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REVIEW ARTICLE

Exploring Collaborative Mechanisms between Universities and Primary Education in the Era of Digitalized Education

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ABSTRACT

To address the challenges currently affecting research-based learning activities in primary education—such as limited resources, lack of content diversity, and insufficient teacher expertise—this study utilizes the resource advantages of the Eco-Environmental Science Education Base at Guilin University of Technology and employs the Virtual Professional Learning Community (VPLC) as a technological support platform to establish a triadic collaborative model: "VPLC + Science Education Base + Primary School." Operated through an integrated mechanism comprising collaborative design, resource sharing, and practice feedback, the model enables the effective alignment and integration of university-level science outreach resources with primary education needs. Case analyses indicate that this model significantly enhances students' practical skills and environmental awareness, fosters the professional growth of primary school teachers, and improves the societal impact of university resources. This study offers a viable reference framework for the collaborative and innovative development of basic and higher education.

Contribution/Originality: This study originates new model: "VPLC + Science Education Base + Primary School." Operated through an integrated mechanism

comprising collaborative design, resource sharing, and practice feedback, the model enables the effective alignment and integration of university-level science outreach resources with primary education needs.

1. Introduction

Research-based learning is instrumental in fostering students' comprehensive competencies during foundational education (Khuana, Khuana, & Santiboon, 2017). It serves as a conduit for translating theoretical understanding into practical application. Immersed in authentic learning contexts, students deepen their comprehension, improve their problem-solving abilities, and cultivate both scientific reasoning and an investigative mindset (Kotsis, 2024). However, in practice—particularly within primary education—such initiatives frequently fall short due to the shortage of quality resources, overly simplistic content structures, and gaps in professional training among teachers (Barrett et al., 2007; Fan, 2024; Santiago, 2002). These limitations contribute to inconsistent educational outcomes and hinder the transformative potential of research-based pedagogy.

In recent years, universities have assumed an increasingly vital role in supporting primary education, leveraging their capacities as hubs of knowledge, technology, and human capital (Harris & Holley, 2016; Wolfe, 2005). University-based science education centers offer substantial academic resources and state-of-the-art facilities, making them suitable partners for enhancing experiential learning in primary schools. Concurrently, advancements in digital technology have enabled the development of platforms such as Virtual Professional Learning Communities (VPLCs), which facilitate access to online instructional resources, enable real-time collaboration, and foster cross-institutional engagement (Carpenter & Munshower, 2020; Rolandson & Ross-Hekkel, 2022). These platforms have become integral channels for extending the reach of university-generated knowledge into public education (Galdames et al., 2024).

In this context, a triadic collaborative model has emerged—linking VPLCs, university science education bases, and primary schools—as a practical solution for embedding higher education resources within basic education. Under this model, universities function as providers of academic content and instructional resources; VPLCs serve as the technological intermediary; and primary schools play a central role in the implementation of project-based learning. This structured interaction ensures that educational needs are matched effectively with resource capabilities, allowing for contextually grounded and well-supported learning activities.

Guilin University of Technology, through its national-level Eco-Environmental Science Education Base and a mature virtual teaching platform, has piloted this collaborative model in partnership with its affiliated primary school. Centered on eco-environmental science education, the model provides a systematic response to common challenges—such as resource shortages, curriculum rigidity, and insufficient teacher training—while creating new pathways for research-based learning. This paper provides an in-depth examination of the model's conceptual framework, operational mechanism, and implementation outcomes, aiming to contribute practical and theoretical insights for strengthening research-based learning and expanding the societal impact of university engagement in basic education.

2. Methodology

To ensure transparency in how the supporting literature was gathered and synthesised, we adopted a structured review procedure inspired by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Page et al., 2021) framework while keeping the process concise and focused on relevancy.

2.1. Search Strategy

Databases consulted: Web of Science Core Collection, Scopus, ERIC, Google Scholar (first few result pages), and CNKI (Table 1). Time frame: Publications from 2010 to 2024 were considered to reflect recent developments in research-based learning and school–university collaboration. Keywords (Boolean logic): ("research-based learning" OR "inquiry-based learning" OR "problem-based learning") AND ("primary school" OR "elementary school") AND ("university–school partnership" OR "collaborative teaching" OR "community of practice"). Language scope: English and Chinese sources were included to capture both international and local insights.

