

AI Empowerment Integrated with Engineering Practice: Pathways and Practices of Teaching Reform in Emerging Engineering Education

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Keywords: Emerging Engineering Education; AI Empowerment; Engineering Practice; Teaching Reform; Talent Cultivation

Abstract: Against the dual backdrop of the popularization of higher education and the rapid advancement of artificial intelligence (AI) technology, engineering education is facing a transformative challenge: shifting from an academic research-oriented paradigm to a practical talent cultivation model. Currently, engineering teaching is plagued by prominent issues such as outdated pedagogical concepts, lagging curriculum content, inadequate practical training, and simplistic assessment methods. These problems lead to a disconnect between students' theoretical knowledge and practical application as well as insufficient innovative capabilities. As a disruptive educational tool, AI technology has demonstrated tremendous potential in personalized teaching, expansion of practical scenarios, and support for scientific research and innovation, providing core support for the reform of engineering education. This study focuses on the core logic of integrating AI technology with engineering education, proposes a trinity teaching reform pathway of theory-practice-AI empowerment, and constructs a scientific and efficient teaching system by optimizing the entire teaching process, enriching practical scenarios, and strengthening competency development through AI. The feasibility of this model is verified through specific practical cases, which can effectively enhance students' practical abilities, innovative thinking, and industry adaptability, thereby providing a viable solution for the high-quality development of emerging engineering education.

1. Introduction

In the process of the popularization of higher education, the core goal of undergraduate engineering education has shifted from cultivating top-tier research-oriented talents to nurturing practical and innovative talents who meet the needs of society and enterprises [1]. With the rapid iteration of technologies such as intelligent manufacturing and artificial intelligence (AI), the development of Emerging Engineering Education (EEE) requires teaching to not only strengthen theoretical foundations but also emphasize practical application and the cultivation of innovative

capabilities [2]. The traditional engineering education model can no longer adapt to technological advancements and industry demands.

Leveraging its core advantages in data processing, intelligent simulation, and personalized adaptation, AI technology has evolved from an auxiliary tool to a core support in the field of education [3][4]. It can automatically generate teaching materials, construct virtual practical scenarios, provide personalized guidance and automated assessment, thereby offering new possibilities for addressing the traditional dilemmas in engineering education [5][6]. Relevant research data indicate that AI-empowered teaching models can boost teaching efficiency up to 96% [1][7], and they demonstrate remarkable value in knowledge transmission, competency development, and research support. Based on this, this study focuses on the application logic and practical pathways of AI technology, explores a teaching reform plan for its deep integration with engineering practice, and promotes the high-quality transformation of engineering education.

2. Current Status and Core Issues of Engineering Teaching

2.1. Misalignment between Talent Cultivation Orientation and Social Demands

For a long time, undergraduate engineering education has not fully completed the transformation from an academic-oriented model to an application-oriented one, and it still tends to emphasize theory over practice. Many enterprises report that recent engineering graduates often lack practical engineering skills and problem-solving abilities, making it difficult for them to adapt quickly to job requirements. After completing their undergraduate studies, some students still have a vague understanding of the practical application scenarios of their professional knowledge, and feel confused about their career development, thus increasing the risk of unemployment upon graduation. At a time when AI technology is widely applied in various links of industrial production, students' lack of ability to use AI tools and intelligent engineering thinking has further intensified the structural contradiction between talent supply and demand. Some studies indicate that only a small proportion of engineering graduates can proficiently use AI tools to solve practical engineering problems, while most remain at the level of basic operations, failing to meet the industry's demand for interdisciplinary talents [8].

2.2. Multiple Shortcomings in the Teaching Model

Outdated teaching philosophy: Traditional teaching is dominated by one-way knowledge imparting, neglecting the cultivation of students' independent thinking and innovative abilities, which makes it difficult to meet the demand for interdisciplinary talents under the Emerging Engineering Education initiative. Meanwhile, students vary widely in their academic foundations, making it difficult for teachers to implement personalized instruction. This results in some students being under-challenged while others struggle to keep up. Without AI assistance, instructors cannot accurately grasp each student's learning status, making personalized teaching difficult to put into practice [9].

