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A Reform and Practical Application of a PBL Pedagogical Model Integrating Local Scenarios, Scientific Frontiers, and Innovative Experiments

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Abstract

In response to the demand for practical and innovative abilities in engineering talent under the "New Engineering" initiative, and to serve the development of the Environmental Science and Engineering program and enhance student employability, this study addresses issues in the traditional teaching of the Soil Pollution Remediation Technology course at Mianyang Normal University, such as the disconnect between theory and practice, by designing and implementing a project-based learning (PBL) reform. This PBL model is grounded in the university's mission to serve the local region, is closely integrated with representative soil pollution issues of the surrounding area, incorporates scientific frontiers in soil remediation, and is linked with provincial-level innovative experimental projects. Through one cycle of pedagogical practice and a mixed-methods evaluation, the results confirm that PBL significantly stimulated students' interest in learning, improved their ability to apply knowledge and solve complex engineering problems, strengthened practical skills, including those from innovative experiments, and fostered teamwork. Concurrently, the study identified practical challenges in implementing PBL at local application-oriented universities, including limited experimental resources, complexity in process assessment, and high demands on faculty time and effort. The research indicates that a PBL model that integrates local conditions and scientific frontiers is an effective pathway for enhancing the comprehensive abilities and industry readiness of environmental science students; its sustainable development requires the university to optimize resource allocation, assessment mechanisms, and faculty support. This study provides an empirical reference for curriculum reform in similar institutions.

Keywords

Project-Based Learning (PBL)
Soil Pollution Remediation Technology
Pedagogical Reform
Curriculum Design
Application-Oriented Talent Cultivation

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1. Introduction

The current wave of technological revolution and industrial transformation, driven by information technology, artificial intelligence, and big data, is profoundly reshaping the global socioeconomic landscape, presenting higher engineering education with both severe challenges and historic opportunities for adaptive change. The "New Engineering" initiative emerged against this backdrop[1]. Its core philosophy is to deepen the reform of engineering education, advocating for breaking down traditional disciplinary barriers, strengthening interdisciplinary integration, and promoting collaborative education between industry, academia, and research. This initiative is dedicated to cultivating high-caliber, versatile talent who can meet the future needs of industry and address increasingly complex engineering challenges[2]. The cultivation of "New Engineering" talent is no longer confined to knowledge transmission but now emphasizes the comprehensive development of students' outstanding engineering-practice abilities, innovative spirit, systems thinking, and lifelong learning skills[3].Amidst the growing complexity and severity of global environmental issues, the field of Environmental Science and Engineering has become a crucial arena for implementing the "New Engineering" philosophy. Soil pollution, in particular, presents a major challenge to ecosystem stability, food safety, and human health due to its complex origins, concealed processes, lasting impacts, and remediation difficulty[4]. This situation creates an urgent need for environmental professionals who can integrate knowledge from multiple disciplines—such as environmental chemistry, biology, geology, and engineering—and can master and innovatively apply advanced remediation technologies, possess solid engineering practice skills, and efficiently solve real-world problems[5].

2. Current State and Reform Needs of the Course

2.1. Course Positioning

The *Soil Pollution Remediation Technology* course is a core component of the Environmental Science and Engineering curriculum, serving as a critical bridge between foundational environmental science theories and practical environmental engineering applications. Upon completing this course, students are expected to possess a preliminary ability to analyze real-world soil pollution problems and to select and justify remediation technology plans. This lays a solid professional foundation for their future work in soil environmental protection and remediation-related technical, managerial, or research roles. The quality of teaching in this course directly impacts the effectiveness of application-oriented talent cultivation and the students' future professional competence in the industry.

