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A Study on the Current Status, Problems, and Optimization Paths of Primary School Science Education Professional Development and Teacher Training Models

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ABSTRACT

This study examines the professional development of primary school science education programs and teacher training models in China through an integrated theoretical and practical analysis. The research reveals that despite sustained national policy support for science teacher workforce development and the establishment of science education majors at selected normal universities, significant challenges persist. These include ambiguous professional positioning, outdated curriculum systems, insufficient teacher professional competence, and incomplete training mechanisms. Nationally, approximately 240,000 full-time primary school science teachers serve in schools, representing a critical shortage, with over 70% lacking science and engineering backgrounds. This deficit substantially constrains improvements in science education quality. Adopting a problem-oriented approach, this study proposes four optimization pathways: refining training programs and curriculum systems while strengthening interdisciplinary course development; establishing a tripartite collaborative training model integrating normal universities, education departments, and primary and secondary schools; enhancing teacher training quality and optimizing recruitment structures; and implementing comprehensive evaluation and incentive mechanisms. The study concludes that systematic reform and strategic resource integration can effectively elevate the quality of primary school science teacher preparation, thereby providing essential talent support for building a scientifically and technologically innovative nation.

KEYWORDS

Primary school science education; Teacher training models; Professional development; Collaborative education

1 Introduction

Primary school represents a critical developmental period for cultivating students' scientific interest and literacy, with science teachers serving as the pivotal determinant of educational quality in this domain. Research demonstrates that the construction of teaching staff in school science education, particularly the professional development of science teachers, constitutes a key factor influencing science education quality. In recent years, the Chinese government has issued multiple policy documents, including the "New Era Basic Education Teacher Strengthening Plan" and the "Notice on Strengthening Primary School Science Teacher Training," emphasizing the imperative to strengthen primary school science teacher supply and training mechanisms at the teacher education level[1]. Against this backdrop, this study seeks to analyze the current status and challenges of primary school science education professional development and teacher training models in China, proposing optimization strategies to provide substantive guidance for enhancing teacher training quality and elevating science education standards.

2 Theoretical framework

The theoretical foundations of primary school science education encompass the cultivation of students' core scientific competencies and constructivist pedagogical principles. The newly revised "Compulsory Education Science Curriculum Standards (2022 Edition)" explicitly emphasizes creating conducive learning environments and designing appropriate inquiry-based questions to enable students to experience the practical processes of scientific inquiry, technology, and engineering. This framework underscores inquiry-centered teaching methodologies that prioritize student engagement through hands-on experimentation, collaborative problem-solving, and real-world application of scientific concepts[2]. Consequently, science teachers must possess both robust scientific knowledge and proficiency in inquiry-based teaching approaches and interdisciplinary learning concepts.

The theoretical underpinnings of effective science teacher preparation draw significantly from social constructivism, which posits that knowledge construction occurs through social interaction and authentic practice within communities of learners. This perspective suggests that teacher education programs must provide extensive opportunities for prospective teachers to engage in scientific practices themselves before facilitating such experiences for their students. Additionally, pedagogical content knowledge frameworks emphasize that effective science teaching requires more than disciplinary expertise alone; teachers must understand how students learn scientific concepts, common misconceptions that emerge during learning, and appropriate instructional strategies to address diverse learning needs.

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At the policy level, the Chinese government demonstrates strong commitment to science teacher workforce development through comprehensive policy initiatives that address both immediate needs and long-term strategic goals[3]. The "Opinions on Strengthening Science Education in Primary and Secondary Schools in the New Era," issued by the Ministry of Education and related ministries, calls for elevating science teacher training standards and promoting the optimization of science education curricula and training models at normal universities. This policy framework recognizes that high-quality science education serves as a critical foundation for national innovation capacity and technological advancement. Furthermore, the "Notice on Strengthening Primary School Science Teacher Training" specifically mandates that normal universities optimize training programs in accordance with new curriculum standards, strengthen practical teaching components, and encourage students to pursue minors in science and engineering disciplines. These policy directives reflect recognition that traditional teacher preparation models have inadequately addressed the specialized knowledge and pedagogical skills required for effective science instruction at the primary level.

Collectively, core competency-oriented educational philosophies and national policies provide both theoretical guidance and policy support for primary school science education professional development and teacher training. The integration of these theoretical perspectives with practical policy implementation creates a framework for systemic reform that addresses curriculum design, pedagogical approaches, assessment practices, and institutional structures within teacher education programs.

3 Current practice status

Currently, primary school science education professional development and teacher training in China demonstrate accelerating progress across multiple dimensions, reflecting increased recognition of science education's critical role in fostering innovation and scientific literacy. First, regarding program offerings, select high-caliber normal universities have established science education majors or specialized tracks, creating foundations for primary school science teacher preparation through professional training and interdisciplinary minor programs. These programs typically integrate content from multiple scientific disciplines with educational theory and pedagogical methods specific to elementary instruction. Concurrently, education authorities encourage other teacher education programs, including primary education, physics, chemistry, and biology, to expand enrollment capacity to supply talent for primary school science instruction.

