of teacher competence models, and strategy suggestions. However, it remains relatively weak in terms of the continuity of training pathways, the progression of curriculum modules, and the accessibility of classroom practices [31]. Moreover, constrained by the curriculum structure of teacher training institutions, limited practical resources, and a lack of interdisciplinary teaching staff, the training often shows a "many project-based attempts, weak normalization mechanisms" pattern.

To clarify the comparison, the domestic and international training strategies are summarized in **Table 2**.

Table 2. Comparison of domestic and international strategies for developing pre-service teachers' interdisciplinary teaching competence

Comparison dimension	Common practices abroad	Common situation in China	Key differences
Course organization	Normalization of interdisciplinary course modules, project-driven	Discipline-based courses dominate, interdisciplinary courses are fragmented	Lack of systematization
Teaching methods	PBL, inquiry-based learning, continuous training with real tasks	Primarily case-based teaching and short-term activities	Insufficient depth in practical training
Collaboration mechanisms	Teacher team collaboration, interdisciplinary co-planning	Weak interdisciplinary collaboration, homogeneous teacher backgrounds	Lack of professional support
Evaluation methods	Rubric-based evaluation + project evaluation + process evidence chain	Emphasis on results with weak process focus and feedback mechanisms	Insufficient diagnostic functions

3.3. Research progress on knowledge anchors and interdisciplinary teaching

In recent years, interdisciplinary teaching research has gradually shifted from "strategy advocacy" to "mechanism construction," focusing on how teachers can achieve disciplinary integration, meaning construction, and knowledge transfer in the realm of instructional design [32]. Against this background, "knowledge anchors" have gradually become an important conceptual resource for explaining how interdisciplinary teaching can achieve "deep integration."

(1) Knowledge anchors as a "structural mediator" for interdisciplinary integration

The challenge of interdisciplinary teaching lies not in the "appearance of multiple disciplines," but in whether a central problem or core concept can be formed to unify multiple disciplines. This shifts teaching organization from "disciplinary parallelism" to "knowledge aggregation around real-world tasks" [33]. Knowledge anchors, with their characteristics of "connectivity, contextuality, and drive," can serve as structural support for interdisciplinary teaching: they can transform local cultural resources or key disciplinary concepts into central nodes that can be invoked in teaching design, thereby driving the overall organization of teaching content.

(2) Knowledge anchors facilitate knowledge integration and disciplinary transfer mechanisms

From the perspective of knowledge integration theory, the key to forming interdisciplinary competence lies in whether teachers can achieve "structured organization–contextual expression–task-based application" of knowledge [34]. Knowledge anchors provide visual and operable core knowledge points, enabling teachers to build interdisciplinary knowledge networks around these anchors. Through a progressive task chain, teachers guide students to transfer knowledge to new contexts, thus achieving deep learning and competency development.

(3) Integration of knowledge anchors with local cultural resources to enhance the locality and educational value of interdisciplinary teaching

Existing research emphasizes that interdisciplinary teaching should be rooted in real-world contexts and life experiences to form a sustainable, understandable, and transferable learning process [35]. Shaanxi, for example, has rich cultural resources such as Qin culture, intangible cultural heritage, and regional ecology, which have natural advantages for transformation into knowledge anchors. Refining local cultural resources into knowledge anchors not only provides real-world carriers for interdisciplinary tasks but also fosters cultural understanding, value identification, and the simultaneous development of disciplinary competence, thus reflecting the comprehensive educational value of interdisciplinary teaching.

3.4. Review of this study and research gaps

As discussed, both domestic and international research have explored the value, pathways, and teacher competence models of interdisciplinary teaching from different perspectives, but there are still the following deficiencies:

(1) At the pre-service teacher stage, interdisciplinary competence training lacks "operable intermediary mechanisms." Existing pathways often emphasize strategies and models, but there is insufficient explanation on "how to organize interdisciplinary knowledge structures."

(2) The course design for interdisciplinary teaching still lacks "replicable structured plans." Especially in primary education, interdisciplinary activities are often driven by experience, making them difficult to implement consistently.

(3) The systematic conversion logic for integrating cultural resources into interdisciplinary teaching is still lacking. While local cultural resources are abundant, the "anchoring mechanism" to transform these resources into teaching tasks requires further development.