Outdated teaching content: The update speed of textbooks lags behind the development of industrial technology. Especially against the background of the deep integration of AI technology and traditional engineering, technological breakthroughs brought by interdisciplinary integration have not been incorporated into teaching in a timely manner, resulting in a disconnect between students' knowledge system and industrial practice. For example, core technologies in intelligent manufacturing, such as AI-based quality inspection and intelligent scheduling, still lack systematic explanation in some traditional engineering courses. Studies indicate that the lag between engineering curriculum content and actual industrial demand can reach 3–5 years, and the rapid

iteration of AI technology has further widened this gap [10].

Weak practical training: Existing practices are mostly intermittent enterprise internships or simple experiments. They can hardly participate in the whole project process comprehensively, nor can they deeply understand the gap between theory and engineering practice. Restricted by practical conditions, some complex and high-risk engineering scenarios cannot be carried out in practice, which further restricts the quality of practical teaching. In addition, problems such as unbalanced allocation of practical teaching resources and insufficient depth of university-enterprise cooperation also prevent practical teaching from achieving the expected effects.

Single assessment system: Assessments are dominated by written scores, lacking scientific evaluation of practical ability, innovative ability, and AI application ability. Subjective practical evaluation is easily affected by teachers' personal preferences, making it difficult to objectively reflect students' true levels. The existing assessment system fails to fully reflect the requirements for students' comprehensive abilities in the AI era, leading students to focus on scores rather than abilities, which is not conducive to cultivating innovative talents [11].

2.3. Deficiencies in Student Competency Development

Due to the disconnection between theoretical learning and practical application, students generally lack the ability to solve real engineering problems. When faced with complex issues, they tend to seek ready-made answers from textbooks or the Internet instead of drawing conclusions through experimental verification and practical exploration, ignoring the differences in engineering applications under varying conditions [12]. This learning pattern results in insufficient subjective initiative among students, and their innovative thinking and creativity cannot be effectively cultivated.

Meanwhile, students lack the ability to analyze and solve engineering problems using AI tools, making it difficult for them to adapt to the needs of intelligent industrial development. Relevant surveys show that more than 60% of engineering students lack effective problem-solving strategies when dealing with complex engineering problems, and only about 30% can proficiently use AI tools to assist in completing learning tasks [13].

3. The Integration of AI Empowerment and Engineering Practice

3.1. AI Empowerment: Optimizing the Entire Teaching Process

(1) Implementation of Precise Teaching: AI technology is used to collect data on students' academic foundation, learning progress, practical performance, and other indicators, establishing individual and class-level learning profiles to accurately diagnose learning needs and problems. Teachers formulate personalized teaching objectives and content based on AI analysis results, realizing on-demand teaching and teaching in accordance with aptitude, and solving teaching difficulties caused by students' learning differences.

For example, the mechanical engineering program at University of Shanghai for Science and Technology uses an AI teaching platform to analyze students' learning data in mechanics courses (Fig.1). It provides personalized practice questions and explanatory videos targeting weak points such as strength calculation and vibration analysis, which has significantly improved teaching effectiveness.

This precise teaching model fully considers individual differences and enhances teaching pertinence and effectiveness. Relevant studies show that AI-assisted precise teaching can improve students' academic performance by 10%–15% [14].