Table 1: Inclusion and Exclusion Principles

Aspect	Inclusion Focus	Exclusion Focus
Publication type	Peer-reviewed journal articles, indexed conference papers	Theses, editorials, non-indexed blogs
Educational level	Primary/elementary education with university involvement	Studies confined to secondary or higher education
Content relevance	Empirical or conceptual work on tri-party collaborations and measurable teaching/learning outcomes	Descriptive reports with no mention of outcomes or transferable models

2.2. Screening Procedure

Duplicates were removed, after which titles and abstracts were reviewed for relevance. Potentially suitable studies were read in full, and any uncertainties were resolved through discussion among the authors to reach consensus.

Although we broadened the search to multiple databases and two languages, relevant studies published in other languages may have been overlooked.

3. Responding to Contemporary Needs: Rationale for the "Virtual Professional Learning Community + Science Education Base + Primary School" Model

3.1. Educational Imperatives for Research-Based Learning in Basic Education

China's current education reforms emphasize the development of students' comprehensive abilities, with a particular focus on fostering creativity, practical skills, and civic responsibility (Dilnoza, 2023; Hayati 2024; Hoggan-Kloubert et al., 2023). Research-based learning, as a critical extension of classroom instruction, facilitates the integration of theoretical knowledge with real-world application. It provides students with authentic contexts in which they can deepen understanding, address real-life challenges, and cultivate scientific thinking and inquiry-based learning.

Despite policy-level emphasis, the implementation of research-based learning in primary schools faces persistent challenges (Barrett et al., 2007; Fan , 2024; Santiago, 2002): (1) A chronic scarcity of high-quality educational resources, particularly in underdeveloped regions; (2) Oversimplified and repetitive activities that lack structured curriculum design and depth; (3) Limited capacity among teachers to design and facilitate engaging, inquiry-driven instruction aligned with contemporary educational demands.

These limitations significantly constrain the educational efficacy of research-based learning. There is an urgent need for a new model that integrates digital technologies and external high-quality resources to meet the increasingly complex educational demands of the digital era.

3.2. Distinct Advantages of University-Based Science Education Resources

As institutions of knowledge creation and public service, universities offer rich academic expertise, modern teaching infrastructure, and experienced faculty (Hmelo-Silver, 2004). Science education bases affiliated with universities are particularly well-equipped to support primary research-based learning (James & Singer, 2016). These bases house advanced laboratories, ecological modeling systems, environmental monitoring tools, and original science education content—including multimedia instructional materials and simulation-based learning tools. Collectively, these resources provide immersive learning environments that bridge the gap between abstract knowledge and practical application in primary education.

3.3. The Enabling Role of Virtual Professional Learning Community

Virtual Professional Learning Community (VPLC) serve as digital platforms that connect primary schools with university resources (He & Goto, 2023). Their functions include real-time interaction, remote collaboration, integrated resource access, and learning analytics. By overcoming spatial and temporal constraints inherent in traditional models, VPLC enable seamless coordination and co-development across institutions.

These platforms allow primary school students and teachers to access university-designed virtual courses and simulation environments, thus enriching the content and delivery of research-based learning. Moreover, VPLC facilitate collaboration between university faculty and primary school educators, supporting joint curriculum design and iterative course improvement. This ensures a responsive alignment between the expertise and resources of higher education and the evolving pedagogical needs of basic education (Farrell, 2023).

4. Building and Sustaining a Collaborative Research-Based Learning Model

4.1. Conceptual Framework and Design Principles

The core of the "Virtual Professional Learning Community + Science Education Base + Primary School" model lies in the digital integration of university resources to meet the practical teaching needs of primary schools. Through the alignment of curriculum development goals with institutional strengths, the model aims to elevate both instructional quality and learning effectiveness.

The model begins with a thorough understanding of school-level learning needs and progressively incorporates the instructional resources of science education bases. The VPLC serves as the coordination hub, ensuring systematic interaction among stakeholders. Consequently, the model can be described through foundational components.

4.1.1. Triadic Collaboration Mechanism.

In this configuration: Primary schools articulate learning objectives, content requirements, and feedback mechanisms; Science education bases provide contextualized knowledge, instructional content, and practice-based learning environments; VPLC coordinate resource alignment, communication flow, and implementation monitoring. This tripartite relationship forms a feedback-driven system in which primary schools identify needs, science education bases deliver appropriate resources, and VPLC facilitate iterative adjustments and continuous improvement (Kim et al., 2012).

