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Constructing a Structural Model and Development Mechanism of Rural Kindergarten Teachers' Scientific-Domain Teaching Competence in Ethnic Minority Areas of Sichuan, China

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Abstract:

Early childhood science education serves as a critical foundation for cultivating future scientific innovation and enhancing public scientific literacy. Competent kindergarten teachers are pivotal to the quality of this scientific initiation, particularly in under-resourced ethnic rural areas. Based on a literature review and regional analysis, this study constructs a theoretical model of teaching competency in science education for kindergarten teachers in these settings, comprising four core dimensions: scientific conception and thinking, professional ethics, teaching practice ability, and educational competence. We further propose and test a set of hypotheses concerning the developmental mechanisms among these dimensions. Survey data from 519 kindergarten teachers engaged in science education in rural ethnic regions of Sichuan Province (W County and X City) were analyzed. The findings indicate that: (1) "Scientific thinking" and "professional ethics" significantly positively influence "competencies" (i.e., teaching practice ability and educational competence); (2) "Professional ethics," "scientific thinking," and "educational competence" all exert significant positive effects on teaching practice ability; and (3) educational competence plays a mediating role between scientific thinking and teaching practice ability. Based on these results, targeted recommendations are proposed to support the professional development of kindergarten teachers in ethnic rural areas.

Keywords:

Science education, rural teachers, teacher professional development, teaching efficacy

1.Introduction

Education lays the foundation for the great rejuvenation of the Chinese nation, while science and technology constitute its strategic pillars. Science education bears the dual mandate of cultivating future innovators and elevating the scientific literacy of all citizens; the presence of well-qualified science teachers is therefore a non-negotiable lever for reform [1]. In early childhood, the Trial Guidelines for Kindergarten Education designate science as one of the five core learning domains and explicitly call for horizontal integration across domains to foster children's emotions, attitudes, abilities, knowledge, and skills. Reinforcing this priority, the

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newly enacted Preschool Education Law of the People's Republic of China (effective 1 June 2025) requires balanced development across health, language, social studies, science, and the arts. Kindergarten science education thus functions as the first rung of the national STEM ladder; the instructional competence of preschool teachers directly determines the quality of children's earliest scientific enculturation.

Situated at the intersection of these policy imperatives and the unique ecology of rural, ethnic-minority communities in Sichuan, this study asks a single pragmatic question: What constellation of key competencies and ethical dispositions enables a kindergarten teacher to deliver effective, culturally responsive science instruction in village contexts? Guided by the Party-state's latest mandates for rural teacher development and the moral imperative of "fostering virtue through education," we construct a theoretically grounded model of science-teaching competence, derive a corresponding assessment system, clarify its mechanisms of influence, and propose sustainable strategies for long-term capacity building among rural preschool educators.

2. Literature Review and Research Hypotheses

2.1 Literature Review

2.1.1 Teaching Competency in Science and Teacher Competence

Since the 1960s, a body of international scholarship has focused on teaching competency in science within school settings. Scholars such as Butzow and Qureshi identified twelve key indicators for effective science teaching, encompassing subject knowledge, positive teacher-student relationships, recognition of individual differences, creating dynamic classrooms, instructional design capabilities, and critical thinking[2]. Alake-Tuenter et al. conceptualized science teaching competency as a comprehensive personal performance ability, integrating extensive knowledge structures, essential cognitive and psychological skills, attitudes, and values. This complex competency is seen as crucial for executing professional tasks, solving problems, and fulfilling specific roles within educational contexts[3]. Further refining this concept, Alake-Tuenter, Sedibe, and colleagues argued that core science teaching competency stems from three fundamental elements: subject matter knowledge, pedagogical content knowledge, and teaching attitudes. Complementing these theoretical frameworks, research involving practicing teachers highlights that they highly value competencies such as enthusiasm for teaching science, relevant qualifications and experience, and access to supportive instructional materials. Collectively, this literature suggests that science teaching competency in schools primarily involves knowledge, pedagogical skills, attitudes, and values.

Beyond the general exploration of science teaching competency, other researchers have specifically investigated teachers' competence in science education—that is, their teaching competence in the science domain. Putter-Smits argued that the focus of teaching STEM or science subjects should be to cultivate teachers' pedagogical competence in science education, which primarily includes teaching practice, lesson preparation, student interaction, and learning assessment. In a similar vein, the U.S. Committee on Science Education Standards and Assessment identified 23 essential elements for teacher competence in science education, including assessing student performance, selecting and designing instructional materials, defining curriculum and unit objectives, and guiding practical activities[4]. Putter-Smits et al. further categorized this competence into five dimensions: contextual management, regulation, focus, design, and school innovation. Meanwhile,

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Wu Lizhen et al. developed a questionnaire to explore teachers' perceptions of their professional teaching competence, particularly regarding creating cooperative learning environments that can enhance students' attitudes towards mathematics/science. Synthesizing these studies, research on teacher competence in science education appears to concentrate on three main areas: instructional design (e.g., analyzing curriculum content and students, setting learning objectives, designing activities), instructional implementation (e.g., organizing inquiry-based learning, utilizing technology and multimedia, encouraging collaboration), and learning assessment (e.g., evaluating and providing feedback on the learning process).