2.2. Shortcomings of the Traditional Teaching Model

In our institution, the long-standing teaching practice for this course has been found to have significant bottlenecks that constrain the cultivation of high-quality talent, a conclusion drawn from internal faculty reflections and comparisons with peer institutions. A primary issue is the pronounced disconnect between theory and practice; the curriculum is heavily skewed toward theoretical explanation, lacking a strong connection to complex engineering realities and leaving students ill-equipped to apply classroom principles to solve real-world soil pollution problems[6]. This is compounded by monotonous, instructor-dominated teaching methods that fail to fully leverage student autonomy, leading to low engagement and a lack of proactive inquiry. Furthermore, the program offers insufficient development of practical skills, with existing hands-on sessions being weak and poorly integrated with theoretical instruction, resulting in a deficit in students' engineering design and operational abilities[7]. Finally, these issues are reinforced by a limited assessment system that relies heavily on final, closed-book examinations focused on memorization, which cannot comprehensively evaluate higher-order competencies such as complex problem-solving, teamwork, and innovative thinking[8].

3. Introduction of the Project-Based Learning (PBL) Model

Project-Based Learning (PBL) is a student-centered, inquiry-based pedagogical method driven by authentic or near-authentic problems or projects. In PBL, students, under the guidance of an instructor, engage in sustained inquiry, collaboration, and practice centered around a challenging, complex topic or task. They learn relevant knowledge in-depth, develop critical skills, and enhance their overall competencies through the process of actively solving problems. The core features of PBL are its contextual, practical, collaborative, and results-oriented nature, requiring students to be proactively engaged in the learning process, while instructors act as facilitators, promoters, and resource providers. The PBL model aligns closely with the cultivation objectives championed by the "New Engineering" initiative, both of which emphasize strengthening engineering practice skills, innovative thinking, interdisciplinary integration, and the ability to solve complex engineering problems. Particularly in practice-intensive fields like environmental engineering, PBL is widely regarded as an effective means to overcome the shortcomings of traditional lecture-based instruction and to improve students' knowledge application, teamwork skills, and ultimate industry readiness, thereby better meeting the demands of industry and society for high-caliber engineering talent. Therefore, introducing PBL into the *Soil Pollution Remediation Technology* course is an essential step to address the aforementioned teaching challenges, deepen pedagogical reform, and enhance the quality of talent cultivation.

4. PBL-Based Curriculum Design for Soil Pollution Remediation Technology

4.1. Redefined Learning Objectives

Knowledge Objectives: Students will not only master the basic theories of soil pollution remediation but also gain a deeper understanding of the principles, applicability, limitations, and underlying mechanisms of mainstream remediation technologies such as physical, chemical, and biological methods. They will also learn about the application principles and research progress of emerging environmentally friendly remediation materials like biochar and sulfur-modified biochar.

Skill Objectives: Students will be able to apply interdisciplinary knowledge, including environmental chemistry, to analyze specific soil pollution problems. They will be capable of independently or collaboratively selecting and comparing remediation technologies and completing preliminary engineering design schemes. Their academic skills, including literature retrieval, information assessment, data processing, and scientific report writing, will be improved, as will their ability to communicate, collaborate, and present effectively within a team.

Dispositional Objectives: The course aims to cultivate students' critical thinking, systems thinking, and engineering innovation awareness. It seeks to enhance their capacity for autonomous and lifelong learning and to strengthen their sense of social responsibility for soil environmental protection and their adherence to engineering ethics.

4.2. Integration of Teaching Content and Project Selection

The selection of PBL projects strictly followed core principles designed to maximize pedagogical effectiveness. Emphasis was placed on local relevance and authenticity, as well as on cutting-edge and innovative aspects, ensuring precise alignment with the redefined course objectives while also considering an appropriate level of difficulty. Based on these principles, a case library with three types of projects was developed to offer diverse learning paths and cover core competency goals:

Case Study and Technology Assessment Projects: For instance, students were required to conduct a risk assessment based on a real-world scenario, such as cadmium (Cd) pollution in farmland in the Anzhou District of Mianyang, and perform a comprehensive evaluation of the technical, economic, and environmental aspects of a remediation plan using biochar.

Experimental Research Projects: Closely linked with provincial-level innovative experimental projects, these guided students to participate in the preparation and characterization of functionalized sulfur-modified biochar and to investigate its effectiveness in remediating simulated Cd-contaminated soil.

Remediation Scheme Design Projects: These projects simulated scenarios such as local PAH-contaminated sites, training students to complete the entire engineering process from site investigation and risk assessment to technology selection, process design, and feasibility analysis.