4.1.2. Functional Roles of the Virtual Professional Learning Community

The VPLC assumes three central roles: Resource Aggregator- Collects and distributes instructional videos, datasets, and simulation tools; Collaboration Facilitator- Hosts joint design and review sessions between teachers and experts; Feedback Processor-Monitors learning activity, analyzes engagement data, and informs ongoing instructional refinement. By consolidating technology infrastructure with collaborative instructional practice, the VPLC creates a sustainable and adaptive system for delivering high-quality research-based learning (Carpenter & Munshower, 2020).

4.2. Operational Mechanism: From Collaborative Design to Practice Feedback

The operational functionality of the triadic model is structured around three interdependent stages: collaborative design, resource sharing, and feedback analysis. Each is supported by the digital capabilities of the VPLC platform.

In the collaborative design stage, teachers initiate the process by identifying instructional goals and student needs. Science education staff propose preliminary content based on available resources. University experts review and enhance the curriculum to ensure academic rigor. The result is a jointly developed program that is pedagogically coherent and scientifically sound.

The process moves naturally into resource sharing, in which educational content—including virtual experiments, course modules, and instructional videos—is centralized through the VPLC and made accessible to both teachers and students (Asghar et al., 2012). These resources reinforce theoretical learning through simulation-based practice and digital engagement.

Finally, during feedback and evaluation, the VPLC records participation and engagement data. Post-activity reflections and questionnaires provide additional qualitative feedback. This data is then analyzed to produce evaluative reports and inform the revision of future teaching strategies. The mechanism functions as a closed-loop system that enables continuous improvement.

5. Case Study and Outcome Assessment

5.1. Case Overview

To evaluate the practical implementation of the "Virtual Professional Learning Community + Science Education Base + Primary School" collaborative model, this study presents a case analysis of the Eco-Environmental Science Research-Based Learning program. The initiative was jointly developed by the national-level Eco-Environmental Science Education Base at Guilin University of Technology and its affiliated primary school.

The science education base spans over 1,000 square meters and includes a variety of specialized facilities such as a water environment monitoring laboratory, an ecological simulation teaching center, and interactive exhibits focused on environmental protection. The base is staffed by a dedicated science communication team of 15 professionals and supports over 5,000 student visits annually for research-based learning.

Complementing the physical base, the university has established a comprehensive Virtual Professional Learning Community platform offering more than 20 online courses and over 50 virtual experiments in eco-environmental science. These digital resources enable blended learning approaches that integrate theoretical instruction with practical exploration.

As the primary implementing institution, the university-affiliated elementary school benefits from solid educational infrastructure and a team of well-qualified teachers. The school has embedded ecological civilization education into its curriculum plan and emphasizes the development of student creativity, practical competence, and environmental awareness. It actively explores the integration of university resources to enhance instructional effectiveness and broaden learning experiences.

5.2. Evaluation of Implementation Outcomes

Regarding student learning outcomes, the collaborative model has led to marked improvements in the quality and impact of research-based learning for primary school students. Based on random surveys and on-site evaluations, 92% of participating students expressed strong interest in eco-themed research activities; 86% were able to accurately recall key knowledge content; and 85% reported an improved understanding of environmental protection principles and their practical significance (Sari et al., 2021). In the Li River Ecological Protection Exploration activity, more than 90% of students were able to independently explain key ecological challenges and the importance of water quality protection. Many accurately described the procedures used in water quality testing, such as measuring turbidity, pH levels, and dissolved oxygen. Additionally, 87% of students expressed increased environmental awareness and a willingness to engage in eco-friendly behaviors. These findings suggest a transformation from passive observation to active inquiry, resulting in enhanced cognitive development, practical skills, and environmental responsibility.

In terms of teacher professional development, the model has also facilitated substantial professional growth among participating teachers. Eighty percent reported significant improvements in their ability to design and implement research-based learning curricula. Additionally, 80% noted that collaboration with university faculty and science educators deepened their understanding of core concepts such as ecological science and China's national ecological civilization framework. This has enabled teachers to more effectively translate abstract academic theories into concrete and developmentally appropriate learning activities for students.

From the perspective of university resource utilisation, the collaborative model has significantly expanded the social value of university educational resources by embedding them in basic-education practice. Feedback from primary school implementation has informed the revision of instructional content, enabling better alignment with students' cognitive levels and local contexts.
Furthermore, the data generated from these collaborative research activities has contributed to university-led educational research. Analyses of student engagement trends and thematic interests provide valuable insights for curriculum design in environmental science and foster deeper collaboration between basic and higher education institutions.