Furthermore, McClelland emphasized that true "competence" refers to the underlying personal characteristics that distinguish high performers from average ones. From this perspective, teacher research itself should be considered a vital domain of teacher competence in science education. For instance, the Australian Association of Science Teachers' National Professional Standards for Highly Accomplished Teachers of Science indicates that accomplished science teachers are often active beyond their classrooms, contributing to journal articles and participating in research projects. This aligns with Stenhouse's concept of the "teacher as researcher," where teachers systematically investigate their own practice and student learning. Zhu Chang and Wang Di also identified teaching research capability as a key teacher competency. Within the specific context of science education, research has often focused on Pedagogical Content Knowledge (PCK), views on the nature of science, and attitudinal dispositions, with relatively fewer studies directly addressing the core teaching competence of science educators.

In summary, regarding the target teaching level, existing research on science teaching competency and teacher competence has predominantly involved primary school teachers or pre-service teachers. Studies specifically focusing on the science teaching competency or competence of kindergarten teachers are notably scarce, and research that further narrows the focus to rural kindergarten teachers is even more limited. Additionally, many studies on science teacher competencies primarily focus on identifying and listing competency components without comparatively analyzing their relative importance (i.e., weighting), which limits the depth of the findings and conclusions. In short, unlike the sustained research emphasis on science teaching competency related to children's science curricula, conceptual learning, and scientific literacy, the science teaching competence of kindergarten teachers has received considerably less scholarly attention internationally.

2.1.2 Research on Indicators and Elements of Teaching Competence in Science Education

In the context of the new era, scholars have increasingly emphasized the educational capacity of teachers in science education, particularly the work and scope of fostering student development with a focus on moral education through the discipline. This shift aligns with the evolving trend in teacher education in China, which advocates a transition from general teaching competence to a broader educational capacity. For instance, Luo Bin argues that in the current environment, teachers' professional growth should progress from focusing on individual subject teaching competence to developing disciplinary moral education capacity[5]. Similarly, Dong Qi underscores the importance of educational capacity, positing that the cultivation and enhancement of teachers' educational and teaching abilities should center on their capacity to educate[6].

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Specifically within science education, Eichinger provides a concrete description of an effective science teacher: one who shows interest in science, possesses the ability to demonstrate and teach experiments, can design experiments with limited equipment and chemicals, and is willing to invest time in preparing experiments and demonstrations. Champagne, Hornig, and colleagues contend that a qualified science teacher should educate students to become productive and responsible citizens, spark their interest in science, and prepare them for potential scientific careers. Research by Bruce & Leonie identifies key characteristics of effective science teachers, including teaching methods, communication skills, enthusiasm, organizational ability, teacher-student relationships, and student assessment practices. In summary, rational-logical thinking, instructional design capability, personal ethical cultivation, scientific concepts and thinking, teaching practice ability, and professional ethics are widely recognized in academia as core components of teaching competence in science education.

At the national level, countries such as the United States and Australia have established professional standards defining core teaching competencies for science educators. The U.S. National Science Education Standards outline core teaching capacities encompassing the implementation of inquiry-based teaching, the assessment of students' inquiry abilities, and engagement in educational research. Meanwhile, Australia's National Professional Standards for Highly Accomplished Teachers of Science particularly emphasize assessment literacy, inquiry-based teaching practices, digital literacy, and educational research skills[7].

However, unlike the U.S. and Australia, which have issued specific professional standards for core competencies in science teaching, China lacks targeted textual standards for science education specifically, beyond general standards for kindergarten, primary, and secondary school teachers. Furthermore, research focusing on the core teaching competence of kindergarten teachers in science is relatively scarce. Therefore, investigating the core teaching competence of kindergarten teachers in science is significant for the comprehensive implementation of integrated science education across both urban and rural areas in China. This research can not only effectively promote the professional development of teachers across all educational stages and support the nationwide implementation of integrated science education but also contribute to the future construction of a core teaching competency system and professional standards encompassing the five key learning areas for kindergarten teachers.

2.1.3 Research on Teaching Competence of Rural Teachers in Science Education

While direct research focusing on the science teaching competence of rural kindergarten teachers is limited, studies concerning rural teachers' science teaching competence at other educational levels offer valuable references and insights for this research. A review of the literature reveals three main thematic areas: the constituent elements of rural teachers' science teaching competence, the mechanisms through which this competence functions, and the mechanisms and strategies for its sustainable development.

