

Enhancing Teaching Competence of Physics Pre-Service Teachers in Applied Undergraduate Institutions: Reflections and Exploration from a PCK Perspective

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Abstract

This study employs the Pedagogical Content Knowledge (PCK) theoretical framework to address the enhancement of teaching competence among physics pre-service teachers in applied undergraduate institutions. Through literature reviews, case analyses, and questionnaire surveys, it identifies major challenges faced by physics pre-service teachers in transforming disciplinary knowledge into teaching content and analyzing student learning needs. Corresponding strategies are proposed. The PCK theory emphasizes the organic integration of disciplinary knowledge and pedagogical knowledge, offering a systematic framework for the professionalization of pre-service teachers. This study further suggests strategies such as establishing a systematic training system, strengthening PCK development, enhancing practical teaching skills, improving evaluation mechanisms, and fostering school-local cooperation and resource sharing. These strategies aim to provide practical references for cultivating the teaching competence of physics pre-service teachers in applied institutions based on PCK theory.

Keywords

PCK, Physics Pre-Service Teachers, Teaching Competence, Applied Undergraduate Institutions, Teacher Education

1. Introduction

In recent years, with the deepening of educational reforms and the advancement

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of “Double First-Class” initiatives in China, the quality of teacher education has become a critical factor in enhancing national educational competitiveness. In the field of basic education, the teaching competence of pre-service teachers directly impacts the professional quality and teaching effectiveness of future teacher cohorts. Applied undergraduate institutions, as key bases for training primary and secondary school teachers, bear significant responsibility for cultivating physics pre-service teachers. However, they still face numerous challenges in enhancing the teaching competence of these pre-service teachers, which to some extent affects the quality of basic education.

It is emphasized that teachers should deeply integrate Content Knowledge (CK) with Pedagogical Knowledge (PK) to form unique teaching professional competence, which serves as a core tool in teacher education research and is widely applied to enhance teacher professional development (Shulman, 1986, 1987). In the domain of physics education, due to the highly abstract and complex nature of the discipline, PCK theory is particularly crucial for guiding pre-service teachers in transforming theoretical knowledge into teaching content tailored to students’ cognitive characteristics (Zheng, 2025; Grobe-Heilmann, 2022; Xie, 2017).

This study adopts a PCK perspective, combined with the characteristics of applied undergraduate institutions, to analyze the current state of teaching competence among physics pre-service teachers and explore pathways for improvement. By reviewing and synthesizing domestic and international research, it proposes five strategies, including the construction of a systematic training system, to provide practical references for cultivating teaching competence in physics pre-service teachers at applied universities.

2. Insights on Enhancing Teacher Teaching Competence from a PCK Perspective

2.1. Core Connotations and Theoretical Value of PCK

Pedagogical Content Knowledge (PCK) is a core component of teacher professional knowledge, designed to guide teachers in transforming disciplinary content into teaching forms that students can easily understand. Shulman noted that PCK is the ability of teachers to “present disciplinary knowledge in a way that is comprehensible to others” and to “understand the factors that make learning a particular subject topic easy or difficult.” This highlights that PCK differs from pure disciplinary knowledge or pedagogical knowledge, emphasizing their integration. It requires teachers not only to master the physics discipline itself but also to understand how to design teaching strategies and select presentation methods that enable students to effectively learn and grasp key disciplinary points (Shulman, 1986, 1987). The theoretical value of PCK lies in providing a systematic framework for enhancing teacher competence. In physics education, where topics such as mechanics, electromagnetism, and optics involve abstract concepts, mere knowledge transmission struggles to engage students. Through PCK, teachers can design teaching activities rooted in real-life contexts, making complex concepts

intuitive and directly impacting teaching effectiveness and student academic achievement (Bai, 2013; Shao et al., 2025; Lan, 2025). For physics pre-service teachers in applied undergraduate institutions, cultivating and enhancing PCK is both a guide for improving instructional design and a key to enhancing educational outcomes.