Therefore, this study attempts to use knowledge anchors as the core intermediary, combining ITC theory and knowledge integration theory, to construct an integrated "cognitive–curriculum–task–evaluation" development pathway. This aims to provide a more explanatory and operable solution for the cultivation of pre-service primary school teachers' ITC.

4. Constructing the knowledge anchor-based pathway

In the process of developing pre-service primary school teachers' ITC, the knowledge anchor-based pathway forms a complete competency development system through the combination of cognitive restructuring, curriculum design, instructional practice, and assessment mechanisms. This system not only relies on the integration of disciplinary knowledge but also fully incorporates Shaanxi's local cultural resources, ensuring the integration of educational practice with local characteristics and promoting the regional and innovative aspects of teacher education.

4.1. Cognitive restructuring: Cultivating interdisciplinary cognition and knowledge integration abilities

The effective implementation of interdisciplinary teaching first requires teachers to undergo a deep cognitive restructuring regarding interdisciplinary teaching. Pre-service teachers often view interdisciplinary teaching as a simple addition of subject knowledge, neglecting the deeper integration and organic fusion of knowledge across disciplines [24]. Therefore, the cognitive restructuring should begin with the following aspects:

(1) Building the interdisciplinary cognitive framework: First, by introducing knowledge anchors, teachers can extract interdisciplinary teaching nodes from local culture and core subject knowledge. For example, elements of Shaanxi's Qin culture can be integrated with mathematics, history, and art courses, enabling teachers to understand and practically apply the "culture–subject–task" organic fusion.

(2) Integrating and transferring multidisciplinary knowledge: During cognitive restructuring, teachers should be guided to understand how to link knowledge from different disciplines in teaching and help students transfer the knowledge they have learned across disciplines. For instance, paper-cutting art is not only part of the art curriculum but can also be linked to geometry and cultural history. Through this method, students can solve problems in interdisciplinary contexts.

Through cognitive restructuring, teachers can gain a profound understanding of the essence of

interdisciplinary teaching and carry out effective knowledge integration in their teaching practice.

4.2. Curriculum design: Developing interdisciplinary courses integrating local cultural resources

Curriculum design is the core component of interdisciplinary teaching. This study advocates for designing interdisciplinary courses that integrate Shaanxi's local cultural resources, enabling teachers to cultivate interdisciplinary teaching abilities while offering students an educational experience with local characteristics.

(1) Course module design: Course design should incorporate Shaanxi's rich cultural resources. For example, the historical background of the Terracotta Warriors can be combined with the "geometric shapes" in mathematics or the "timeline" in history, designing a multidisciplinary project task. Through such tasks, students can not only learn about historical culture but also find real-world applications in subjects such as art and mathematics.

(2) Task-driven and project-based learning design: Curriculum design should cultivate students' interdisciplinary thinking through project-based learning and problem-based learning. For example, an interdisciplinary project based on "Shaanxi traditional handicrafts" can be designed, allowing students to explore and create while applying multidisciplinary knowledge (such as craftsmanship, mathematics, history, and culture), enhancing their critical thinking and innovative abilities.

4.3. Instructional practice: Project-based learning and problem-based learning strategies

Project-based learning and problem-based learning are essential strategies for implementing interdisciplinary teaching. Through these strategies, teachers can help students develop interdisciplinary abilities in real learning contexts.

(1) Project-based learning practice: Teachers can design interdisciplinary project tasks that allow students to integrate multidisciplinary knowledge in real-world tasks. For example, in a project based on "Shaanxi cultural heritage protection," students can research, create, and present from multiple disciplinary perspectives such as art, history, and culture, thereby enhancing their ability to integrate knowledge across disciplines.

(2) Problem-based learning strategy: In problem-based learning, teachers should design challenging learning tasks and guide students to solve specific social or cultural problems, stimulating interdisciplinary thinking. For example, through the issue of Shaanxi cultural heritage protection, teachers can guide students to explore how to solve real-world cultural preservation problems through interdisciplinary knowledge integration.

4.4. Assessment mechanisms: Formative and comprehensive evaluation tool systems

An effective assessment mechanism is key to the continuous improvement of pre-service teachers' ITC. Research indicates that interdisciplinary teaching assessment should focus not only on the "results" of learning outcomes but also on the generation of competencies and knowledge transfer during the learning process.

(1) Formative evaluation tools: Process evaluations can be conducted through classroom observations, teacher feedback, student self-assessments, and peer reviews. Teachers should continuously adjust teaching strategies during the teaching process to ensure that students gradually develop interdisciplinary abilities through the tasks.