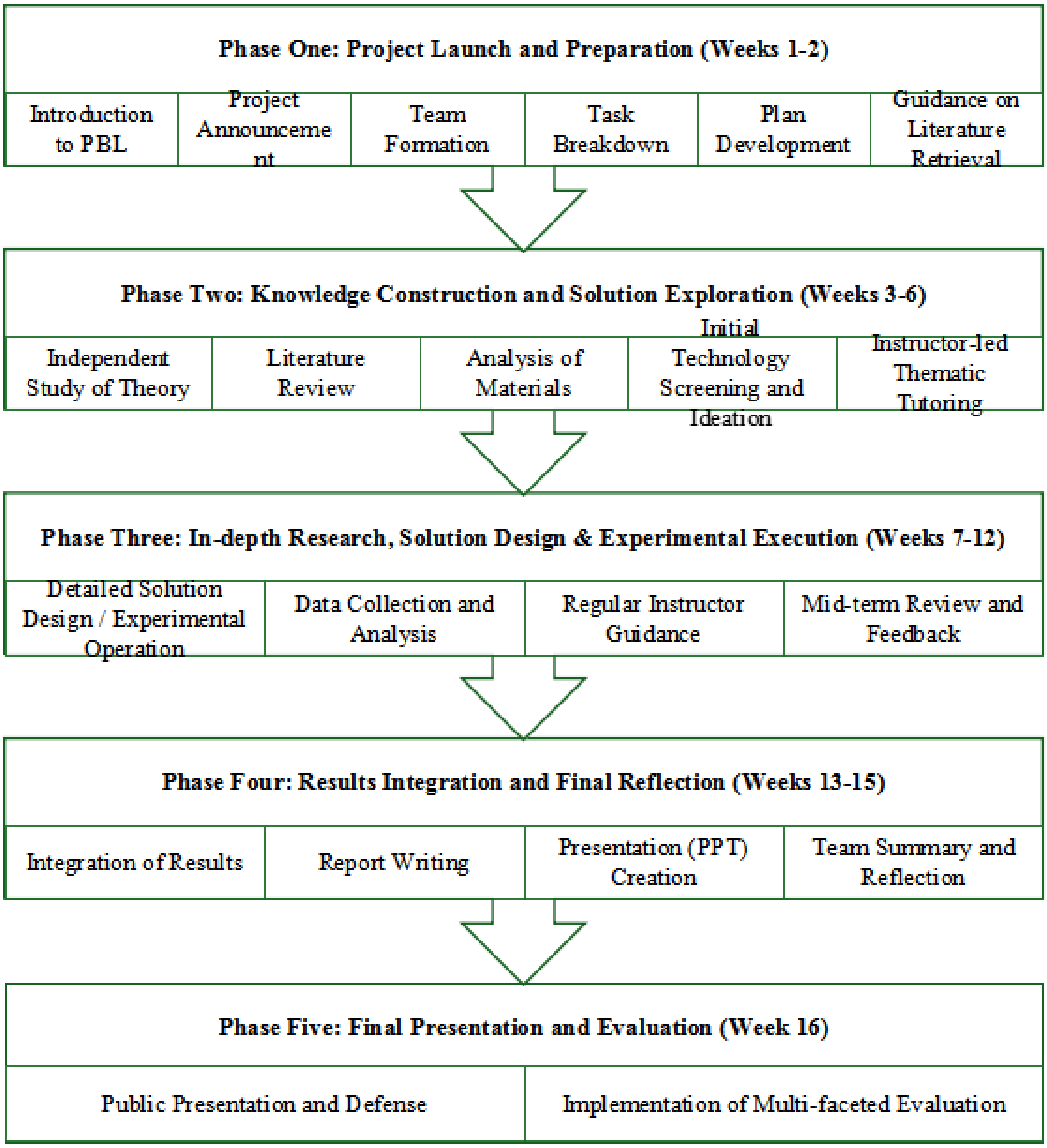

Figure 1. The Five-Stage Implementation Process of the PBL Model

4.3. Project Implementation Process Design

To ensure the orderly progression of PBL teaching, this study designed a five-stage implementation process spanning the entire semester (16 teaching weeks), as detailed in **Figure 1**.

