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Pedagogical Reform and Practice of the "Python Programming" Course for Emerging Engineering Education

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Abstract

Addressing challenges such as outdated knowledge content, insufficient industry-academia integration, and other related issues in the "Python Programming" course within the context of Emerging Engineering Education, this paper proposes a pedagogical reform framework characterized by 'industry orientation, competition-education integration, and multi-dimensional assessment.' By restructuring the curriculum, developing an Online Judge (OJ) platform-driven mechanism for integrating competitions with education, establishing a university-enterprise collaborative education platform, and innovating a four-dimensional assessment system, this study tackled issues of pedagogical relevance and the fostering of engineering innovation capabilities. Post-reform, significant improvements were observed in student competition awards, internship retention rates by enterprises, as well as code standardization levels and debugging efficiency. These outcomes validate the effectiveness of the 'four-in-one' integrated pathway, offering a replicable model for the development of Emerging Engineering Education courses in regional higher education institutions.

Keywords

Emerging Engineering Education, Industry-Education Integration, Curriculum reform, Teaching-Competition Integration, Multidimensional Evaluation, Online Judge (OJ) Platform.

1. Introduction

Under the context of Emerging Engineering Education[1,2] construction, higher engineering education faces dual challenges from industrial transformation and technological iteration. Traditional curricula suffer from issues such as outdated knowledge, insufficient industry-academia integration, and misalignment between practical skills and industrial demands, making it difficult to meet the needs of composite innovative talents in fields like intelligent manufacturing and industrial internet. Liaoning University of Science and Technology, leveraging the revitalization strategy of the old industrial base in Northeast China, took the "Python Programming" course as a reform vehicle. After three years of teaching practice, the institution constructed a reform framework characterized by "industry-demand orientation, competition-education integration, and multi-dimensional evaluation," exploring pathways for Emerging Engineering Education course development in regional universities.

This study restructured a "foundation layer - application layer - innovation layer" three-tier progressive curriculum system, established an Online Judge (OJ) platform-driven competition-education integration mechanism[3,4], built an industry-academia collaborative practical education platform[5,6], and formed a "four-dimensional integration" evaluation system covering programming ability, practical skills, innovation capacity, and professional competence. During the reform implementation, three key issues were prioritized:

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Dynamic Adaptation to Industrial Demands: Modular curriculum design was employed to align knowledge systems with industrial needs. Typical scenarios such as Ansteel's intelligent manufacturing and industrial data analysis were developed into case libraries.

Gradient Competition System: A "weekly competition - monthly competition - semester competition" system was constructed, integrating real enterprise projects into teaching processes.

Industry-Academia Integration Ecosystem: A "dual mentor system + joint laboratories + internship bases" ecosystem was established, fostering a deep integration of theoretical teaching, practical guidance, and industrial cognition.

By comparing key indicators, the reform demonstrated significant efficacy: the proportion of students winning provincial-level and above academic competitions and enterprise internship retention rates increased markedly. These results indicate that the reform measures effectively bridged the gap between engineering practical skills and industrial demands, providing a replicable practical model for Emerging Engineering Education course development in regional universities. This paper systematically elaborates on the reform framework, implementation pathways, and effectiveness verification, offering theoretical and practical references for innovating industry-academia integrated education models.

2. Student Learning Situation and Pain Point Analysis

2.1. Learning Situation Analysis

As direct participants in the Emerging Engineering Education initiative, students majoring in computer-related fields at Liaoning University of Science and Technology exhibit distinct temporal characteristics and personalized learning demands in their study of the Python Programming course. Based on big data of learning behaviors, course assessment data, and teacher-student interviews, four core issues were identified:

Structural Contradiction Between Foundational Skills and Engineering Thinking: While students master structured programming in C language, their ability to apply this knowledge in engineering contexts remains insufficient. Data from 2023 course practices revealed that only 28.6% of students could independently complete comprehensive experiments involving data cleaning, algorithm implementation, and visualization output. Analysis highlighted deficiencies in requirement analysis, modular design, and system integration, reflecting a dual lack of engineering thinking and systemic capabilities. This skill gap directly impacts their ability to address complex scenarios in Ansteel's intelligent manufacturing transformation.