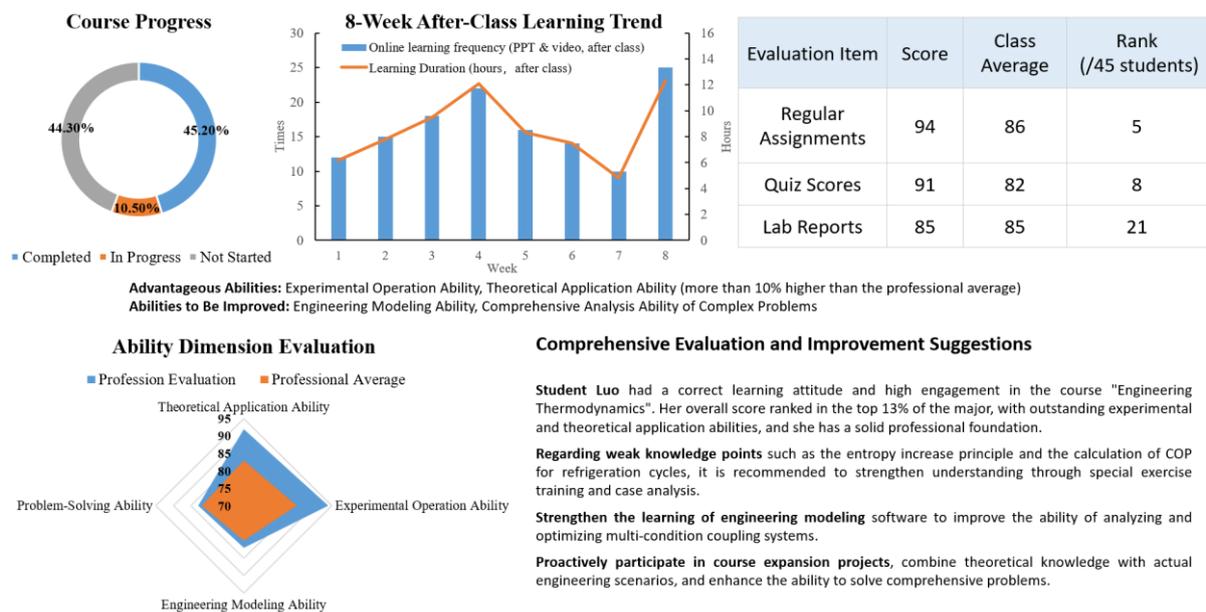


Figure 1: Suggestions on Student Course Data Collection and AI Analysis

(2) Enrichment of Teaching Content and Forms: AI technology is used to construct professional knowledge graphs and explore the internal connections among theoretical knowledge. With intelligent tools, students are provided with personalized services including real-time Q&A and updates on cutting-edge academic developments. Contextualized and gamified learning resources are adopted in class, while adaptive learning platforms such as Knewton and CogBooks are used outside class to realize a flexible online-offline integrated teaching mode, stimulating students' learning interest.

For instance, in the course Principles of Intelligent Control, teachers use AI tools to build virtual control systems. Students can observe system responses in real time by adjusting parameters, thus deepening their understanding of control theories.

AI technology enriches the presentation of teaching content and improves students' learning engagement and interest. Relevant practices show that contextualized and gamified learning modes can increase students' learning initiative by more than 20% [14].

(3) Improvement of the Whole-Process Assessment System: An AI-enabled intelligent evaluation system is constructed to track multi-dimensional data in real time, including classroom performance, virtual practical operation, and project quality, so as to realize objective and quantitative evaluation of the learning process and outcomes. The assessment covers theoretical mastery, practical operation, innovative thinking, and AI application ability, forming a closed-loop management of evaluation–feedback–improvement to ensure the scientificity and fairness of evaluation results.

For example, in the assessment of the course Fundamentals of Mechanical Design, the AI evaluation system provides a comprehensive score for students' course design from multiple dimensions: rationality of the design scheme, proficiency in applying AI tools, and innovative highlights, accompanied by detailed improvement suggestions.

Such a whole-process assessment system can comprehensively and objectively evaluate students' learning effectiveness and comprehensive abilities, providing a solid basis for teaching improvement.

3.2. Engineering Practice: Strengthening the Core Cultivation of Competencies

(1) Construction of a Multi-Level Practical System: Breaking through the limitations of traditional intermittent internships, a three-level system of curriculum practice – project practice – enterprise practice is established. Curriculum practice focuses on basic skill training through simulations on AI virtual platforms. Project practice relies on university-enterprise cooperation projects, allowing students to participate in the whole process from scheme design and experiment implementation to result verification. Enterprise practice includes immersive internships of no less than six months, enabling students to deeply understand industrial needs and technology applications.