(2) Comprehensive evaluation system: A comprehensive evaluation tool should be designed based on the integration of subject knowledge, cultural understanding, interdisciplinary task design abilities, and teaching effectiveness. Through task design, classroom presentations, student projects, and reflection

reports, a comprehensive evaluation ensures that interdisciplinary abilities are assessed from multiple dimensions.

4.5. Development pathway model and feedback mechanism

Based on the above content, the knowledge anchor-based pathway model for developing pre-service primary school teachers' ITC is shown in **Figure 1**.

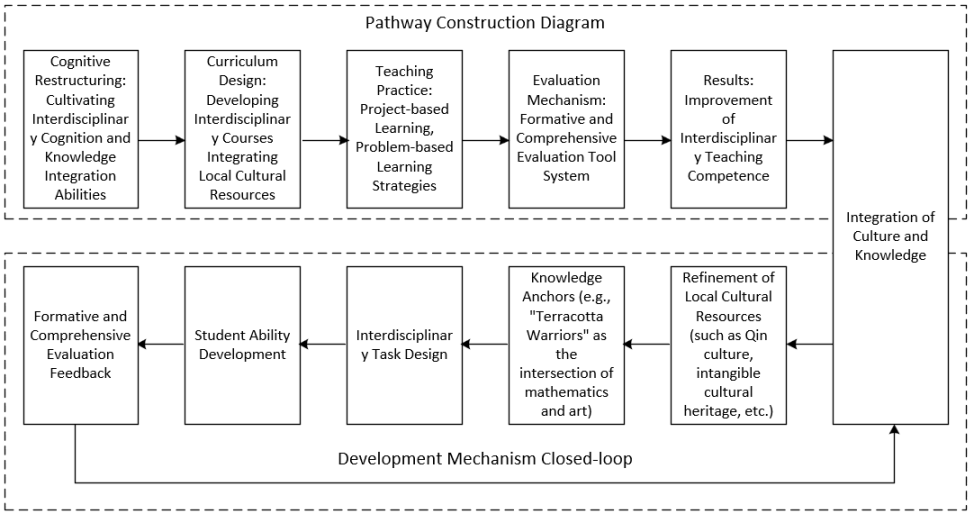

Figure 1. Knowledge anchor-based pathway model for developing pre-service teachers' interdisciplinary teaching competence

Figure 1 shows the knowledge anchor-based pathway model for developing pre-service primary school teachers' ITC. This model promotes the comprehensive development of teachers' interdisciplinary competence through the close integration of four modules: cognitive restructuring, curriculum design, instructional practice, and assessment mechanisms. The core of the pathway lies in the close connection between "local cultural resources–knowledge anchors–interdisciplinary task design," while the integration of comprehensive evaluation and feedback mechanisms forms a closed-loop for the continuous improvement of teaching competence.

Through this knowledge anchor-based competency development pathway model, pre-service primary school teachers can achieve a comprehensive enhancement in areas such as cognitive restructuring, curriculum design, instructional practice, and assessment mechanisms. This model not only provides a systematic theoretical framework for developing pre-service teachers' ITC but also offers a practical pathway for the educational transformation of Shaanxi's local cultural resources. By following this integrated development pathway, teachers can effectively apply their interdisciplinary abilities to classroom teaching, thereby fostering innovation in teacher education and promoting deep development in educational reform.

5. Examples and practical strategies

Interdisciplinary teaching is not only a core aspect of teacher professional development but also a key focus of current basic education curriculum reform. To enhance the operability and transferability of pre-service primary school teachers' ITC, this section offers practical recommendations from three aspects: "task examples–implementation pathways–evaluation tools." On one hand, examples of interdisciplinary task designs

incorporating Shaanxi's local cultural resources are provided as references for transforming knowledge anchors into teaching practices. On the other hand, systematic implementation strategies are proposed, focusing on teaching activity organization, teacher training support, and evaluation feedback mechanisms, ensuring the path's executability and sustainability.

5.1. Example of interdisciplinary teaching task design: Knowledge anchors developed from local cultural resources

The quality of interdisciplinary teaching task design directly determines the depth and effectiveness of interdisciplinary teaching. Based on the concept of knowledge anchors, interdisciplinary tasks should follow the basic structure of "cultural resources–core concepts–real-world problems–learning activity chain," transforming local cultural resources into meaningful knowledge points, thereby guiding students to integrate knowledge and transfer abilities in real-world contexts.