First, regarding the constituent elements, some scholars have begun by delineating the core elements of rural teachers' science education competence, subsequently clarifying the relationships and interactions among these elements to understand the internal structure of this competence. This line of inquiry suggests that "thinking" and "ability" are two core competency elements constituting rural teachers' science teaching competence[8].

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Second, exploring the functional mechanisms of rural teachers' science teaching competence, researchers have primarily investigated the specific relationships between particular types of thinking, specific professional ethics content, and individual professional capabilities, employing methods such as empirical studies and mixed-methods research[9]. For example, Distler's empirical study indicated that teaching strategies oriented toward critical thinking positively enhance nursing students' clinical practice abilities. Thompson's empirical research demonstrated that teachers' science teaching beliefs significantly influence their teaching behaviors. Hashweh's survey research showed that teachers' beliefs about science education positively influence their own conceptual change regarding science during teaching practice. Tang Mingcheng's mixed-methods study also revealed a significant impact of secondary school science teachers' beliefs on their teaching practices. Notably, numerous scholars have specifically discussed the relationship between "professional ethics" and "professional ability." Vanaki and Memarian argue that professional ethics has become a core variable reflecting professional dedication, responsibility, and obligation, serving as a fundamental guarantee for individual professional competence and a crucial foundation for applying professional knowledge and skills. Skelton acknowledges professional ethics as a significant factor influencing the development of individual key competencies but cautions that some key aspects of current ethical codes and regulations are counterproductive to developing contemporary core literacies. Farazmand discusses the micro-level impacts and new challenges posed by ethical accountability and moral norms on professional capacities like global governance and management in the context of globalization[10].

Analysis of existing literature reveals that much of the research by domestic and international scholars investigating professional teaching competence tends to focus on quantitative analysis of the relationship between two core variable types. There is a scarcity of studies that systematically and quantitatively analyze three or more core variables as an integrated whole based on a self-constructed model. This gap provides a new perspective and foundation for the present study to explore the interaction mechanisms among three core elements holistically.

Finally, concerning the sustainable development mechanisms and strategies for rural teachers' science teaching competence, scholars have explored specific mechanisms related to value identity in science education, cultural interaction in science education, reflective practice of science teachers in rural kindergartens, and the cultivation of a scientific spirit in rural science education. Proposed development strategies include constructing multi-stakeholder collaborative systems to enhance the teaching practice ability of rural science teachers; fostering moral education capacity in science education based on core scientific literacy; and leveraging contemporary opportunities to actively develop scientific thinking among rural science teachers[11].

In summary, domestic and international scholars have conducted a series of studies on the science teaching competence of rural teachers, providing significant insights and references for this research. However, in terms of the research subjects, the focus has primarily been on science education for primary school teachers and pre-service teachers, with relatively little attention given to science education for kindergarten teachers in ethnic regions. Furthermore, most studies on science teacher competencies tend to focus on identifying and listing competency components without further comparing their relative importance or weighting, often failing to yield in-depth results and conclusions. Additionally, regarding the construction of the most critical indicator systems and theoretical models for science teaching competence among rural teachers in ethnic

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regions, few studies have systematically and quantitatively analyzed three or more core variables as an integrated whole based on a self-constructed model. Based on this gap, this study attempts to focus on the science teaching competence of kindergarten teachers in rural ethnic areas of Sichuan and holistically explore the interaction mechanisms among three or more core teaching competency variables, alongside strategies for their sustainable development.

2.2 Research Hypotheses

The competency model for kindergarten teachers in rural science education primarily comprises three core elements: "Ethics"(E) "Thinking"(T) and "Capability"(C) Among these, the Capability element mainly includes core competencies such as teaching practice ability and educational competence. The Ethics element pertains to professional ethics, including teachers' professional ethical standards. The Thinking element primarily encompasses scientific conceptions and scientific thinking. An analysis of existing literature reveals that scholars have primarily conducted quantitative analyses on the relationships between pairs of these core variables[12]. However, it is undeniable that interactions exist among all three elements within the competency model for rural kindergarten science teachers. The mechanisms underlying these interactions—between Ethics, Thinking, and Capability—are extremely complex, making it challenging to systematically and scientifically delineate their interrelationships.

Therefore, this study takes the Capability element as the dependent variable and focuses on exploring the mechanisms through which the other elements (Ethics and Thinking) operate as independent variables. It examines the developmental relationships specifically from the perspectives of "the influence of Ethics on Capability" and "the influence of Thinking on Capability."[13] Accordingly, the following four hypotheses are proposed:

H1: "Thinking" and "Ethics" each have a significant positive influence on "Capability" (i.e., teaching practice ability and educational competence).