Taking the cooperation project between the University of Shanghai for Science and Technology and an automotive parts enterprise as an example, students used the AI quality inspection system provided by the enterprise in project practice to participate in optimizing product defect recognition algorithms, applying machine learning knowledge learned in class to real engineering problems.

This multi-level practical system can gradually improve students' practical abilities and realize effective integration between theoretical knowledge and engineering practice.

(2) Strengthening Competency Cultivation in Practice: Real-world engineering problems are set in engineering practice to guide students in exploratory problem-solving using theoretical knowledge and AI tools. Completing project tasks through teamwork cultivates students' communication and collaboration abilities. Students are encouraged to identify new problems and propose innovative solutions in practice, stimulating innovative thinking. Meanwhile, by taking different roles in projects, students can recognize their own strengths, clarify career development directions, and reduce uncertainty after graduation.

For example, in an intelligent warehouse system design project, student teams divide responsibilities for demand analysis, AI scheduling algorithm design, system simulation and testing, and other tasks. They complete project development through collaboration, which comprehensively cultivates their comprehensive abilities.

Competency cultivation in practice can effectively improve students' innovative thinking and teamwork abilities. Relevant studies show that project-based practical teaching can enhance students' innovative ability by more than 25%.

(3) Promoting the Two-Way Transformation of Theory and Practice: Guided by real-world problems in engineering practice, teaching content is optimized in reverse, and the latest technologies, standards, and demands of the industry are integrated into the curriculum system. Students verify theoretical knowledge in practice and deepen their understanding; through the transformation of practical achievements, professional knowledge is converted into actual productivity, enhancing learning initiative and sense of achievement.

For example, in response to enterprise challenges in AI-driven equipment fault prediction, universities incorporate relevant content into the Equipment Fault Diagnosis course. After classroom learning, students participate in the analysis of real enterprise data and model optimization, realizing the coordinated improvement of teaching and practice.

This two-way transformation model keeps teaching content aligned with industrial needs and improves the practicality and pertinence of education.

3.3. Integration Mechanism: Constructing a Trinity Teaching System

Establishment of a Collaborative Mechanism for Theoretical Teaching – AI Empowerment – Engineering Practice (Fig.2): Theoretical teaching serves as the foundation, AI technology as the tool and carrier, and engineering practice as the application scenario and ability evaluation platform. The three components support each other and achieve dynamic optimization: Theoretical

knowledge is initially applied through AI-enabled virtual practice and further consolidated through real engineering practice; problems identified in practice drive the updating of teaching content and the optimization of AI tools, forming a virtuous circle of Teaching–Learning–Practicing–Evaluating.

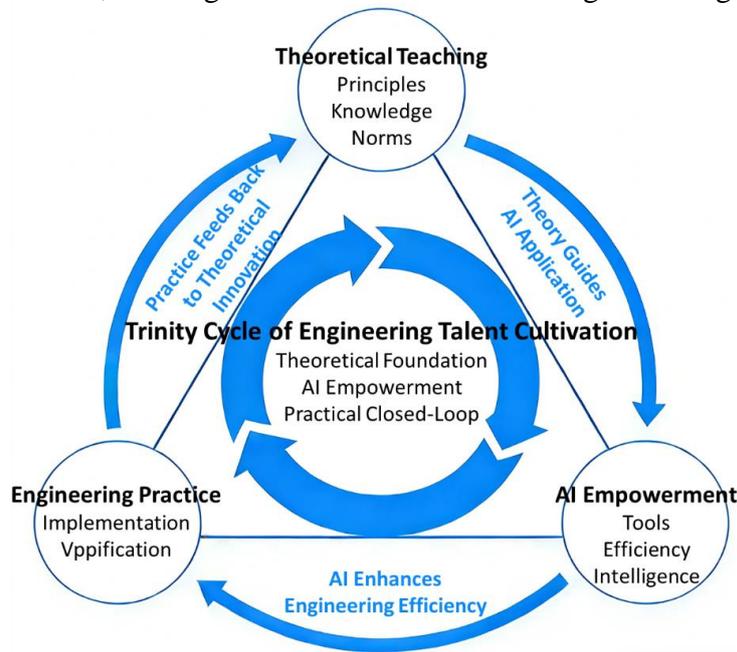


Figure 2: Trinity Cycle of Engineering Talent Cultivation

This trinity teaching system gives full play to the synergistic effect of theoretical teaching, AI empowerment, and engineering practice, realizing the comprehensive improvement of students' comprehensive abilities. Relevant practices show that the system can significantly improve students' academic performance, practical ability and innovative thinking, and greatly enhance graduates' industrial adaptability and employment competitiveness.