To present the organization of different cultural resources in interdisciplinary tasks, this study selects typical cultural resources from Shaanxi (such as Qin culture, intangible cultural heritage paper-cutting, and the ancient city of Chang'an) to design three types of interdisciplinary task examples. These tasks cover integration pathways across subjects such as mathematics, language arts, art, science, history, and geography. The related combinations of subjects, cultural carriers, task objectives, and educational purposes are summarized in **Table 3**, which can serve as a reference for pre-service teachers' instructional design and classroom presentations.

Table 3. Examples of interdisciplinary teaching task design

Example number	Subjects integrated	Local cultural resources	Task objectives	Educational objectives
Example 1	Mathematics, Art, History	Qin culture, Terracotta Warriors	Learn geometry through geometric shape analysis	Cultivate students' ability to apply mathematics practically and create art, enhance cultural identity
Example 2	Language Arts, Art, Social Science	Paper-cutting art	Learn the combination of paper-cutting and literary creation	Enhance students' aesthetic, creativity, and language expression abilities
Example 3	History, Geography, Science	Ancient city of Chang'an, Ecological environment	Study the impact of the geography and ecosystem of the ancient city of Chang'an	Cultivate students' interdisciplinary knowledge integration and innovative design abilities

5.2. Implementation pathway and practical strategies: Integrated advancement of teaching activities–teacher training–evaluation and feedback

Examples of interdisciplinary teaching tasks provide teachers with references for "how to design" tasks, but to achieve stable improvement in pre-service teachers' ITC, a sustainable implementation mechanism must be established. This means forming a structured collaboration between teaching activity organization, teacher professional support, and evaluation feedback systems. To achieve this, this paper further refines the "knowledge anchor-based development pathway" into three actionable implementation steps: teaching activity design, teacher training and support, and evaluation tools and feedback mechanisms. To enhance the structural clarity and replicability of this presentation, key implementation points are further integrated into **Table 2**, allowing readers to quickly grasp the "what to do–how to do it–what tools to use" practical framework.

5.2.1. Teaching activity design: Task chain organization driven by knowledge anchors

(1) Introducing interdisciplinary themes: Constructing cultural and problem contexts

The effective initiation of interdisciplinary teaching relies on engaging contextual introductions. Teachers can use Shaanxi's cultural resources (such as the Terracotta Warriors, ancient cities, water conservancy sites, and paper-cutting patterns) as "cultural anchors" by establishing learning contexts through images, short videos, physical displays, or storytelling, guiding students to pose questions and develop an inquiry-driven motivation. This facilitates a natural transition from "cultural perception" to "learning tasks."

(2) Task-driven learning: Embedding project-based/problem-based strategies into activity chains

Interdisciplinary tasks should present a clear activity chain structure, including stages such as "posing questions–gathering materials–designing solutions–presenting outcomes–reflection and improvement." Teachers can organize the classroom using project-based learning or problem-based learning, allowing students to apply knowledge from various disciplines to complete research in real-world tasks, thus promoting knowledge integration and the development of competencies.

(3) Cultural element integration: Achieving simultaneous development of disciplinary fusion and cultural understanding

In the implementation of tasks, cultural resources should not merely serve as "background decoration" but should become the core driving force for integrating disciplinary knowledge. For example, paper-cutting patterns are not just part of the art curriculum but can also be connected to concepts in mathematics like symmetry and geometric transformations. Similarly, the ancient city of Chang'an is not only part of history lessons but can also be linked to geographical spatial structures and ecological system analysis, thus achieving the collaborative development of "cultural understanding–knowledge integration–competency enhancement."

5.2.2. Teacher training and support: Enhancing pre-service teachers' implementable interdisciplinary teaching abilities

(1) Training on interdisciplinary teaching concepts: From "understanding" to "designing"

Pre-service teacher training should focus on core elements of ITC, including: methods for refining knowledge anchors, strategies for building interdisciplinary task chains, integrating multidisciplinary knowledge, and using classroom organization and evaluation tools. Training formats could include case discussions, collaborative lesson planning, task breakdowns, and simulation designs to transform theory into practical tools.