H2: "Ethics," "Thinking," and "educational competence" all have a significant positive influence on teaching practice ability.

H3: Educational competence plays a mediating role between scientific thinking and teaching practice ability.

H4: Educational competence plays a mediating role between teachers' professional ethics and teaching practice ability.

3. Research Methodology and Design

3.1 Research Sample and Data Collection

This study was conducted between September and October 2025, targeting kindergarten teachers engaged in science education in rural areas of W County (Aba Tibetan and Qiang Autonomous Prefecture) and X City (Liangshan Yi Autonomous Prefecture) in Sichuan Province. Data were collected using a self-designed ques-

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tionnaire, the "Questionnaire on Science Teaching Competency of Kindergarten Teachers in Rural Ethnic Areas of Sichuan." The questionnaire was distributed through a combination of online surveys and on-site visits. A total of 519 questionnaires were distributed across W County and X City, all of which were returned. After excluding 126 invalid responses—based on criteria such as excessively short completion time, uniform answers across all items, and logically inconsistent responses—393 valid questionnaires were retained, yielding a valid return rate of 75.53%.

3.2 Data Analysis Methods

The study employed a mixed-methods approach to data analysis. Initially, NVivo qualitative analysis software was used to analyze research topics and keywords related to science teaching standards for kindergarten teachers, both domestically and internationally. This analysis provided a reference for constructing the theoretical model. Subsequently, multiple rounds of Delphi expert surveys were conducted to develop a structural framework of teaching competencies tailored to kindergarten teachers in rural ethnic areas. Finally, quantitative data analysis was performed using SPSS 24.0 and AMOS 24.0. Techniques such as difference analysis, regression analysis, and Bootstrap testing were applied to examine the data and investigate internal interaction mechanisms.

3.3 Research Framework Design

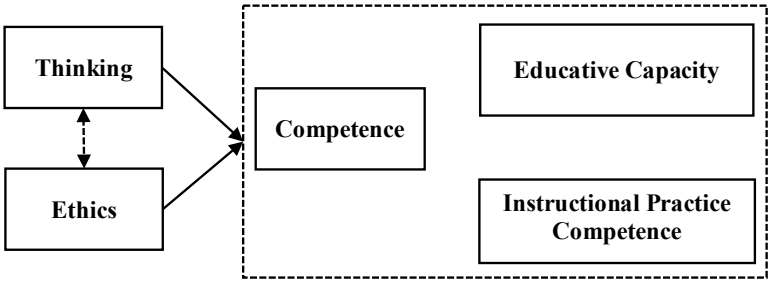


Figure 1. Research Framework Design

4. Research Findings

4.1 Demographic Information and Dimension Scores

Analysis of the demographic characteristics of the research sample revealed the following composition: Regarding gender, 121 participants (30.79%) were male and 272 (69.21%) were female. In terms of teaching experience, 180 teachers (45.80%) had 1–5 years of experience, 148 (37.66%) had 5–9 years, 41 (10.43%) had 9–14 years, and 24 (6.11%) had over 14 years. Concerning professional title, 47 participants (11.96%) held a first-level teacher title, 137 (34.86%) held a second-level title, 184 (46.82%) held a third-level title, and 25 (6.36%) were ungraded. The age distribution was as follows: 112 teachers (28.50%) were aged 20–30, 201 (51.15%) were 30–40, 51 (12.98%) were 40–50, and 29 (7.38%) were over 50. In terms of educational background, 113 participants (28.75%) had completed high school or vocational secondary education or below, 186 (47.33%) held a diploma (associate degree), and 94 (23.92%) held a bachelor's degree or higher. Regarding kindergarten type, 291 teachers (74.05%) worked in public kindergartens, 88 (22.39%) in affordable private kindergartens, and 14 (3.56%) in other private kindergartens.

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Descriptive statistics for the competency dimensions indicate that the science teaching competency of kindergarten teachers in rural ethnic areas of Sichuan was rated highest in the "Capability" dimension (4.03 ± 0.79). Within this dimension, the corresponding scores were 4.03 ± 0.76 for teaching practice ability and 4.01 ± 0.65 for educational competence. This was followed by the "Ethics" dimension (4.01 ± 0.77), while the "Thinking" dimension received the lowest score (3.72 ± 0.78).

4.2 Analysis of Influencing Factors and Developmental Mechanisms

4.2.1 Path Analysis and Model Fit Assessment

To test the hypotheses proposed above, path analysis was conducted using SPSS 24.0 and AMOS 24.0, and the hypothesized paths are presented in Table 1.