Dual Challenges of Fragmented Technical Application and Fuzzy Industrial Awareness: Insufficient practical skills manifest in two ways: (1) fragmented technical application, where most students can only complete modular programming tasks but lack experience in system-level development; and (2) fuzzy industrial awareness, with 67% of students lacking knowledge of key technologies in Ansteel's "Digital Steel Plant." This misalignment prevents students from connecting Python data analysis techniques to real-world problems like blast furnace temperature prediction and equipment fault diagnosis, creating a "theory-practice disconnect." For instance, students struggle to apply Python anomaly detection models to industrial real-time monitoring needs, underscoring deficiencies in industrial cognition and technological innovation capacity.

Insufficient Autonomous Learning Motivation and Imbalanced Process-Oriented Skill Development: Under traditional teaching models, students' autonomous learning abilities remain underdeveloped. Data show that less than 15% engage in active out-of-class learning, reflecting a lack of intrinsic motivation. Learning behavior data further indicate a "result-focused, process-neglecting" tendency, with coding debugging frequency and annotation

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standards significantly below industry benchmarks. This learning attitude and methodological bias conflicts with the Emerging Engineering Education goal of "lifelong learning," necessitating pedagogical innovation to address the imbalance.

Low Competition Participation and Discontinuity in Engineering Innovation Cultivation: While competitions like the Blue Bridge Cup significantly enhance programming skills, student participation rates remain below 30%, with award-winning rates at only 12%. Analysis attributes this to the absence of competition-driven mechanisms in traditional teaching, which hinders the conversion of course knowledge into engineering practice. For example, in Ansteel's equipment fault prediction projects, students must integrate data acquisition, modeling, and deployment techniques, yet most can only complete single-module tasks, failing to develop system-level solutions. This reveals a critical gap in engineering innovation capabilities.

2.2. Pain Point Summary

Based on the learning situation analysis, the Python Programming course at Liaoning University of Science and Technology faces four structural contradictions that directly impede the realization of Emerging Engineering Education goals:

Inadequate Dynamic Alignment Between Curriculum Content and Industrial Demands: Course content lags behind regional industrial technological iterations. Existing case studies focus on traditional software development (e.g., student management systems), diverging sharply from scenarios like industrial internet platform development and smart equipment control in Ansteel's "Digital Steel Plant." 2023 industry surveys revealed a 30%+ capability gap among graduates in industrial big data analysis roles, weakening their professional competitiveness. The curriculum update mechanism fails to synchronize with enterprises like Ansteel, creating "temporal" and "capability" mismatches between talent cultivation and industrial demands.

Insufficient Synergy Between Teaching Models and Engineering Innovation Cultivation: Classroom instruction exhibits a "three-heavy-three-light" pattern: (1) heavy emphasis on syntax explanation but light on algorithm design training, leading to low scores in algorithmic questions during competitions like the Blue Bridge Cup; (2) heavy focus on single-machine debugging but light on distributed system development and collaborative practices, leaving students unprepared for modern engineering tools like Git and Docker; and (3) heavy reliance on knowledge dissemination but light on innovation and critical thinking training, resulting in inadequate problem-posing and problem-solving abilities. This model struggles to meet the demands of complex engineering challenges in the Emerging Engineering Education context.

Misalignment Between Evaluation Systems and Engineering Literacy Cultivation: The current assessment framework suffers from "two deficiencies and one loss": (1) lack of process-oriented evaluation, with final exams dominating and failing to reflect soft skills like coding habits and debugging efficiency; (2) lack of industry involvement, as practical evaluations are solely conducted by faculty without industrial perspectives; and (3) absence of code quality metrics, such as coding standards and debugging efficiency, in the evaluation system. This mechanism fails to comprehensively measure engineering literacy, perpetuating the phenomenon of "high grades but low practical skills."