5. Implementation Path of the PBL Pedagogical Model

5.1. Project Launch and Team Collaboration Mechanism

At the beginning of the course, students were given a detailed introduction to the requirements of project-based learning, expected outcomes, timelines, and the multi-faceted assessment method. The importance of the PBL model for enhancing personal comprehensive abilities and future industry readiness was particularly emphasized to guide students in transitioning from passive listening to active inquiry and autonomous learning. Team formation was based on a combination of “student interest first, with instructor adjustments.” Students were encouraged to form groups freely based on project choices, while instructors made minor adjustments based on students’ backgrounds and abilities to promote heterogeneity and complementarity within teams, ensuring each team had exposure to different types of project tasks. Team size was controlled at 4-5 members. To ensure effective team operation, each group was required to develop a detailed team charter at the outset, defining goals, member roles, communication protocols, meeting schedules, and progress management plans. A weekly team reporting system was also established to allow instructors to monitor project progress and team dynamics. Instructors conducted workshops early on to train students in essential teamwork skills such as effective communication, task management, and conflict resolution.

5.2. Redefining the Instructor's Role and Guidance Strategy

The successful implementation of PBL hinges on the successful transformation of the instructor's role. In this practice cycle, the teaching team positioned themselves as "guides," "facilitators," and "coordinators" of the learning process, rather than mere "transmitters of knowledge". First, they designed guiding questions to be used throughout the project instead of providing direct answers. For example, for teams choosing the biochar remediation project, questions were posed such as, "What potential advantages might sulfur-modified biochar have over regular biochar in remediating cadmium pollution in soil? What are the potential mechanisms? How could you design an experiment to verify this?" to stimulate deep thinking and inquiry. Second, they provided timely "scaffolding" support. Fixed weekly "project clinic" hours were scheduled to offer personalized guidance based on the needs of different teams at various project stages, covering recommendations for key literature, explanation of core theoretical difficulties, demonstration of experimental or software skills, advice on data analysis, and guidance on critical thinking. Third, they strengthened process monitoring and feedback by reviewing weekly team reports, participating in team discussions, and organizing mid-term presentations to stay informed of project progress and student difficulties, providing constructive feedback along the way. Lastly, they actively cultivated an open, inclusive, and inquiry-friendly atmosphere that encouraged trial and error, guiding students toward effective intra- and inter-team communication and collaboration to jointly overcome project challenges.

5.3. Execution of Student Practical Activities

Under instructor guidance, student teams engaged in a variety of hands-on activities centered on their chosen projects. All teams were required to conduct extensive literature searches and analyses and to apply basic methods of site investigation and risk assessment. Specific practical tasks varied by project type. Case study and technology assessment projects focused on applying theoretical knowledge to comprehensively evaluate the suitability, cost-effectiveness, and environmental impact of remediation technologies for specific sites. Experimental research projects guided students to engage deeply in scientific research practices, including the laboratory preparation and characterization of functionalized sulfur-modified biochar, quantitative study of its Cd adsorption performance, and evaluation of its effects in pot experiments, effectively enhancing students' hands-on research skills and data analysis literacy. Remediation scheme design projects required students to simulate the entire engineering process from problem identification to conceptual design.

5.4. Construction and Application of a Multi-faceted Assessment Framework

To overcome the limitations of a single, summative final exam and to comprehensively and objectively evaluate student learning outcomes and competency development throughout the PBL process, this study constructed and implemented a multi-faceted assessment framework. By increasing the weight of formative assessment and introducing multiple assessment subjects, the framework aimed to combine formative and summative evaluation, individual and team evaluation, and knowledge and skills assessment. This approach was intended to more fully reflect the students' learning process and true competency development, guiding them to shift their focus from merely pursuing grades to emphasizing a deep understanding of knowledge, the practical improvement of skills, and synergistic teamwork. The specific evaluation criteria are shown in **Table 1**.