Table 1. Path Test

Hypothesized Paths	β	S.E.	C.R.	p	SRW	Supported or Not
1.Teacher Professional Ethics → Student Nurturing Competence	0.550	0.161	3.425	0.000	0.619	Supported
2.Scientific Concepts and Thinking → Teaching Practice Capability	1.351	0.256	5.275	0.000	0.658	Supported
3.Teacher Professional Ethics → Teaching Practice Capability	0.588	0.202	2.905	0.004	0.561	Supported
4.Student Nurturing Competence → Teaching Practice Capability	0.837	0.132	6.335	0.000	0.859	Supported
5.Scientific Concepts and Thinking → Student Nurturing Competence	1.332	0.335	3.972	0.000	0.706	Supported
6.Teacher Professional Ethics → Scientific Concepts and Thinking	0.601	0.171	3.521	0.000	0.792	Supported

The results from Path 1 support the segment of Hypothesis 1 stating that "Ethics has a significant positive influence on educational competence," as evidenced by a standardized regression coefficient of 0.619 ($p < .001$) from teachers' professional ethics to educational competence. Similarly, Path 5 confirms that "Thinking has a significant positive influence on educational competence," with a standardized regression coefficient of 0.706 ($p < .001$) from scientific conceptions and thinking to educational competence. Together, Paths 1 and 5 indicate that both professional ethics and scientific conceptions and thinking positively predict educational competence among rural kindergarten teachers in ethnic areas.Paths 2, 3, and 4 further reveal that teachers' professional ethics ($\beta = 0.561$, $p = .004$), scientific conceptions and thinking ($\beta = 0.658$, $p < .001$), and educational competence ($\beta = 0.859$, $p < .001$) all significantly and positively influence teaching practice ability, thereby supporting Hypothesis 2.

Path 6 demonstrates that professional ethics significantly and positively predicts scientific conceptions and thinking ($\beta = 0.792$, $p < .001$), confirming Hypothesis 3.

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Subsequently, model fit indices were examined for all paths. As summarized in Table 2, the X2/df ratios ranged from 0.839 to 1.525, all below the recommended threshold. Both RMR and RMSEA values were under 0.080, while GFI, CFI, TLI, and NFI all exceeded 0.90. These results collectively indicate a good fit for all path models.

Table 2. Model Fit Indices

Fit Indices	Recommended Value	Actual Value					
		Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
X^2/df	<3.00	1.381	1.081	1.521	1.387	1.525	0.839
RMSEA	<0.08	0.065	0.030	0.076	0.059	0.079	0.000
RMR	<0.08	0.048	0.021	0.030	0.035	0.064	0.037
NFI	>0.90	0.959	0.976	0.963	0.918	0.964	0.975
GFI	>0.90	0.947	0.968	0.962	0.976	0.941	0.965
CFI	>0.90	0.988	0.988	0.987	0.994	0.987	1.000
TLI	>0.90	0.979	0.979	0.971	0.984	0.976	1.000

4.2.2 Analysis of Developmental Mechanisms

To further examine the hypothesized relationships among the three core variables—"Thinking," "Ethics," and "Capability"—in the science teaching competency of kindergarten teachers in ethnic rural areas, two regression models were established to analyze the effects of "Thinking" and "Ethics" on teaching practice ability.

(1) In Regression Model 1, which assessed the influence of "Thinking" on teaching practice ability, scientific conceptions and thinking were specified as the independent variable, educational competence as the mediating variable, and teaching practice ability as the dependent variable (see Figure 2). Mediation analysis was conducted to clarify the mechanism through which scientific conceptions and thinking influence teaching practice ability and to identify the internal relationships among these elements.

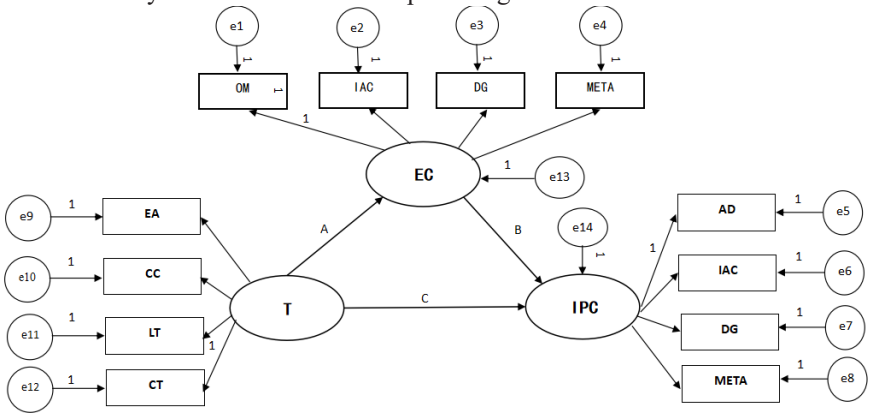


Figure 2. Impact Model of "Thinking" on Kindergarten Teachers' Science-Specific Teaching Practice Capability

The results indicated that scientific conceptions and thinking had a significant positive predictive effect on teaching practice ability ($\beta = 0.278$, $p = 0.003$). Additionally, scientific conceptions and thinking significantly

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predicted educational competence ($\beta = 0.687$, $p < 0.001$), and educational competence, in turn, significantly predicted teaching practice ability ($\beta = 0.669$, $p < 0.001$).