The expansion of program offerings reflects strategic efforts to diversify pathways into science teaching while maintaining quality standards. Some institutions have developed innovative program structures that combine general primary education preparation with intensive science specialization, allowing graduates to serve as both classroom teachers and science specialists within schools. Other institutions have established partnerships with science and engineering departments to provide teacher candidates with deeper disciplinary preparation alongside pedagogical training.

Second, concerning workforce scale, national statistics indicate approximately 240,000 full-time primary school science teachers, averaging 1.61 science teachers per primary school. This aggregate figure remains insufficient to meet the comprehensive demands of science education implementation, particularly given policy mandates to increase instructional time devoted to science and to implement inquiry-based pedagogies that require smaller class sizes and individualized attention. The shortage proves especially acute in rural and remote areas, where schools frequently lack dedicated science teachers and must rely on generalist teachers with limited science preparation to deliver science instruction.

Third, regarding workforce composition, surveys reveal that over 70% of primary school science teachers originate from non-science and non-engineering academic backgrounds, demonstrating deficiencies in both breadth and depth of disciplinary knowledge. This compositional imbalance substantially constrains science education quality enhancement, as teachers without strong disciplinary foundations often struggle to facilitate authentic scientific inquiry, address student questions that extend beyond textbook content, and model scientific thinking processes effectively. Many current science teachers entered the profession through generalist primary education programs that provided limited science content preparation, leaving them inadequately equipped to implement curriculum standards that emphasize deeper conceptual understanding and scientific practices.

Additionally, to implement science education mandates under the "double reduction" policy context, various regions have intensified science teacher training and professional development initiatives through publicly funded normal student programs, excellent teacher plans, and school-based training, thereby enhancing in-service teachers' professional competencies. These initiatives encompass various approaches, including intensive summer institutes focused on specific scientific domains, ongoing professional learning communities that support collaborative curriculum development and lesson study, and partnerships with research institutions that provide access to current scientific knowledge and laboratory facilities.

Overall, China's primary school science teacher training model primarily operates through institutional teacher

education programs. Inter-institutional collaboration and external resource utilization are gradually strengthening; however, a substantial gap persists between current capacity and societal needs. The expansion of training capacity remains constrained by limited faculty expertise in science education pedagogy within many normal universities, insufficient laboratory and field-based learning facilities, and inadequate coordination between teacher preparation institutions and primary schools for sustained clinical practice experiences.

4 Principal challenges

Despite notable progress, current primary school science education professional development and teacher training encounter multiple substantive challenges that require systematic attention and strategic intervention. First, professional positioning remains insufficiently defined. Some universities conceptualize the primary school science education major within traditional primary education program frameworks, lacking training objectives and curriculum designs that distinctively emphasize science education characteristics. This results in ambiguous talent cultivation positioning that fails to adequately prepare graduates for the specialized demands of science instruction while also not providing the comprehensive preparation needed for general classroom teaching.

Second, curriculum design demonstrates relative obsolescence that undermines alignment with contemporary science education goals and pedagogical approaches. Certain normal universities inadequately update science education curriculum content in timely fashion. The interdisciplinary and inquiry-based content advocated by new curriculum standards remains disconnected from actual teaching arrangements, with teachers maintaining outdated pedagogical concepts and demonstrating insufficient comprehension of new curriculum standards. Course sequences often emphasize factual knowledge transmission rather than experiential learning that develops scientific reasoning and inquiry skills.

Third, teacher professional competence deficiencies constitute a prominent concern requiring urgent attention and comprehensive intervention. As previously noted, substantial numbers of science teachers lack science and engineering backgrounds, resulting in inadequate understanding of scientific nature and inquiry-based teaching methodologies. These teachers demonstrate limited proficiency in implementing project-based and inquiry-based instructional models that require facilitating open-ended investigations, supporting student-generated questions, and scaffolding scientific reasoning processes. Additionally, relatively weak experimental operations and practical components in pre-service training mean that teacher education students lack sufficient teaching practice opportunities, thereby impeding professional competence development. Many programs provide limited opportunities for candidates to practice implementing inquiry-based lessons with actual students under mentorship from experienced science educators.

Finally, training mechanisms require comprehensive refinement to establish more coherent and sustained preparation pathways. Current training models predominantly operate through single-institution frameworks. Collaborative mechanisms among schools, local governments, and community organizations remain incompletely established. High-quality educational resource sharing proves insufficient, and the development of internship and off-campus practice bases necessitates further strengthening to provide authentic contexts for developing teaching expertise.