6. Innovation and Practical Impact of the Collaborative Model

6.1. Advancing Research-Based Learning in Primary Education

The integration of the Virtual Professional Learning Community and the Eco-Environmental Science Education Base has significantly enhanced the diversity, depth, and structure of research-based learning in primary schools. This collaborative model provides students with more engaging and intellectually rigorous learning opportunities compared to traditional formats, which have typically relied on unstructured field visits and observational activities. These conventional approaches often lacked systematic curriculum design and resulted in superficial learning outcomes dependent on intuitive impressions.

By contrast, the collaborative model provides comprehensive support across all phases of the learning process—preparation, implementation, and reflection—thus addressing key limitations such as fragmented content and a lack of pedagogical continuity. Specifically, it improves students' cognitive engagement, scientific understanding, and practical competence through a well-integrated system of online and offline resources.

During the preparatory phase, the VPLC plays a crucial role in equipping students with foundational knowledge prior to field-based activities. The platform offers thematic online courses in eco-environmental science, allowing students to engage in self-directed learning in advance of hands-on experiences. For instance, before participating in the Li River Ecological Protection Exploration, students completed digital modules covering the geographical characteristics of the Li River basin, current water quality conditions, pollution sources, and remediation strategies. These courses utilized animations, videos, and interactive exercises to translate abstract environmental issues into accessible and engaging learning content. This preparatory phase fostered students' conceptual understanding and problem-awareness, effectively compensating for the typical knowledge gaps encountered in traditional research-based activities (Fu & Komatsu, 2024).

As learning moves into practice, the science education base, in turn, offers immersive learning environments that reinforce and extend students' theoretical understanding. A wide range of virtual and physical practice modules allow students to conduct hands-on experiments and engage in direct observation. For example, they can simulate wastewater treatment processes, analyze water samples for turbidity, pH, and dissolved oxygen levels, and observe ecological system dynamics using interactive sand tables. These activities facilitate the internalization of scientific knowledge and provide students with a comprehensive understanding of environmental systems and remediation techniques.

Finally, thematic activities further enhance student motivation and participation. The Li River Ecological Protection Exploration integrates local environmental issues and familiar geographical features to guide students through a series of inquiry-based tasks. Students are encouraged to examine the relationship between human activity and ecological impact, interact with educators, and propose solutions to identified problems. Similarly, the Low-Carbon Lifestyle Experience engages students in carbon footprint analysis and decision-making exercises to promote awareness of the environmental consequences of everyday behavior (AlAli & Al-Barakat, 2024). These problem-driven activities leverage students' lived experiences to stimulate curiosity, critical thinking, and collaborative exploration, resulting in deeper learning and stronger cognitive retention (Farrell, 2023).

6.2. Enhancing Teachers' Professional Competence through Immersive Collaboration

The collaborative integration of the Virtual Professional Learning Community and the Eco-Environmental Science Education Base has provided primary school teachers with systematic and structured professional development opportunities. This model significantly strengthens teachers' expertise in research-based curriculum design, instructional delivery, and classroom management.

First, collaborative curriculum design is realised through the VPLC platform, where teachers engage in sustained interaction with university faculty and science-education professionals. By jointly designing learning activities based on student needs and instructional objectives, teachers develop greater confidence in formulating scientifically grounded and pedagogically effective curricula. This process enhances the educational value of the learning programs and helps teachers build long-term competence in designing inquiry-based lessons.

Second, hands-on engagement in field instruction further deepens teachers' subject-matter knowledge and practical skills. During practical sessions held at the science education base—such as water quality testing—teachers work alongside students and receive real-time guidance from expert facilitators. This not only deepens their understanding of environmental science concepts but also sharpens their skills in experiment facilitation, inquiry guidance, and classroom adaptation (McConnell et al., 2013).

Finally, the model promotes the development of organisational and instructional leadership. Supported by both the VPLC and the science base, teachers learn to manage multifaceted teaching scenarios in which they serve simultaneously as instructional leaders, group facilitators, and safety supervisors. Ongoing practice and reflection enable them to coordinate student activities, foster cooperative learning, and monitor classroom dynamics more effectively. For example, during the Low-Carbon Lifestyle

Experience, teachers guided group discussions that linked environmental issues to students' daily lives, leading them through problem formulation, collaborative analysis, and solution design—skills central to student-centred inquiry-based learning (Kidman & Casinader, 2019).

6.3. Optimizing the Use of University Educational Resources

The integration of university resources into primary education, mediated by the Virtual Professional Learning Community, has significantly expanded the public service functions of higher education institutions (Jones et al., 2013). By consolidating instructional content, simulation tools, and interactive platforms, the model enables a more equitable and efficient distribution of high-quality educational resources (Ernest et al., 2013).