Subsequent Bootstrap analysis revealed that the total effect of scientific conceptions and thinking on teaching practice ability was significant (95% CI [0.550, 0.911], $p = 0.001$). A significant direct effect was also observed (95% CI [0.018, 0.477], $p = 0.044$). Furthermore, educational competence partially mediated the relationship between scientific conceptions and thinking and teaching practice ability (95% CI [0.263, 0.826], $p = 0.001$), thus supporting Hypothesis 3.

In summary, a substantial portion (62%) of the influence of scientific conceptions and thinking on teaching practice ability was mediated by educational competence. The model fit indices for Model 1 indicated a good fit with the data: X2/df < 3, RMSEA and RMR both below 0.08, and NFI, TLI, CFI, RFI, and IFI all above 0.90. All fit indices exceeded the recommended thresholds, confirming that the model is well-supported by the data.

(2)In Regression Model 2, which examined the influence of "Ethics" on teaching practice ability, teachers' professional ethics was specified as the independent variable, educational competence as the mediating variable, and teaching practice ability as the dependent variable (see Figure 3).

The results showed that teachers' professional ethics did not have a significant direct predictive effect on teaching practice ability ($\beta = -0.067$, $p = 0.427$). However, professional ethics significantly predicted educational competence ($\beta = 0.679$, $p < 0.001$), and educational competence, in turn, significantly predicted teaching practice ability ($\beta = 0.915$, $p < 0.001$).

Bootstrap mediation analysis further revealed that the total effect of professional ethics on teaching practice ability was significant (95% CI [1.196, 5.759], $p = 0.001$). In contrast, the direct effect of professional ethics on teaching practice ability was not significant (95% CI [–3.199, 0.307], $p = 0.395$), while the indirect effect through educational competence was significant (95% CI [1.204, 8.228], $p = 0.001$). These results indicate that educational competence fully mediates the relationship between professional ethics and teaching practice ability, thereby supporting Hypothesis 4.

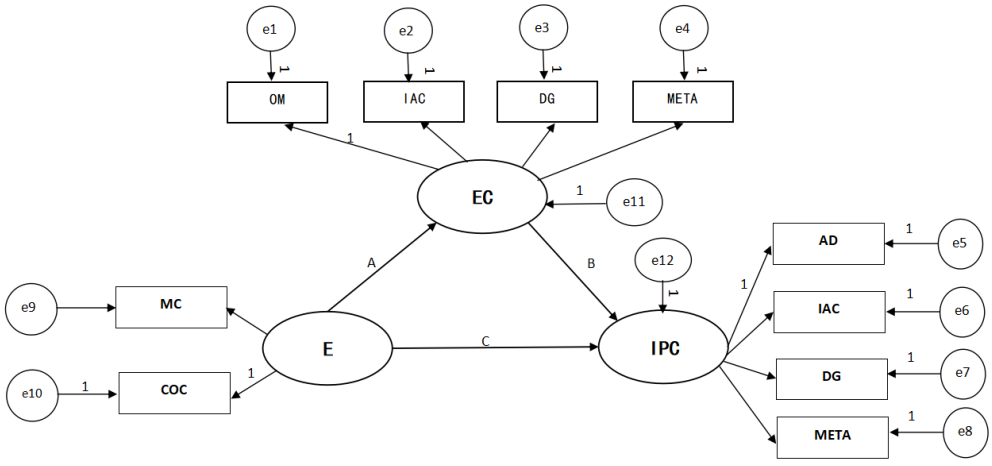


Figure 3. Impact Model of "Ethics" on Kindergarten Teachers' Science-Specific Teaching Practice Capability

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Finally, model fit indices for Model 2 suggested a good fit with the data: X2/df < 3, RMSEA and RMR both below 0.08, and NFI, TLI, CFI, RFI, and IFI all above 0.90. All indices exceeded recommended thresholds, confirming that the model fits the data well.

5. Discussion and Recommendations

5.1 Discussion

5.1.1 Imbalanced Development Across Dimensions of Kindergarten Teachers' Science Teaching Practice Ability

Teaching practice ability, as the core competency for effectively conducting science activities, demonstrated a relatively high overall level (4.03 ± 0.76). Further analysis of its four sub-dimensions revealed that rural kindergarten teachers' evaluation, design, and implementation abilities for science activities were slightly above the overall average. However, their research ability in science activities fell below the overall average.