2.2. Transformation of Disciplinary Knowledge into Teachable Content and Student Needs Analysis

From a PCK perspective, teaching competence emphasizes transforming disciplinary knowledge into “teachable” content. This process requires teachers to deeply understand the essential structure of physics and tailor their teaching to students’ cognitive characteristics and learning backgrounds. For example, the concept of “electromagnetic induction,” which involves Faraday’s law of electromagnetic induction and changes in magnetic flux, can be abstract and confusing if taught solely through formula derivation. Leveraging PCK, teachers can design simple experimental demonstrations (e.g., generating current by moving a magnet near a coil) and connect them to real-life examples like generator principles, guiding students to understand induced current through hands-on experience. Similarly, when teaching “resolution of forces,” teachers can use inclined plane demonstrations and animated simulations to enable students to explore the application of Newton’s second law independently, thereby mastering the principle of force resolution. These teaching designs reflect the core of PCK: teachers not only impart physics knowledge but also adjust instruction based on students’ prior knowledge to make learning “easy” rather than “difficult.” Additionally, PCK underscores the importance of analyzing student needs. Effective teaching requires teachers to understand students’ knowledge foundations, interests, and common misconceptions, incorporating these into instructional design. For instance, in teaching “refraction of light,” if teachers know that some students already have intuitive experience with changes in light speed, they can introduce new content using examples like refraction in water or fiber optic communication. Through such student needs analysis and contextual design, teachers can develop targeted strategies in advance, enhancing the relevance and effectiveness of instruction. This process relies on teachers’ ability to integrate teaching theory with actual student contexts, embodying the professionalization of teaching from a PCK perspective.

2.3. Reflections on Enhancing Teaching Competence from a PCK Perspective

PCK theory provides a reflective pathway for enhancing teaching competence. First, it prompts teachers to reflect on the degree of integration between disciplinary knowledge and pedagogical knowledge. Traditional teaching often prioritizes knowledge transmission while neglecting the design of teaching methods, whereas PCK emphasizes their synergy. For example, when teaching “heat transfer,” teachers can combine experiments (e.g., heat conduction in metal rods) with theoretical explanations to address the limitations of sole lecturing. Second, PCK

encourages teachers to focus on teaching effectiveness. By analyzing students' classroom performance and learning outcomes, teachers can evaluate the effectiveness of their strategies and optimize them. For instance, if students struggle to understand "refraction of light" in optics, teachers can add refraction demonstration experiments and adjust the sequence of explanations. Finally, PCK encourages teachers to continuously focus on their own professional development, refining their teaching abilities through learning and practice to develop a personalized teaching style.

3. Specific Strategies for Enhancing Physics Pre-service Teachers' Teaching Competence Based on a PCK Perspective

To effectively enhance the teaching competence of physics pre-service teachers in applied undergraduate institutions, this study proposes the following systematic strategies based on PCK theory. These strategies cover course design, practical training, and reflective improvement, aiming to holistically optimize the cultivation of pre-service teachers' teaching competence. Details are presented in **Table 1**.

Table 1. Strategies for enhancing physics pre-service teachers' teaching competence based on a PCK perspective.

Strategy Category	Specific Strategy	Description	Teaching Example
Establishing a Systematic Training System	Optimize Course Settings	Integrate PCK content into physics courses, add teaching transformation modules, and offer PCK theory and practice courses.	In a "Mechanics" course, include discussions on "how to transform Newton's laws into teaching content" and design related teaching activities.
	Strengthen Practical Training	Provide simulated classrooms, micro-teaching, and internship opportunities to enhance real teaching experience.	Organize pre-service teachers to simulate "electromagnetic induction" teaching, improving design and implementation skills through practice.
Emphasizing Systematic PCK Cultivation	Enhance Integration of Professional Knowledge and Teaching Methods	Guide pre-service teachers to transform complex concepts into understandable content.	In an "Optics" course, design "refraction of light" experiments and real-life examples (e.g., refraction on water surfaces) to deepen understanding.
	Focus on Interdisciplinary Knowledge Integration	Encourage the integration of mathematics, information technology, and other disciplines to design comprehensive teaching plans.	In "Conservation of Energy" teaching, combine chemical thermodynamics and data analysis tools to enrich content.
	Strengthen Reflective and Improvement Skills	Foster reflective habits through teaching seminars and case analyses to optimize PCK levels.	Analyze a "projectile motion" teaching case, reflect on issues, and propose improvement measures.