Shallow Industry-Academia Integration and Ineffective Collaborative Education Mechanisms: Industry-academia collaboration remains superficial, with less than 12% of students participating in internships over the past three years. Internship tasks often involve basic work like equipment maintenance and system testing, excluding core R&D activities. Faculty members lack industrial engineering experience, with low representation of "dual-qualified" instructors, further limiting the delivery of industry-relevant case studies. This "surface-level integration" creates a "disconnect zone" between talent cultivation and

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industrial demands, necessitating a new teaching system guided by "demand-driven, competence-oriented, and industry-academia integrated" principles.

In conclusion, the Python Programming course currently faces dual challenges of complex learning situations and urgent reform needs. Only through systematic reforms—including curriculum content restructuring, pedagogical innovation, evaluation system optimization, and deepened industry-academia integration—can the disconnect between talent cultivation and industrial demands be resolved, thereby supporting the Emerging Engineering Education initiative in Liaoning Province and the digital transformation of Anshan's industries.

3. Course Construction Reform and Practice for Emerging Engineering Education

3.1. Reform Objectives

Based on the current status and pain point analysis of the Python Programming course, this study establishes four reform objectives aligned with the talent cultivation needs of Emerging Engineering Education [7]:

Construction of an Industry-Demand Oriented Curriculum System [8,9]: Guided by the development strategy of Emerging Engineering Education in Liaoning Province, the course integrates the digital transformation needs of Anshan's pillar industries (e.g., steel and equipment manufacturing) into its design. A "foundation-application-innovation" three-tier progressive modular system is reconstructed. Key industrial case libraries, such as Ansteel's intelligent manufacturing and industrial big data analysis, are developed to enable dynamic alignment between teaching content and industry demands through typical scenario-based instruction, ensuring the course's cutting-edge relevance and practicality.

Innovation of Competition-Driven Teaching Models: Centering on the Online Judge (OJ) platform, the reform integrates pedagogical approaches such as the "flipped classroom" and "blended learning" to establish an integrated "teaching-competition-practice" system. Automated coding evaluation via the OJ platform enhances teaching efficiency and learning outcomes; interactive tools like Rain-Classroom improve classroom engagement. The Blue Bridge Cup and similar competitions drive experimental courses, with enterprise mentors guiding student teams to strengthen engineering innovation and collaborative skills.

Deepening Industry-Academia-Research Collaboration Mechanisms: Joint laboratories are co-built with enterprises like Ansteel to introduce real-world projects as teaching cases, enabling enterprise engineers to actively participate in instruction. Through internship base construction, dual-mentor systems, and competition project incubation, a "learning-practice-innovation" cyclical education ecosystem is established. Emphasis is placed on industry awareness and theory-practice integration, cultivating high-quality composite talents meeting the digital transformation needs of regional industries.

Construction of a Four-Dimensional Integrated Evaluation System: Breaking away from the traditional "final-exam-centric" model, the reform builds a dynamic evaluation mechanism across four dimensions: programming ability, practical skills, innovation capacity, and professional competence. Leveraging automated evaluation on the OJ platform, Git version control tracking, and enterprise mentor feedback, the system integrates formative and summative assessments, as well as academic and industry evaluations, comprehensively reflecting students' engineering literacy and comprehensive capabilities.

3.2. Reform Content and Implementation Plan

Reconstructing an Industry-Demand Oriented Modular Curriculum System: To address the disconnection between traditional curricula and industrial needs, as well as insufficient engineering practice skills, the course system is restructured according to Liaoning's Emerging