4. Practical Cases and Effect Outlook

4.1. Practical Cases: Reform of Intelligent Manufacturing Program at University of Shanghai for Science and Technology

The University of Shanghai for Science and Technology has implemented a teaching reform integrating AI empowerment and engineering practice for its intelligent manufacturing major, and constructed a trinity teaching system of theory–AI–practice.

In terms of curriculum design, core courses such as AI Engineering Applications and Intelligent Simulation Technology have been added, deeply integrating AI knowledge including machine learning and deep learning with professional knowledge such as mechanical manufacturing and control engineering.

In practical teaching, the university has cooperated with an intelligent equipment enterprise to build an AI virtual factory practice platform, which can simulate the whole process of intelligent production lines including scheduling, assembly, and quality inspection.

Through this platform, students complete the complete practical training from order receiving to product delivery, use AI tools to optimize production scheduling schemes, and verify design rationality through virtual simulation.

Meanwhile, students participate in real enterprise projects, use the AI quality inspection system provided by enterprises to take part in optimizing product defect recognition algorithms, and apply

machine learning knowledge learned in class to solve practical engineering problems.

In the assessment system, a combination of AI intelligent evaluation and practical achievement evaluation is adopted to conduct comprehensive evaluation of students from multiple dimensions: theoretical mastery, practical operation, innovative thinking and AI application ability.

Since the implementation of the reform, students' AI application ability and engineering practice ability have been significantly improved. Students have won many awards in the National College Student Intelligent Manufacturing Competition, and graduates' employment rate and employment quality have been remarkably improved, gaining wide recognition from enterprises.

Relevant data show that after the reform, students' average scores increased by 12%, practical operation proficiency increased by 35%, and participation rate in innovative projects increased by 40%.

4.2. Outlook on Effectiveness

The teaching reform model integrating AI empowerment and engineering practice can effectively address many dilemmas in traditional engineering education. By optimizing the entire teaching process with AI technologies, personalized instruction can be achieved to enhance the relevance and effectiveness of teaching. Rich virtual practice scenarios can make up for the limitations of on-site practice, reducing practice costs and risks. A multi-level engineering practice system can strengthen students' knowledge application and innovation capabilities.

Looking ahead, with the continuous advancement of AI technologies, engineering education will further break the constraints of time and space, and realize the deep integration of virtual practice and real-world projects. Through the organic combination of AI empowerment and engineering practice, universities will become talent cultivation bases keeping pace with industrial development, delivering more innovative and practical engineering talents for society, and providing solid talent support for the transformation and upgrading of the manufacturing industry as well as scientific and technological innovation. Meanwhile, the integration of AI technologies and engineering education will continue to deepen, forming a more complete teaching system and talent cultivation model, and promoting the high-quality development of emerging engineering education.

5. Conclusion

The core goal of engineering education is to cultivate high-quality talents with solid theoretical foundation, practical ability and innovative thinking. In response to prominent problems in current teaching and drawing on advanced international experience in integrating AI with engineering education, constructing a teaching system featuring the deep integration of AI empowerment and engineering practice is a key path for the reform of emerging engineering education.

By optimizing teaching models and enriching practical scenarios through AI technologies, and strengthening knowledge application and competency cultivation through engineering practice, the dilemma of disconnection between theory and practice can be effectively resolved, and students' initiative and creativity can be stimulated.

In the future, it is necessary to further deepen the integrated innovation of AI and education, improve the engineering practice teaching system, promote the high-quality development of emerging engineering education, and provide solid talent support for the transformation, upgrading, and technological innovation of the manufacturing industry.

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