Continued

Enhancing Practical Teaching Skills	Strengthen Experimental Teaching Design and Implementation	Use experimental teaching to help students understand physics concepts and improve experimental skills.	In “Circuit Analysis,” design an experiment to verify Ohm’s law.
	Emphasize Inquiry-Based Learning Guidance	Encourage students to ask questions, design experiments, and develop inquiry skills.	In “Mechanics,” explore Newton’s second law through experiments to increase student engagement.
	Strengthen Integration with Information Technology	Apply virtual experiment platforms and smart classroom tools to enhance teaching interactivity.	Use virtual experiments to demonstrate “electromagnetic induction,” improving students’ intuitive understanding.
Improving the Teaching Competence Evaluation System	Establish Multi-Dimensional Evaluation Standards	Assess competence from multiple perspectives, including knowledge mastery, teaching design, and implementation effectiveness.	In “Optics” teaching, evaluate pre-service teachers’ abilities through student feedback and classroom observation.
	Focus on Formative Evaluation	Provide timely guidance for teaching improvement through regular observation and reflection.	Conduct regular teaching reflection activities, gather feedback, and optimize methods.
	Strengthen Evaluation of Practical Components	Assess teaching effectiveness during internships through feedback from students and mentors.	Evaluate effects during internships using student questionnaires and mentor comments.
Strengthening School-Local Cooperation and Resource Sharing	Establish Stable Internship Bases	Collaborate with primary and secondary schools to provide long-term internship opportunities.	Partner with secondary schools to offer “Mechanics” teaching internship opportunities.
	Promote Resource Sharing and Exchange	Organize teaching seminars and invite outstanding teachers to share experiences.	Invite secondary school teachers to share “Optics” teaching cases and conduct discussions.
	Strengthen Feedback and Improvement Mechanisms	Collect internship feedback to optimize training programs.	Adjust training plans based on feedback from internship schools.

Through the implementation of these strategies, physics pre-service teachers in applied undergraduate institutions can achieve a balance between theoretical learning and practical operation, comprehensively improving their teaching competence. This strategy system emphasizes the application of PCK theory across all aspects of classroom teaching, laying a systematic and targeted growth path for pre-service teachers.

4. Instructional Design for Enhancing Physics Pre-Service Teachers’ Teaching Competence Based on a PCK Perspective

Instructional design goals should highlight the cultivation of Pedagogical Content Knowledge (PCK) among pre-service teachers, organically integrating physics

disciplinary content with teaching strategies. Taking the momentum theorem as an example, the teaching objectives include: enabling pre-service teachers to deeply understand the concept and expression of the momentum theorem, master its application in variable force and variable mass systems (e.g., rockets), and develop their ability to transform physics knowledge into teaching content and design appropriate instructional scenarios. PCK theory posits that teachers must “transform disciplinary knowledge into a form that students can learn,” considering students’ cognitive levels and interests based on a thorough understanding of the content. Therefore, the instructional design for the momentum theorem should address common student misconceptions (e.g., confusing momentum with energy) and leverage real-life experiences to formulate a reasonable content structure and tasks.

From a PCK perspective, the instructional content structure design emphasizes a “progressive, step-by-step” approach. First, create a scenario to introduce the new lesson, such as using the 2021 “Long March 2” rocket launch as a context, posing the question, “How can a rocket be designed to send astronauts into orbit?” This problem-based introduction aligns with PCK’s strategy of using real-life scenarios to spark interest, guiding pre-service teachers to connect the momentum theorem to real-world problems. Next, introduce the mathematical form of the momentum theorem step-by-step through analogy and model building, analyzing the reasons for momentum changes in the context of particle system dynamics. Finally, extend to various practical problems, such as rocket propulsion, collisions, and momentum analysis in variable mass systems, forming a coherent content framework. The entire design progresses layer by layer, transitioning from specific scenarios (e.g., rocket launches) to general principles (e.g., momentum theorem), reflecting the content transformation and hierarchical organization principles of PCK.

In terms of teaching method selection, diverse strategies should be employed based on the needs of physics experiments and thinking processes, designing inquiry-based experiments and discussion activities. For example, pre-service teachers can participate in collision experiments: using cart collisions and spring buffers with recording devices to visually demonstrate how impulse changes momentum, or designing a variable mass balloon propeller experiment to observe the impact of gas expulsion on system momentum. PCK emphasizes “problem-based, heuristic” teaching; thus, guiding pre-service teachers to ask questions and design experiments to solve problems is crucial in teaching activities. Instructional activities may include: exploratory problem discussions (e.g., “How can we verify that the momentum theorem holds under variable force?”), real-life case analyses (e.g., football collisions, curling game scenarios), and demonstration experiments (e.g., ball collisions, balloon-powered cars). These activities not only reflect the essence of disciplinary content (momentum and impulse) but also enhance understanding through methods aligned with students’ cognitive levels, fully embodying the content transformation and method selection guided by PCK theory (**Table 2**).