(2) Demonstration lessons and peer support: Forming transferable practical experience

Through observation of demonstration lessons and peer evaluations, pre-service teachers can better understand how to implement interdisciplinary tasks. A "demonstration–practice–feedback–improvement" cyclical mechanism is recommended in the training, allowing teachers to accumulate experience in organizing interdisciplinary classrooms through multiple rounds of trial lessons, thus enhancing their adaptability and ability to implement evaluations in the classroom.

5.2.3. Evaluation tools and feedback mechanisms: Forming a "evaluation–improvement" development loop

(1) Formative evaluation: Focusing on process evidence and competency development trajectory

Formative evaluation for interdisciplinary teaching can combine classroom observation records, learning portfolios, self-assessments, peer evaluations, and group collaboration performance to gather process-oriented evidence, focusing on evaluating students' knowledge integration, strategy selection,

collaboration, and expression abilities during tasks.

(2) Comprehensive evaluation system: Reflecting interdisciplinary outcomes and overall competence levels
Comprehensive evaluation should emphasize the quality and innovation of interdisciplinary outcomes. Tools such as project rubric evaluations, outcome presentation scoring sheets, and reflection report evaluation forms can be used to provide structured judgments on students' knowledge transfer and achievement of overall competencies.

(3) Feedback and improvement: Promoting iterative enhancement of teachers' teaching design abilities
Evaluation results should not only be used to assess students but also serve as critical input for teachers to optimize their teaching design. Through the "classroom observation–evaluation results–reflection and revision–secondary implementation" mechanism, pre-service teachers can gradually develop reflective abilities in interdisciplinary teaching and continuous improvement skills, thus creating a stable competency development path.

5.3. Summary

In summary, the knowledge anchor-based interdisciplinary teaching practice requires both task design examples with local cultural features (see **Table 1**) and support from executable, replicable implementation mechanisms (see **Table 4**). By advancing through the pathway of "cultural resource extraction–knowledge anchor construction–interdisciplinary task design–evaluation feedback and improvement," pre-service primary school teachers can achieve gradual development of interdisciplinary teaching abilities in practice, ultimately forming a sustainable implementation plan for basic education classrooms.

Table 4. Knowledge anchor-based interdisciplinary teaching implementation pathway and practical recommendations

Practical step	Key activities	Specific content
Teaching activity design	Introducing interdisciplinary themes	Use local cultural resources to create contexts and trigger inquiry questions
	Task-driven learning	Organize learning activity chains through project-based/problem-based learning, promoting knowledge integration
	Cultural element integration	Transform cultural resources into knowledge anchors to support interdisciplinary integration
Teacher training and support	Concept and tool training	Training in anchor refinement, task chain design, classroom organization, and evaluation tools
	Demonstration lessons and peer support	Demonstration → trial teaching → peer evaluation → improvement, forming practical experience
Evaluation and feedback	Formative evaluation	Classroom observation, portfolios, self-assessment, peer assessment, focusing on process evidence
	Comprehensive evaluation	Project rubrics, outcome presentations, and reflection reports, evaluating overall performance
	Feedback improvement mechanism	Use evaluation results to revise task designs, forming a continuous improvement loop

6. Discussion

This study, based on ITC theory and knowledge integration theory, proposes and constructs a "knowledge anchor-based pathway for developing pre-service primary school teachers' interdisciplinary teaching

competence" and uses Shaanxi's local cultural resources as a key source of knowledge anchors, realizing the contextual and localized expression of ITC development. This paper discusses the effectiveness and process feedback of the implementation, focusing on the advantages and limitations of the pathway, implications for teacher education reform, and directions for future research.

6.1. Advantages and limitations of the implementation pathway

6.1.1. Advantages of the implementation pathway

(1) Enhancing the structure and operability of interdisciplinary integration through knowledge anchors

One of the core challenges in practical interdisciplinary teaching is that the "parallelism of multiple disciplines" can easily lead to a "mosaic-style addition," causing teaching activities to lack a unified central problem. The "knowledge anchors" proposed in this study play a key structural role in the pathway: by refining the connection points between local cultural resources and core disciplinary concepts, they help pre-service teachers form a "central concept–task chain–activity chain" structure for interdisciplinary teaching, making the teaching process less dependent on personal experience and more logically organized. This structured approach effectively enhances the replicability and transferability of interdisciplinary teaching design.