5 Optimization pathways

To address these challenges, improvements must be implemented across multiple dimensions through coordinated efforts among stakeholders in education, government, and research sectors. The following strategic pathways offer comprehensive approaches to strengthening primary school science teacher preparation and professional development.

First, training programs and curriculum systems require systematic refinement to ensure coherent preparation that meaningfully integrates disciplinary knowledge, pedagogical expertise, and authentic practical experience. Normal universities should establish clear training objectives and distinctive professional positioning aligned with Science Curriculum Standards requirements while continuously updating curriculum content to reflect advances in scientific understanding and evidence-based pedagogical approaches. This necessitates moving beyond traditional lecture-based instruction toward experiential learning models that engage prospective teachers in authentic scientific inquiry and reflective teaching practice. Science education concentration modules should be strategically integrated into comprehensive primary education majors, strengthening connections among interdisciplinary courses, including STEM curricula and comprehensive practical courses, with foundational pedagogical coursework. This integration enhances both curriculum comprehensiveness and practical applicability while developing candidates' capacity to facilitate meaningful interdisciplinary learning experiences for elementary students. Concurrently, teacher candidates should be actively encouraged to pursue minors in science and engineering disciplines or participate in micro-credential programs that broaden their disciplinary foundations and deepen understanding of authentic scientific inquiry processes, research methodologies, and contemporary developments within scientific fields.

Second, industry-academia-research collaboration and inter-institutional coordination must be substantially strengthened to leverage diverse expertise and resources across multiple sectors effectively. A robust tripartite

collaborative training model should be established among normal universities, local education departments, and primary and secondary schools, systematically leveraging the mentorship capacity and practical wisdom of experienced frontline teachers and science and technology educators. Institutional support mechanisms should actively facilitate strategic partnerships among teacher training institutions, comprehensive science and engineering universities, and research organizations to jointly develop open courses, establish mutual credit recognition systems, and share laboratory facilities, research equipment, and faculty expertise. These collaborative arrangements create enriched learning environments that provide teacher candidates access to cutting-edge scientific knowledge, advanced research facilities, and diverse pedagogical models. Furthermore, sustained collaborative relationships with science and technology museums, natural history museums, botanical gardens, and science communication centers should be formalized through memoranda of understanding that specify mutual obligations and benefits. Such partnerships enrich teachers' practical experiences, provide ongoing access to current scientific developments and discoveries, and offer innovative pedagogical resources including exhibit-based learning materials, scientist-educator collaborations, and public engagement opportunities that can be adapted for classroom instruction.

Third, teacher training quality must be enhanced through selective recruitment processes and intensive preparation programs that simultaneously prioritize robust disciplinary knowledge and sophisticated pedagogical skill development. Education departments should expand and strengthen publicly funded teacher training programs and the "Excellent Teacher Program" while strategically elevating recruitment standards to attract high-achieving candidates, particularly those with demonstrated academic achievement in science and engineering disciplines, for primary school science education positions. Selection criteria should assess not only academic credentials but also candidates' scientific reasoning abilities, communication skills, and commitment to equitable education. Comprehensive in-service teacher training should incorporate multiple evidence-based professional development modalities, including specialized content workshops that deepen disciplinary knowledge, demonstration teaching sessions that model exemplary inquiry-based instruction, collaborative lesson planning activities that foster professional learning communities, and structured mentoring relationships with accomplished science educators. These professional development experiences should explicitly promote exemplary teaching cases and inquiry-based instructional methods while establishing transparent incentive mechanisms that recognize and reward teachers' professional growth, instructional innovation, and contributions to science education improvement.

Finally, evaluation and incentive mechanisms require substantial strengthening to support continuous improvement and meaningfully recognize excellence in science teaching practice. The management and evaluation system for science teachers should be comprehensively refined to incorporate multiple measures of professional development achievements, including advanced coursework completion, action research projects, curriculum development contributions, and demonstrated improvements in instructional practice, into institutional incentive and recognition frameworks. These refined systems should establish a virtuous developmental cycle that encourages sustained engagement in professional learning, pedagogical innovation, and collaborative inquiry into teaching practice.

6 Conclusion

Through theoretical and practical analysis of primary school science education professional development and teacher training models, this study identifies current challenges including unclear positioning, outdated curricula, and insufficient teacher capacity. The research proposes optimization pathways encompassing improved training programs, deepened collaborative education, and enhanced training quality. The study concludes that implementing these measures will facilitate construction of a more systematic and coordinated science teacher training system, thereby elevating primary school science education quality. Future efforts should pursue institutional innovation and resource integration to continue deepening teacher education reform, creating primary school science teacher training models aligned with contemporary requirements, and providing robust talent support for building a scientifically and technologically innovative nation.

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