Table 2. Instructional design.

Instructional Design Dimension	Content	Implementation Method	PCK Manifestation
Teaching Goal Design	Enable students to understand the physical meaning and mathematical expression of the momentum theorem and apply it in various physics contexts; foster problem-solving and scientific inquiry skills.	Achieve goals through classroom introduction, experimental exploration, and real-life scenario training.	Transform disciplinary knowledge into a student-accessible form, focusing on simultaneous development of knowledge and skills.
Scenario Creation	Use “rocket launch” as the main scenario to introduce momentum conservation and variable mass system problems.	Play a rocket launch video, ask “Why can a rocket fly?” to provoke student exploration of momentum transfer principles.	Leverage real-life experiences to create cognitive conflict, facilitating knowledge construction.
Concept Teaching Strategy	Outline the derivation process of the momentum theorem formula and the concept of impulse, compare similarities and differences between momentum and energy, and emphasize vector properties.	Use blackboard formulas, animated demonstrations, and combine teacher lectures with student group discussions.	Balance Content Knowledge (CK) and Pedagogical Knowledge (PK) integration.
Instructional Activity Design	Design collision and “balloon car” experiments to explore momentum transformation processes; use virtual simulations to reinforce understanding of momentum conservation.	Group experimental operations, data analysis, and return to the momentum theorem; apply virtual experiment software like PhET for verification.	Experimental design reflects inquiry, constructing a student-centered learning environment.
Student Needs Analysis and Feedback Mechanism	Diagnose student misconceptions about “momentum” and “force-time relationship,” identify difficulties.	Pre-class questionnaires, in-class quizzes, and group feedback.	Teachers dynamically adjust teaching focus based on student responses.
Teaching Reflection and Optimization	Collect student feedback after teaching and organize teaching research reflections to adjust instructional design.	Teacher reflection records, student interviews, and peer evaluations.	Form a continuous improvement loop for teaching competence development, reflecting professional growth.

5. Analysis of Teaching Practice Outcomes for Enhancing Physics Pre-Service Teachers’ Teaching Competence Based on a PCK Perspective

To validate the effectiveness of teaching interventions based on the perspective of Pedagogical Content Knowledge (PCK) in enhancing the teaching competence of physics pre-service teachers, this study conducted a teaching practice within the physics education program at an applied undergraduate institution in China. Second-year physics pre-service teachers were selected and assigned to two groups using a quasi-experimental design: an experimental group (20 participants receiving PCK training) and a control group (20 participants receiving traditional teaching). Both groups consisted of pre-service physics students with no significant dif-

ferences in gender, age, or other demographic factors, and their teaching competence levels were comparable prior to the experiment. The experimental group incorporated PCK modules into traditional teaching, including training in content transformation, student needs analysis, instructional design, and reflection, aiming to comprehensively improve pre-service teachers' teaching competence across five dimensions: content transformation, student needs analysis, instructional design, teaching implementation, and teaching reflection. The control group relied primarily on traditional theoretical lectures.

To measure the teaching competence of pre-service teachers, a teaching competence assessment questionnaire was designed, consisting of 20 items divided into five dimensions: content transformation ability (4 items), student needs analysis ability (4 items), instructional design ability (4 items), teaching implementation ability (4 items), and teaching reflection ability (4 items). Each item used a 5-point Likert scale (1 = "Strongly Disagree," 5 = "Strongly Agree"), with higher scores indicating stronger competence in each dimension. The assessment questionnaire was developed based on the PCK theoretical framework and relevant literature. Following the completion of the initial draft, a small-scale pre-test was conducted to refine and finalize the questionnaire. After data collection, the Cronbach's α value was calculated at 0.85, with α values for each dimension exceeding 0.80, indicating strong reliability and validity. Data were gathered before and after the experiment, and differences between the two groups were analyzed using independent samples t-tests and Cohen's d effect size measures.

5.1. Descriptive Results

Descriptive statistics of the teaching competence questionnaire results for the control group (traditional teaching) and experimental group (PCK training) are shown in the **Table 3** below.

Table 3. Descriptive statistics.