Table 1. The Multi-faceted Assessment Framework for the PBL-based *Soil Pollution Remediation Technology* Course

Assessment Category	Content	Weight	Assessor & Method
Formative Assessment (50%)	Project Proposal & Literature Review Report	10%	Instructor evaluation
	Mid-term Progress Report & Submitted Phase-Work (incl. lab records)	15%	Instructor evaluation
	Teamwork Performance & Individual Contribution	15%	Instructor observation, team weekly reports, standardized anonymous peer evaluation
	In-class Participation & Discussion Performance	10%	Instructor observation and records
Summative Assessment (50%)	Final Project Report / Design Document	30%	Teaching team (scored based on a detailed rubric)
	Final Presentation & Defense	20%	Joint evaluation by teaching team and external experts (incl. industry experts)

6. Analysis and Discussion of Pedagogical Reform Outcomes

6.1. Significant Improvement in Student Learning Outcomes

The evaluation of this PBL pedagogical reform confirmed its multi-dimensional, significant improvement of student learning outcomes. Quantitative analysis showed that, compared to the traditional teaching model, students in the PBL experimental group demonstrated stronger abilities in knowledge application and higher-order thinking in their assessments. The quality of their submitted project reports was also high, generally showing an effective integration of theoretical knowledge with practical data to propose well-reasoned solutions. Students' self-assessed ability to solve complex environmental problems improved substantially. Qualitative feedback particularly affirmed the substantive role of the experimental research projects in developing students' hands-on skills, experimental design capabilities, and understanding of the scientific research process. Furthermore, the PBL model successfully stimulated students' interest and initiative in learning through its challenging and engaging nature and its high relevance to local environmental issues and cutting-edge research technologies. The project process also concurrently promoted the development of students' comprehensive competencies, including information literacy, critical thinking, scientific writing, and communication skills, laying a solid foundation for enhancing their industry readiness.

6.2. Enhancement of Teamwork and Communication Skills

Project-based learning provided students with a valuable platform for practicing teamwork. Students' self-assessed collaboration and communication skills improved significantly after the course, and most teams demonstrated good collective collaboration in their final presentations. The results also indicated that some teams still faced challenges during the collaboration process, such as uneven task distribution, inefficient communication, and disparities in member participation. This phenomenon reveals that while PBL creates a collaborative context, it is still necessary to continuously strengthen guidance and training in effective teamwork techniques, responsibility, and problem-solving skills.

6.3. Problems and Challenges in Practice

Although the PBL reform achieved significant positive outcomes, its implementation at Mianyang Normal University also highlighted challenges common to local application-oriented universities. First, there were constraints on experimental resources coupled with pressures related to safety management. Second, the assessment system needs further optimization to ensure the objectivity, fairness, and operational efficiency of evaluating both the process and individual contributions. Third, from the faculty perspective, there was an increased guidance workload and higher demands on instructors' interdisciplinary knowledge and facilitation skills. Fourth, effectively addressing individual student differences and providing personalized support to help all students adapt to and benefit from the PBL model remains a topic for ongoing exploration.

7. Conclusion

This study systematically explored and verified the significant efficacy of implementing a PBL pedagogical model in the *Soil Pollution Remediation Technology* course at Mianyang Normal University, a model that deeply integrates local soil pollution realities, scientific research frontiers in soil remediation, and innovative experimental projects. The findings show that this model effectively enhances students' multi-dimensional abilities required in the "New Engineering" context, including integrated knowledge application, engineering practice, complex problem-solving, and active learning. It strongly supports the substantive development of the application-oriented Environmental Science and Engineering program and provides valuable empirical evidence for improving students' industry readiness. At the same time, the study objectively revealed common challenges faced by local application-oriented universities when promoting such reforms, particularly in optimizing experimental resource allocation, ensuring the validity and reliability of formative assessment, and securing faculty investment in guidance, all of which require continuous improvement and systemic support. In the future, PBL practices can be continuously optimized through strategies such as deepening industry-academia integration, innovating resource utilization models, refining competency-based assessment tools, building faculty development communities, and implementing stratified and classified guidance. The experience from this study can provide a contextualized reference for similar institutions.

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Disclosure statement

The author declares no conflict of interest.

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