Among these dimensions, science teaching implementation ability received the highest scores. Liu found no significant differences in science teaching implementation ability between kindergarten teachers from different regions or of different genders, indicating similar practical ability scores between rural and urban kindergarten teachers in conducting science activities[14]. Consistent with this, our comparison of science teaching implementation ability between rural teachers in W County and X City and their urban counterparts also revealed closely aligned scores across regions.

In contrast, research ability in science activities received the lowest scores and exhibited the greatest individual variation. This reflects a considerable disparity in the research proficiency levels among some rural kindergarten teachers in ethnic areas of Sichuan. In practice, these teachers face tensions between heavy childcare and educational responsibilities and the pressing need to enhance children's competencies. Coupled with the relatively stable external environment in these rural ethnic regions, a lack of professional learning awareness and insufficient motivation to delve into science education research further contribute to teachers neglecting scientific inquiry. This neglect results in noticeable gaps between individual teachers.

5.1.2 Significant Differences in Science Teaching Competency by Gender and Teaching Experience among Rural Kindergarten Teachers in Ethnic Areas

On one hand, gender differences are primarily concentrated in educational competence, where female teachers scored lower than their male counterparts. Specifically, female teachers scored lower on three indicators: classroom organization and management, teacher-child interaction, and child development guidance. However, in the dimension of moral education within activities, female teachers scored higher than male teachers. An imbalance in the gender ratio exists in rural schools, where male teachers often have greater opportunities for promotion and career advancement compared to females. Consistent with findings from Glover et al., male teachers in educational settings are frequently favored by leadership. Many female kindergarten teachers in rural areas engaged in science education are concentrated at intermediate professional titles[15]. The lower professional title ratings for female teachers can largely be attributed to socio-gender role differ-

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ences, which render female teachers more passive in their career development. This passivity further weakens their professional development awareness and intrinsic motivation for career advancement[16].

On the other hand, differences by teaching experience are also evident. Although science teaching practice ability and educational competence generally improve with increasing teaching experience, development remains uneven across different career stages. According to Huberman's theory of teacher career stages, teachers in their induction phase (internships or 0–2 years of experience) are acclimating to a new environment, focused on survival, and preoccupied with managing various relationships. As teachers progress into the stabilization phase, their social environment becomes more stable, their practical experience in conducting kindergarten teaching activities increases, and they gradually refine a more coherent science activity teaching system, leading to marked improvement in teaching practice ability. However, upon entering the experimentation and reassessment phase, teachers face a crossroads between uncertainty and committed development. For instance, when teaching experience reaches 5–9 years, science teaching practice ability shows noticeable regression, even falling below that of teachers with only 1–5 years of experience. Wang Jinghua's research yielded similar conclusions[17].

5.2 Recommendations

5.2.1 Building a Multi-stakeholder Support System to Enhance Teaching Practice Ability

Teaching practice ability forms the foundation for science education among kindergarten teachers in rural ethnic areas and is directly linked to the effectiveness of science instruction. Establishing a "Visiting Exemplary Kindergartens Program" would enable teachers from these regions to observe high-quality science activities, helping them identify challenges and practical needs in their own teaching through comparison and reflection, thereby inspiring self-improvement and updating educational philosophies. Simultaneously, implementing a "Master Teacher Mentorship Initiative" can strengthen professional guidance for rural kindergarten teachers in designing and organizing science activities. Promoting a "Master-Apprentice Pairing Program" that spans urban and rural areas—through job shadowing, joint teaching research, and other forms of collaboration—can facilitate the dissemination and sharing of high-quality educational resources.

In the context of educational digitalization, it is essential to actively leverage the internet and digital technologies to build a resource platform for science education tailored to rural kindergartens. This will foster the deep integration of information technology into science teaching and effectively translate digital resources into practical teaching capabilities. Furthermore, improvements to the science inquiry environment in rural kindergartens should be prioritized, including the provision of appropriate hands-on materials and activity resources to support teachers' practical innovation. Collaboration with families and communities should not be overlooked; teachers should actively engage parents and villagers in science education activities, extending scientific initiation education beyond the classroom into home and local life. This collective effort will help build a cohesive educational ecosystem that promotes the accumulation of children's scientific experiences.

5.2.2 Cultivating Moral Education Capacity in Science Through a Core Literacy Approach

In developing moral education capacity, rural kindergarten teachers should integrate ethical education or-

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ganically into science activities, guided by the core literacies of science. Educational competence lies at the heart of teacher professionalism, with moral education capacity occupying a central position within it. Teachers must adhere to ethics-based education, follow the developmental patterns of young children, and naturally incorporate character education into scientific inquiry activities. This approach helps children at different developmental stages gradually form positive attitudes toward the world around them and preliminary value judgments.