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Engineering Education strategy and Anshan's industrial digitalization requirements. A "foundation-application-innovation" three-tier modular structure is adopted, with industrial case libraries developed to bridge theoretical and practical gaps. Foundation Layer (48 hours): Focuses on foundational programming skills, structured into three modules: Syntax Basics, Data Structures, and Algorithm Design. Industrial scenarios such as Ansteel's production data cleaning and logistics system optimization reinforce engineering application abilities. Application Layer (32 hours): Aligns with Ansteel's intelligent manufacturing needs, featuring modules on Data Acquisition, Data Processing, and Visualization Analysis. Students train in Python-based data crawling, Pandas/NumPy preprocessing, and Matplotlib/Plotly visualization using scenarios like MES system interface specifications and blast furnace anomaly detection. Innovation Layer (32 hours): Emphasizes system-level innovation through modules on System Architecture Design, Module Development, and Integration Deployment. Using Ansteel's smart factory as a blueprint, students engage in UML modeling, RESTful API development, and Docker containerized deployment to complete intelligent manufacturing system projects. The industrial case library includes scenarios such as Ansteel's blast furnace anomaly detection and equipment manufacturing MES interface development, significantly enhancing students' engineering practice skills and industry awareness through full-cycle technical training.

Innovative Teaching Model Based on OJ Platform for Competition-Integrated Education: Centered on the OJ platform, a competition-driven teaching model is implemented, integrating blended learning platforms, a three-dimensional teaching feedback loop, and competition-driven mechanisms to achieve "learning through competition, teaching through competition, and innovation through competition." Blended Platform: Integrates automated evaluation, interactive teaching, and resource management, supporting multi-language programming and interfacing with Ansteel's MES and industrial big data platforms for real-world scenario practice. Pre-Class Activities: Enterprise datasets (e.g., Ansteel's blast furnace temperature data) are assigned via the OJ platform for analysis tasks. In-Class Activities: Adopt the "flipped classroom" model, combining Rain-Classroom and OJ code demonstrations for interactive learning. Post-Class Activities: OJ platform assignments include Blue Bridge Cup past papers and enterprise projects (e.g., Ansteel's equipment fault prediction system development). The competition-driven mechanism, supported by course competition funds, cross-grade student teams, and a "weekly-monthly-semester" tiered training system, significantly improves students' coding proficiency, engineering literacy, and complex problem-solving abilities.

Strengthening the Industry-Technology-Academia Collaborative Education Mechanism: Guided by the principle of "industry-academia-research collaboration," the reform constructs a "demand-driven, competence-oriented, industry-integrated" education framework through joint laboratories, dual-mentor systems, and expanded internship bases. Joint Laboratories: The "Industrial Intelligence Joint Laboratory" co-built with Ansteel's Information Industry Company deploys MES and SCADA systems to simulate the entire steel production process. Dual-Mentor System: Enterprise mentors guide tasks such as RESTful API interface development and database integration, while academic mentors focus on theoretical instruction. Internship Bases: Expanded partnerships with Ansteel headquarters and Madi Intelligent Technologies provide hands-on experiences in roles like blast furnace control centers and rolling production lines. Students develop industrial apps for production monitoring and equipment fault warning, mastering industrial internet platform development techniques. This ecosystem fosters a "learning-practice-innovation" cycle, comprehensively enhancing industry awareness, engineering skills, and entrepreneurial capabilities.

Optimizing a Multidimensional Quantitative Evaluation Mechanism: A "four-dimensional integrated" evaluation system is constructed, combining formative and summative assessments, as well as academic and industry evaluations, to comprehensively measure

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programming ability, practical skills, innovation capacity, and professional competence. Programming ability is automatically assessed via the OJ platform, practical skills is evaluated through real-world projects in the industrial case library, innovation capacity is quantified by competition awards and innovative outputs, professional competence is assessed through enterprise mentor feedback. Dynamic evaluation mechanisms leverage the OJ platform, Git version control, and enterprise mentor input to track process-oriented metrics (e.g., code submission frequency, debugging efficiency, team collaboration) and evaluate work attitudes, skill mastery, and problem-solving abilities during internships. This system transitions from "knowledge assessment" to "ability evaluation," from "result-based" to "process-based" evaluation, and from "academic-only" to "industry-academic" evaluation, significantly improving code quality indices, competition award rates, and enterprise internship retention rates.