Dimension	Control Group Mean \pm SD	Experimental Group Mean \pm SD	t Value	p Value	Cohen's d
Content Transformation Ability	3.65 \pm 0.59	4.54 \pm 0.51	5.73	<0.001	1.62
Student Needs Analysis Ability	3.69 \pm 0.61	4.45 \pm 0.56	4.51	<0.001	1.29
Instructional Design Ability	4.05 \pm 0.55	4.61 \pm 0.49	3.78	<0.001	1.07
Teaching Implementation Ability	4.14 \pm 0.50	4.58 \pm 0.50	3.07	0.003	0.88
Teaching Reflection Ability	4.00 \pm 0.53	4.46 \pm 0.50	3.12	0.003	0.89

Table 3 shows that the experimental group's mean scores in all dimensions and total scores were higher than those of the control group. T-test results indicate that the differences between the two groups in all five dimensions and total scores were statistically significant. Cohen's d values further reveal that the largest effect size was in content transformation ability, with a generally strong overall effect on teaching competence improvement.

5.2. Results Analysis

The experimental results demonstrate that PCK training significantly enhanced the teaching competence of physics pre-service teachers. Specific performances of the experimental group in each dimension are as follows:

Content Transformation Ability: This dimension's scores were significantly higher than those of the control group ($t = -5.73$, $p < 0.001$, $d = 1.62$), highlighting the prominent effect of PCK training. PCK theory emphasizes that teachers must transform disciplinary knowledge into student-understandable teaching content. The experimental group, through case-based teaching and scenario design training, learned to explain abstract physics concepts using real-life examples (e.g., gravity in daily life), while the control group, lacking such practice, showed limited improvement in this area.

Student Needs Analysis Ability: Performance was superior to the control group ($t = -4.51$, $p < 0.001$, $d = 1.29$). PCK training, through exercises in analyzing student misconceptions and assessing needs, enabled pre-service teachers to identify learning difficulties (e.g., confusion in mechanics concepts) and adjust teaching strategies accordingly. This aligns with the assertion that understanding student cognition is foundational to effective teaching.

Instructional Design Ability: Scores were significantly higher than the control group ($t = -3.78$, $p < 0.001$, $d = 1.07$). PCK training, through inquiry-based instructional design workshops, helped pre-service teachers effectively integrate physics knowledge with teaching goals, designing more targeted classroom activities. In contrast, the control group's designs remained largely traditional and lacked innovation.

Teaching Implementation Ability: The experimental group showed significant improvement ($t = -3.07$, $p = 0.003$, $d = 0.88$), attributed to micro-teaching and simulated classroom practices, which improved classroom organization and experimental demonstration skills. The control group, due to limited practice opportunities, showed smaller improvements.

Teaching Reflection Ability: Scores were higher than the control group ($t = -3.12$, $p = 0.003$, $d = 0.89$). PCK training, through reflection logs and group discussions, cultivated pre-service teachers' self-assessment skills, enabling them to summarize lessons from teaching practice. This is consistent with the view that reflection promotes teacher growth.

Although the experimental group improved in all dimensions, the effect sizes for teaching implementation and reflection abilities were lower ($d < 1.0$), possibly because these skills require long-term practice accumulation, which short-term training cannot fully address.

The study demonstrates that PCK-based teaching interventions significantly improved the teaching competence of physics pre-service teachers, with notable effects in the areas of transforming teaching content, analyzing student learning needs, and instructional design. The experimental group outperformed the control group across all five assessed dimensions, affirming the practical value of PCK

theory in pre-service teacher training. These findings provide empirical evidence supporting the development of teaching competence among physics pre-service teachers in applied undergraduate institutions. However, the discussion primarily relies on self-reported questionnaire data from participants, who may have been inclined to provide more favorable responses. Future research could incorporate objective measures, such as classroom observations or student evaluations, to complement these findings. The proposed PCK cultivation strategies are not only applicable to applied universities but can also be extended to other higher education institutions, such as comprehensive universities or teacher-training colleges, offering practical guidance for enhancing pre-service teachers' teaching competence. Furthermore, these strategies may inform reforms in teacher education policy, advocating for PCK-based training as a central element of teacher professional development and contributing to the overall enhancement of educational quality.

Application Prospects for Enhancing Physics Pre-service Teachers' Teaching Competence Based on a PCK Perspective.

Table 4. Application prospects for enhancing physics pre-service teachers' teaching competence based on a PCK perspective.