(2) Empowering interdisciplinary teaching with real-world contexts and educational value through cultural resources

Interdisciplinary teaching emphasizes real-world problem contexts, and "local cultural resources" inherently offer the advantage of real, tangible, and perceptible contexts. Shaanxi's rich cultural resources, such as Qin culture, intangible heritage, and historical geography, provide vast carriers for knowledge anchors. This study transforms cultural resources into course task design elements, enabling pre-service teachers to simultaneously achieve "knowledge learning–competency development–cultural identity" as comprehensive educational goals, thereby reinforcing the value orientation of interdisciplinary teaching and the significance of local curriculum development.

(3) Forming a "training–evaluation–improvement" closed-loop mechanism to enhance the continuity of competency development

In traditional teacher education, interdisciplinary competence development often stays at the conceptual level or single activity training, lacking process tracking and evaluation feedback. This study clearly integrates formative evaluation and comprehensive evaluation tools into the development pathway, giving the training process observable, recordable, and adjustable characteristics. Through the "evaluation evidence → feedback → improved teaching design" cyclical mechanism, the improvement of pre-service teachers' interdisciplinary competence becomes a gradual development trajectory, rather than a one-time result, promoting the long-term and stable professional growth of teachers.

6.1.2. Limitations of the implementation pathway

Although this study has conducted systematic exploration in both theoretical and practical aspects, there are still the following limitations that need to be addressed and improved in future research and implementation:

(1) Stability of the implementation effectiveness in different contexts still needs further verification

The formation of ITC is influenced by factors such as teachers' prior experience, their subject background, and the resource conditions of the practice schools. While this study's pathway is highly relevant in the Shaanxi context, it is still necessary to test its applicability and transferability in other

regions or school types. Further research in larger samples and more complex contexts is needed to verify the generalizability of this model.

(2) The refinement of knowledge anchors depends highly on teachers' professional literacy

Knowledge anchors emphasize extracting "core supporting points for driving tasks" from cultural resources or core disciplinary concepts, a process that places high demands on pre-service teachers' ability to understand curricula and integrate disciplines. If teachers only remain at the superficial level of presenting cultural resources without the ability to refine concepts and express them in a structured way, the anchors could degrade into mere "material references," weakening the depth of interdisciplinary integration in teaching. Therefore, in the promotion and implementation of this approach, more specific templates for refining knowledge anchors, task chain design examples, and course support packages are needed.

(3) The level of refinement and quantification of evaluation tools still needs improvement

Although this study proposes a combined formative and comprehensive evaluation framework, there is still room for improvement in the weight distribution of evaluation dimensions, the reliability and validity of evaluation criteria, and the contextual applicability of the evaluation tools. Especially considering the complexity of evaluating interdisciplinary teaching competence, further refinement of evaluation rubrics and data collection methods is needed to balance "disciplinary knowledge acquisition" with "comprehensive competency development."

6.2. Implications for teacher education reform

This research provides valuable insights for optimizing pre-service teacher development systems and advancing teacher education reform, mainly in the following three aspects:

(1) The teacher education curriculum system should shift from "disciplinary separation" to "interdisciplinary competency orientation"

The development of interdisciplinary teaching competence cannot be achieved by a single course but requires structural adjustments at the curriculum level. Teacher training institutions should start from the "core competency framework for teachers" and promote the interlinking of curriculum modules, embedding the cultivation of interdisciplinary teaching competence into course design, classroom practice, and educational evaluation, thus forming a continuous competency development chain.

(2) Strengthening the curriculum conversion mechanism for local cultural resources to promote "localized teacher education"

Teacher education reform should not only respond to national curriculum standards and core competency requirements but also activate local cultural and regional resource advantages. Incorporating Shaanxi's local cultural resources into pre-service teacher education helps cultivate teachers' cultural understanding, curriculum development abilities, and teaching innovation capabilities, achieving a systematic transformation of "local resources → course content → teaching tasks → educational value," thus promoting regional development in basic education.

(3) Building a collaborative education mechanism of "on-campus training–off-campus practice–evaluation feedback"

Interdisciplinary teaching competence is highly dependent on real classroom contexts. Therefore, teacher education reform should further strengthen the collaborative mechanism between universities and primary school practice bases, forming a closed-loop training structure of "curriculum learning–

task design–classroom implementation–reflection and improvement." In particular, during internships and practical training, opportunities for interdisciplinary task practice and evaluation support should be provided to help pre-service teachers transform theory into teaching competence.