4. Teaching Reform Outcomes

Since the implementation of the Python Programming course reform at Liaoning University of Science and Technology under the Emerging Engineering Education framework, the reconstructed "foundation-application-innovation" three-tier progressive curriculum system, along with the reform framework of "industry-demand orientation, competition-education integration, and multidimensional evaluation," has yielded significant teaching outcomes.

4.1. Substantial Increase in Student Competition Awards

Prior to the reform, student engagement in academic competitions and award-winning rates were relatively low, with only 12% of students winning provincial-level or higher awards. Post-reform, the establishment of a "weekly-competition, monthly-competition, semester-competition" tiered competition system—integrated with real enterprise projects and supported by a dedicated course competition fund—dramatically enhanced student performance. For instance, in the Blue Bridge Cup National Software and Information Technology Talent Competition, the award-winning rate increased from 12% to 35%, with the first-prize rate rising from 2% to 8%. Additionally, students achieved breakthroughs in competitions such as the China Collegiate Computer Contest and the National College Students' Computer Application Ability and Information Literacy Competition, demonstrating marked improvements in competitive programming skills and innovative practical capabilities.

4.2. Significant Growth in Enterprise Internship Retention Rates

Before the reform, the industry-academia collaborative education mechanism was underdeveloped, with enterprise internship participation rates remaining at 12% over the past three years, and internships often limited to basic tasks like equipment maintenance and system testing. Post-reform, through deepened industry-academia integration—co-building joint laboratories with enterprises such as Ansteel Information Industry Company and Madi Intelligent Technologies, expanding internship bases, and implementing dual-mentor systems—the internship retention rate surged significantly. For example, in the Ansteel Information Industry Company internship program, the retention rate increased from 12% to 45%, a 275% growth. By participating in real enterprise project development during internships, students' engineering practice abilities and professional competencies improved markedly, earning high recognition from enterprises.

4.3. Notable Improvement in Code Quality Metrics

Prior to the reform, code quality was not formally assessed, and metrics such as code standardization and debugging efficiency lacked systematic evaluation. The post-reform "four-dimensional integrated" evaluation system prioritized programming ability, leveraging the

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Online Judge (OJ) platform for automated assessment of programming assignments and experiments. Data revealed significant improvements: the OJ platform's automated evaluation showed the one-time pass rate for student code increased from 65% to 85%, while code standardization (e.g., PEP8 compliance) rose from 21% to 78%. These results indicate that the reform effectively strengthened students' awareness of code quality and enhanced their programming standards and debugging efficiency.

4.4. Summary of Reform Outcomes

In summary, the Python Programming course reform at Liaoning University of Science and Technology has achieved substantial success. Through systematic measures—including curriculum restructuring, pedagogical innovation, deepened industry-academia integration, and evaluation system optimization—key indicators such as student competition award rates, enterprise internship retention rates, and code quality metrics have seen marked improvements. These outcomes validate the efficacy of the reform strategies and provide a replicable model for Emerging Engineering Education course development in regional universities, contributing to the digital transformation of Anshan's industries and the cultivation of composite engineering talents.

5. Conclusion

Under the context of Emerging Engineering Education construction, Liaoning University of Science and Technology has implemented a three-year systematic teaching reform and practice for the Python Programming course to address critical issues such as outdated knowledge updates, insufficient depth of industry-academia integration, and misalignment between student engineering practice capabilities and industrial demands. This study systematically restructured the course system, innovated teaching models, deepened industry-academia integration, and established a multidimensional evaluation framework. These measures effectively enhanced students' engineering practice capabilities and industrial adaptability. Key indicators such as the proportion of student competition awards, enterprise internship retention rates, and code quality metrics have demonstrated significant improvements, validating the effectiveness of the reform strategies.

The outcomes of this reform provide a replicable practical model for Emerging Engineering Education course development in regional universities, supporting the cultivation of high-quality engineering talents aligned with industrial demands. Furthermore, the study contributes to the digital transformation of Anshan's industries by fostering composite talents capable of addressing complex engineering challenges in modern industrial contexts.

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