Teachers should be skilled at identifying moral education elements within science content and activities, using engaging and playful methods to cultivate qualities such as respect for facts, willingness to cooperate, and care for the environment. Additionally, rural kindergarten teachers need to continuously strengthen their own moral integrity and professional commitment, influencing children through their personal character and behavioral example—thereby achieving moral education through virtue and emotional nurturing. Ultimately, teachers should establish sound views of the child, education, and the teaching role, balancing cognitive development and character formation in science teaching to fully realize the holistic educational value of science education.

5.2.3 Empowering the Development of Scientific Thinking in the New Era

In advancing scientific thinking, rural kindergarten teachers should continuously strengthen their own scientific reasoning skills in line with contemporary demands. Scientific thinking is not only a key component of teaching competency in science but also directly influences the development of scientific literacy in children. Teachers in rural ethnic areas can draw on rich local natural and cultural resources to create a science learning environment with local characteristics. They should generate inquiry topics from children's familiar rural daily life, making science activities more relevant and accessible.

At the same time, emphasis should be placed on raising scientific questions in authentic contexts, integrating cross-disciplinary experiences, and enhancing systemic thinking and problem-solving skills in real situations. Teachers should also develop a habit of reflection, continually examining and adjusting their teaching practices to gradually improve the quality of their thinking. Education authorities at all levels should provide targeted thematic training, encourage participation in school-based teaching research and projects, and establish cooperation mechanisms with universities or research institutions. These efforts will help stimulate teachers' research awareness and innovative potential, thereby fostering the sustained development of scientific thinking in professional practice.

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References

[1]Wang, S., Liu, S., & Fang, T. (2021). Forecasting and planning of rural teacher demand structure for 2035. Journal of the Chinese Society of Education, (10), 1–7.

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[2]Mulder, M. (2012). European vocational education and training. In J. P. Wilson (Ed.), Human resource development: Learning, education, and training (pp. 102–105). Kogan.
[3]Burchinal, M., Hyson, M., & Zaslow, M. (2008). Competencies and credentials for early childhood educators: What do we know and what do we need to know? NHSA Dialog Briefs, 11(1), 1–8.
[4]Glover, T. A., Nugent, G. C., Chumney, F. L., et al. (2016). Investigating rural teachers' professional development, instructional knowledge, and classroom practice. Journal of Research in Rural Education, 31(3), 1–16.
[5]Luo, B. (2018). From teaching ability to curriculum-based educating ability: Understanding and application of the Training Curriculum Standards for Kindergarten and School Teachers. Teacher China, (6), 31–34.
[6]Dong, Q. (2017). Educating ability is the core of teachers' teaching competence. Journal of the Chinese Society of Education, (1), 3–5.
[7]Cantó Doménech, J. (2016). What sciences are taught and how are they taught in early childhood classrooms? The perspective of trainee teachers. Enseñanza de las Ciencias, 34(3), 25–50.
[8]Ye, J., Mi, S., & Bi, H. (2022). Construction and analysis of a competency model for science teachers in the new era. Teacher Education Research, 34(1), 71–77.
[9]Long, X. (2021). Shaping the ideal image of rural kindergarten teachers in ethnic regions: A case study of "One Village, One Kindergarten" in Liangshan Prefecture. Journal of Research on Education for Ethnic Minorities, 32(3), 94–101.
[10]McClelland, D. C. (1973). Testing for competence rather than for "intelligence." American Psychologist, 28(1), 1–14.
[11]Sun, Q. (2022). Research and support for early childhood learning: A perspective on the development of kindergarten teachers' professional competence (pp. 52–55). Educational Science Publishing House.
[12]Zhang, H. (2018). Constructing a model for evaluating rural teachers' instructional implementation ability in the "Internet+" era. China Educational Technology, (7), 116–121.
[13]Zhang, J. (2023). Exploring teaching strategies in kindergarten science from the perspective of STEAM education. Language Teaching and Research, (03), 172–174.
[14]Liu, D. (2018). Research on improving kindergarten teachers' instructional implementation ability in the science domain. Teacher Education Research, 30(7), 105–117.
[15]Nugent, G. C., et al. (2017). Rural education research in the United States: State of the science and emerging directions (pp. 11–15). Springer.
[16]Shi, L., & Tian, X. (2018). Development and innovation of rural teacher team building policies in China. Educational Research, 39(9), 149–153.
[17]Wang, D. (2023). A survey on the current status and influencing factors of kindergarten teachers' instructional design ability in the science domain. Theory and Practice of Education, 41(15), 30–34.

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