6.3. Recommendations for future research

Based on the advantages and limitations outlined above, future research can further advance in the following directions to enhance the explanatory power and broader applicability of the study:

(1) Conducting expanded validation research in multiple regions and with larger samples

It is recommended that future studies verify the pathway model in different regions, types of teacher training institutions, and practice schools, comparing the differences in implementation effects in various contexts. This will further test the model's stability, applicability, and the key factors influencing the development of ITC.

(2) Developing a standardized knowledge anchor toolkit and course resource library

Future research can further systematize the "knowledge anchor refinement–task chain design–evaluation rubric–classroom activity examples" process, creating a shareable, scalable resource package. For example, a database of interdisciplinary teaching case studies based on Shaanxi's cultural resources, a knowledge anchor refinement template library, and a task design library could be established to lower the implementation threshold for teachers and improve dissemination efficiency.

(3) Optimizing the ITC evaluation system and strengthening data evidence support

It is suggested that future research refine the evaluation rubrics by clearly defining the key dimensions of ITC (such as knowledge integration, task design, classroom implementation, disciplinary transfer support, cultural integration, etc.), combining diverse data sources like classroom observations, teaching product analyses, interviews, and learning evidence to improve the reliability and interpretability of the findings.

(4) Exploring the role of digital support in the development of ITC

With the development of intelligent educational technologies, future research could explore how digital platforms can support the design of interdisciplinary teaching tasks, learning process tracking, and evaluation feedback, forming a new pathway for competency development enabled by technology, thereby improving the efficiency and accuracy of interdisciplinary teaching competence development.

7. Conclusion, contributions, and limitations

7.1. Main conclusions

In the context of core competency-oriented basic education curriculum reform, interdisciplinary teaching has gradually become an important pathway for driving classroom transformation. The quality of pre-service primary school teachers' ITC determines the depth of interdisciplinary teaching implementation. This study, based on ITC theory and knowledge integration theory, constructs the "knowledge anchor-based pathway for developing pre-service primary school teachers' interdisciplinary teaching competence" (see **Figure 1**), and provides actionable solutions focused on task examples and implementation mechanisms (see **Tables 3** and **4**). Based on comprehensive research and analysis, the following conclusions are drawn:

Conclusion 1: The main bottleneck in developing pre-service primary school teachers' ITC is the "break in the cognitive–curriculum–practice–evaluation" chain.

From problem synthesis and review analysis, it is clear that the difficulties in developing pre-service

teachers' interdisciplinary competence do not stem from a single deficiency but rather from a chain of issues: "superficial understanding–fragmented design–lack of practical experience–absence of feedback mechanisms." This conclusion is supported by the synthesis of the current issues in the development of pre-service interdisciplinary competence and the comparative analysis of domestic and international training strategies (see **Tables 1** and **2**), indicating that interdisciplinary competence development requires an integrated pathway rather than fragmented strategy patches.

Conclusion 2: Knowledge anchors, as a structural mediator, significantly enhance the centrality and integration of interdisciplinary teaching design, avoiding "subject plateaus."

The research shows that "knowledge anchors" are not merely cultural materials or teaching themes, but structural support points connecting core disciplinary concepts, real-world problem contexts, and teaching task chains. The introduction of knowledge anchors shifts interdisciplinary teaching from "disciplinary content parallelism" to "knowledge aggregation around problems," thus enhancing the operability of interdisciplinary task design and course organization. This conclusion is structurally presented in the core logic of the pathway model (see **Figure 1**) and is reflected in the transformation path of "cultural resources → anchor refinement → task generation" in the interdisciplinary task design examples (see **Table 3**).

Conclusion 3: The cultivation of ITC is phased and progressive, requiring coordinated advancement of the "cognitive restructuring–curriculum design–instructional practice–evaluation feedback" four-phase process.

The pathway model constructed in this study shows that the formation of ITC is not achieved by simply "learning a strategy," but is a gradual process from cognitive understanding to design generation, from practical implementation to feedback improvement. In this process, cognitive restructuring is a prerequisite for competence generation, curriculum design and instructional practice are the key carriers for competence formation, and the evaluation mechanism is the safeguard for competence iteration. This phased logic is embodied in the pathway model as a clear sequence structure (see **Figure 1**) and is also reflected in the integrated arrangement of teaching activity organization, teacher training support, and evaluation tools in the implementation recommendations (see **Table 4**).