First, with respect to digital resource accessibility and application, the VPLC allows primary-school students to consult university-level instructional materials in environmental science, including virtual laboratories, courseware, and multimedia simulations. These digital resources support a blended learning environment that reinforces classroom teaching and promotes independent inquiry. Students are able to engage in self-paced study while also gaining practical insights into scientific methods and environmental systems.

Second, the model enhances immersive learning through science-base facilities. The physical infrastructure of the science education base—including its exhibition halls, ecological laboratories, and environmental monitoring stations—provides students with hands-on learning opportunities in various fields, such as water pollution control, ecological restoration, and environmental assessment. These immersive environments foster experiential learning, strengthen conceptual understanding, and enhance student motivation.

Finally, by effectively bridging theory and practice, the model enables pupils to develop scientific literacy and to apply knowledge in real-world contexts. For instance, they can observe virtual simulations of wastewater treatment to understand the application of physical, chemical, and biological processes in pollution management. Similarly, sand table models enable students to visualize hydrological changes and examine their ecological implications. These experiences not only increase students' engagement with university-level scientific content but also reinforce the value of higher education in advancing environmental awareness at the foundational level.

6.4. Addressing Challenges and Future Directions

Despite its demonstrated benefits, the collaborative model also presents several operational challenges that require further attention.

First, platform limitations and coordination issues remain a pressing concern. The current VPLC platform lacks advanced interactive functionalities, which limits the depth of cross-institutional collaboration. Additionally, the absence of a standardized evaluation framework for research-based learning makes it difficult to systematically assess instructional quality and student outcomes. Coordination issues—particularly regarding scheduling and resource availability—also hinder the seamless execution of learning activities (Farrell, 2023).

Second, the model's continued success is highly dependent on sustained institutional support. Without consistent investment and resource allocation, there is a risk of disruption due to external constraints. Long-term mechanisms must be established to ensure that the model remains operational and scalable over time (Asghar et al., 2012).

Finally, there is a clear need for interdisciplinary expansion. Most activities are concentrated within the domain of ecological and environmental science. Future iterations of the model should seek to incorporate a broader range of disciplines—such as information technology, engineering, and social sciences—to promote interdisciplinary learning and foster a more holistic educational experience for primary school students.

7. Conclusion

This study has examined an innovative triadic collaborative model that integrates Virtual Professional Learning Community (VPLC), university-affiliated science education bases, and primary schools to enhance research-based learning in basic education. Through a systematic evaluation of its design, implementation, and outcomes, the study demonstrates the model's effectiveness in addressing longstanding challenges in primary education, including limited access to high-quality resources, fragmented instructional content, and inadequate professional development for teachers.

The model has significantly improved the quality and scope of student learning experiences by combining online theoretical instruction with immersive, practice-based activities. Students not only acquired foundational knowledge in environmental science but also developed critical thinking, problem-solving skills, and a heightened sense of environmental responsibility through experiential engagement.

From the perspective of teacher development, the model has proven effective in fostering sustained professional growth. The collaborative mechanisms embedded in the VPLC platform—particularly those that facilitate co-design with university experts—have enabled primary school teachers to strengthen their curriculum design capabilities and enhance their subject-matter knowledge. Their instructional practices have become more inquiry-oriented, student-centered, and pedagogically coherent.

The model has also extended the social utility of university resources. By leveraging both digital and physical platforms, universities have expanded their engagement with local communities and basic education systems. The resulting synergy not only maximizes the value of academic infrastructure but also contributes to the broader goal of educational equity and innovation.

Despite these achievements, the model is not without limitations. Issues such as insufficient platform interactivity, lack of systematic evaluation mechanisms, and over-reliance on ecological themes highlight the need for ongoing refinement. Future research and implementation should focus on enhancing platform functionality, diversifying subject areas, and institutionalizing long-term operational support.

In conclusion, the "VPLC + Science Education Base + Primary School" model offers a viable and scalable framework for aligning higher education resources with the evolving needs of basic education. It exemplifies how strategic, cross-sector collaboration can yield sustainable improvements in educational quality, teacher capacity, and student outcomes.

Ethics Approval and Consent to Participate

The study did not involve human or animal subjects, and therefore, no ethical approval was needed.

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Conflict of Interest

The authors reported no conflicts of interest for this work and declare that there is no potential conflict of interest with respect to the research, authorship, or publication of this article

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