Application Prospect	Specific Content	Case Analysis
Broad Application of PCK in Teacher Education	As a core tool for teacher professional development, PCK is widely applicable across multiple disciplines. In physics pre-service teacher training, PCK helps transform abstract knowledge into student-understandable teaching content, improving classroom effectiveness.	In teaching "Newton's Laws of Motion," teachers use real-life examples (e.g., force analysis while cycling) to enhance students' intuitive understanding of forces, increasing learning interest and effectiveness.
Integration of PCK with Educational Technology in the Information Age	Information technology provides new tools for teaching, and PCK can be combined with virtual experiments and online platforms to optimize instruction.	In "Electromagnetic Induction" teaching, teachers use virtual experiment software to visually demonstrate the relationship between magnetic field changes and induced current, helping students understand abstract concepts.
Application of PCK in Interdisciplinary Integration	In contexts like STEAM education, PCK guides the design of comprehensive teaching plans, promoting integrated knowledge application.	In "Conservation of Energy" teaching, teachers incorporate engineering cases (e.g., wind power generation principles), combining physics knowledge with engineering practice to stimulate innovative thinking.
Support System for Teacher Professional Development Based on PCK	Build a support system, including PCK courses, practical guidance, and digital resource development, to promote teacher exchange and sharing.	Educational institutions offer PCK theory and practice courses, develop virtual experiment resource libraries, and facilitate teacher experience sharing through school-based training.

In the future, PCK theory can be further integrated with other educational theories (e.g., TPACK) to build a more scientific and comprehensive teacher education model. Simultaneously, with the deepening of educational informatization, the application of PCK in emerging technological environments such as virtual reality and artificial intelligence will become a research hotspot. Additionally,

more empirical studies are needed to verify the effectiveness of PCK cultivation strategies across different educational stages and disciplines, providing theoretical and practical guidance for continuous innovation in teacher education. Specific details are presented in **Table 4**.

6. Conclusion

Analysis from a PCK perspective reveals that Pedagogical Content Knowledge theory provides significant insights for enhancing the teaching competence of physics pre-service teachers in applied undergraduate institutions. PCK emphasizes the organic integration of disciplinary knowledge and teaching strategies, guiding pre-service teachers to transform abstract physics concepts into teaching content aligned with students' cognitive levels, thereby improving the scientific rigor and targeting of instructional design. Through literature reviews, case analyses, and questionnaire surveys, this study identifies current challenges in cultivating pre-service teachers' teaching competence and proposes five strategies: establishing a systematic training system, strengthening theory-practice integration, enhancing practical skills, improving evaluation mechanisms, and fostering school-local cooperation. These strategies focus on developing pre-service teachers' professional teaching competence, aiming to achieve overall improvement through optimized course settings, practical training, expanded teaching resources, and enhanced reflection and assessment. The PCK-based instructional intervention implemented in this study significantly improved the teaching competence of physics pre-service teachers, particularly in content transformation, student needs analysis, and instructional design. The experimental group outperformed the control group across all five dimensions, validating the application value of PCK theory in pre-service teacher training.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- Bai, B. (2013). Comparative Study on Kindergarten Novice-expert Teachers' Science PCK. *Early Childhood Education (Educational Sciences)*, 7, 49-53.
- Grobe-Heilmann, R. (2022). Fostering Pre-Service Physics Teachers' Pedagogical Content Knowledge Regarding Digital Media. *Education Sciences*, 12, Article 440.
- Lan, W. R., Deng, F., & Gan, L. (2025). Investigation on Pre-Service Chemistry Teachers' PCK in Unit Teaching. *Chinese Journal of Chemical Education*, 46, 62-68.
- Shao, C. H., Tao, J. Y., Chi, S. H. et al. (2025). The Transformation of Subject-Specific Normal Graduates into Integrated Science Teachers: A Study on Novice Science Teachers'

PCK Development. *Teacher Education Research*, 37, 31-37.

Shulman, L. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review*, 57, 1-23. <https://doi.org/10.17763/haer.57.1.j463w79r56455411>

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, 15, 4-14. <https://doi.org/10.3102/0013189x015002004>

Xie, S. (2017). Analysis on Structure Characteristics and Development of Pedagogical Content Knowledge: Cases from Mathematics Primary Teachers. *Journal of Schooling Studies*, 14, 93-103.

Zheng, Z. H. (2025). Teachers' Subject-Specific Pedagogical Thinking: Connotation, Elements, and Operational Logic. *Curriculum, Teaching Material and Method*, 45, 153-159.