Conclusion 4: The transformation of Shaanxi's local cultural resources into knowledge anchors enhances the authenticity of interdisciplinary teaching contexts and the integration of educational values, with clear regional applicability.

The study found that transforming Shaanxi's cultural resources, such as Qin culture, intangible cultural heritage, and historical geography, into interdisciplinary task anchors not only enhances the authenticity and inquiry-driven nature of the classroom learning context but also helps achieve the comprehensive educational goal of "disciplinary knowledge learning–cultural understanding–value identification." This conclusion is supported by practical evidence in the task examples: different cultural resources can be transformed into anchors in the integration of different subjects and generate interdisciplinary tasks (see **Table 3**), thus demonstrating the operational evidence of the "teaching transformation potential of cultural resources."

Conclusion 5: The "formative evaluation + comprehensive evaluation" closed-loop evaluation mechanism helps enhance the sustainability and scalability of ITC development.

The development of ITC requires process evidence support. The evaluation mechanism proposed in this study emphasizes formative evaluation focusing on the learning process and competency development trajectory, and comprehensive evaluation focusing on outcome quality and competency achievement levels, thus forming a "evaluation → feedback → improvement" closed-loop structure. This closed-loop logic is systematically presented in the implementation recommendations framework (see **Table 4**) and aligns with the

competence iteration logic in the pathway model (see **Figure 1**), reflecting the internal consistency between the pathway's operation mechanism and the evaluation mechanism.

7.2. Innovations

To enhance the academic recognition and core journal review-friendliness of this paper, the innovations are primarily reflected in the following three aspects:

(1) The introduction of "knowledge anchors" as the key intermediary concept for developing pre-service teachers' ITC, providing actionable implications.

Previous studies mainly focused on the application of interdisciplinary teaching strategies or curriculum integration forms, while this paper clearly defines knowledge anchors as structural support points linking "cultural resources–core disciplinary concepts–interdisciplinary task chains." This shifts interdisciplinary teaching from experiential integration to replicable, structured integration, providing a new explanatory framework and teaching transformation pathway for interdisciplinary teacher education (see **Figure 1**).

(2) The construction of an integrated "cognitive–curriculum–practice–evaluation" four-phase development pathway model, emphasizing the phased and closed-loop nature of competence generation.

This paper breaks away from the fragmented and strategy-driven approach to pathway development, viewing ITC cultivation as a dynamic process. It incorporates the evaluation feedback mechanism into the core structure of the pathway model, forming a "training–evaluation–improvement" closed-loop system, which enhances the systematization and practical feasibility of the model (see **Figure 1**, **Table 4**).

(3) The realization of the transformation of Shaanxi's local cultural resources into interdisciplinary knowledge anchors, creating a replicable regional task development paradigm.

This paper uses Shaanxi's Qin culture and intangible cultural heritage resources as carriers, proposes interdisciplinary task design examples (see **Table 3**), and forms an implementation recommendation framework (see **Table 4**). This enables the transformation of "local cultural resources into interdisciplinary classrooms" to go beyond conceptual advocacy and into a practical, actionable task design pathway, providing a template for regional teacher education reform and local curriculum development.

7.3. Limitations and future research

Despite constructing a relatively systematic competency development pathway and proposing a practical framework, this study still has the following limitations that need to be addressed and refined in future research and implementation:

(1) The scope of empirical verification needs to be expanded.

The pathway model and practical framework need further verification in larger samples, different types of teacher training institutions, and multi-regional practice settings to enhance the stability and universality of the conclusions.

(2) The refinement of knowledge anchors relies heavily on teachers' professional literacy.

The refinement of knowledge anchors requires teachers to have strong curriculum understanding and interdisciplinary integration abilities. Future research can further develop standardized knowledge anchor refinement templates, task chain design toolkits, and teaching case libraries to lower the implementation threshold.

(3) The reliability and validity of ITC evaluation rubrics need further improvement.

Future research can focus on the dimensional indicator system, rubric structure design, process evidence collection, and statistical testing to improve the scientific rigor and comparability of evaluation tools.

(4) Digital and intelligent support mechanisms need further exploration.

With the development of smart educational technologies, future research could explore how to leverage digital platforms to support interdisciplinary task management, learning process tracking, and evaluation feedback automation, forming a new technology-enabled competency development pathway to improve the efficiency and precision of ITC development.

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