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Research on the cultivation of interdisciplinary integration competencies of laboratory teachers in the context of AI+ Engineering Education

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Abstract

This study focuses on the cultivation of interdisciplinary integration competencies of laboratory teachers in the context of AI+ engineering education. As artificial intelligence (AI) becomes deeply integrated with engineering technology, the transformation of new engineering education has imposed new requirements on the interdisciplinary integration competencies of laboratory teachers. This research aims to construct a dimensional model of interdisciplinary integration competencies for laboratory teachers and design a university-enterprise collaborative cultivation path, verifying its effectiveness through empirical studies. The Delphi method was employed to build the competency model, combined with experimental comparisons and quantitative evaluation methods. The findings reveal that the university-enterprise collaborative cultivation path significantly enhances laboratory teachers' technological integration capabilities, pedagogical innovation capabilities, and collaborative transformation capabilities. The research results provide theoretical support and practical guidance for the professional development of laboratory teachers, offer a reproducible paradigm for university-enterprise collaboration, and hold significant implications for cultivating innovative talents capable of meeting future engineering challenges.

Keywords: AI+ engineering education, laboratory teachers, interdisciplinary integration competencies, university-enterprise collaborative cultivation

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1. Introduction

With the development of science and technology, artificial intelligence and engineering technology are deeply integrated to promote industrial upgrading. The new engineering education needs to be transformed to cultivate innovative talents who adapt to future challenges and have interdisciplinary abilities. As the key role of experimental teachers, their interdisciplinary integration ability affects the teaching quality. The rapid development of intelligent manufacturing, smart city and other fields has put forward higher requirements for engineering and technical talents, and the problem of disciplinary barriers in the traditional engineering education model has become prominent.

In this context, this study focuses on the cultivation of interdisciplinary integration ability of experiment teachers in AI+ engineering education, verifies its effectiveness by constructing capability models and designing school-enterprise collaborative training paths, explores key factors, provides theoretical support and practical guidance for the professional development of experiment teachers, and helps cultivate innovative talents.

1.1 Demands for New Engineering Education Transformation

With the rapid progress of science and technology, particularly the flourishing development of AI technology, its integration with engineering technology is leading a new wave of industrial revolution. In this context, the transformation and upgrading of new engineering education have become increasingly crucial, aiming to cultivate compound talents who not only possess a solid foundation in engineering technology but also possess interdisciplinary integration and innovation capabilities. This transformation is not only a profound reform in the field of engineering technology education but also a strong support for the national innovation-driven development strategy.

In recent years, the rapid technological iteration in cutting-edge fields such as intelligent manufacturing and smart cities has posed unprecedented challenges to the comprehensive qualities of engineering and technical talents. Traditional engineering education models often focus on the imparting of knowledge in a single discipline, neglecting the cultivation of interdisciplinary integration and innovation capabilities. Students educated under such models often struggle to provide comprehensive solutions when facing complex and ever-changing engineering problems. Therefore, the transformation of new engineering education aims to break down disciplinary barriers, promote cross-disciplinary integration, and cultivate innovative talents capable of meeting future engineering challenges.

1.2 Challenges of AI+ Engineering Education Integration

In the context of AI+ engineering education, laboratory teachers, as key players in engineering education, play a crucial role in the cultivation of interdisciplinary integration competencies. However, current laboratory teachers face numerous challenges in this regard.

On the one hand, the contradiction between the lag in teacher knowledge updating and industrial technological development has become increasingly prominent. With the rapid development of AI technology, the knowledge system in the engineering field is constantly updating. However, the knowledge structure of some laboratory teachers remains within the framework of traditional engineering education, making it difficult to keep pace with industrial development. This lag in knowledge updating not only limits teachers' innovation and foresight in the teaching process but also affects the cultivation of students' interdisciplinary integration capabilities.

On the other hand, the lack of interdisciplinary instructional design capabilities is also a major challenge for current laboratory teachers. Curriculum design under traditional engineering education models often focuses on the imparting of knowledge in a single discipline, neglecting the cultivation of interdisciplinary integration and innovation capabilities. Therefore, when facing the new requirements of AI+ engineering education, some laboratory teachers struggle to design experimental projects that reflect interdisciplinary integration characteristics and stimulate students' innovative thinking.

1.3 Research Significance

This study focuses on the cultivation of interdisciplinary integration competencies of laboratory teachers in the context of AI+ engineering education, aiming to construct a competency model and verify the effectiveness of cultivation paths, providing theoretical support and practical guidance for the professional development of laboratory teachers. This research not only holds important theoretical value, offering new ideas and methods for engineering education reform, but also has profound practical significance, providing actionable paradigms for the professional development paths of laboratory teachers and promoting the in-depth development of university-enterprise collaborative education.

Specifically, the significance of this research is mainly reflected in the following aspects: first, by deeply analyzing the current status and challenges of interdisciplinary integration competencies of laboratory teachers in engineering education, it reveals existing problems and deficiencies; second, based on the Delphi method, it constructs a dimensional model of interdisciplinary integration competencies, providing clear goals and directions for the professional development of laboratory teachers; third, it designs university-enterprise collaborative cultivation paths and verifies their effectiveness through empirical studies, providing actionable paradigms for the cultivation of laboratory teachers; fourth, it explores key factors influencing the enhancement of interdisciplinary integration competencies of laboratory teachers, providing useful insights and references for future research and practice.

2. Theoretical Framework Construction

2.1 Interdisciplinary Integration Competency Dimensional Model

This study employed the Delphi method, through multiple rounds of expert consultation and feedback, to construct an interdisciplinary integration competency dimensional model, encompassing three dimensions: technological integration capabilities, pedagogical innovation capabilities, and collaborative transformation capabilities.

Technological integration capabilities require laboratory teachers to integrate AI technology into engineering education, utilize AI toolchains for digital modeling and solving of engineering problems, and promote the intelligent transformation of engineering education. Pedagogical innovation capabilities are reflected in teachers' ability to utilize interdisciplinary thinking, innovate teaching modes such as project-based learning and virtual-real fusion experiments, and stimulate students' innovative thinking and practical capabilities. Collaborative transformation capabilities emphasize teachers' cooperation with enterprises to carry out project R&D and technology transformation, converting scientific research achievements into teaching resources, and promoting the deep integration of industry, academia, and research.

2.2 University-Enterprise Collaborative Cultivation Path Design

To enhance the interdisciplinary integration competencies of laboratory teachers, a university-enterprise collaborative cultivation path was designed, divided into three stages.

In the theoretical training stage, through expert lectures, academic seminars, and other forms, teachers are provided with theoretical knowledge and cutting-edge trends of interdisciplinary integration competencies, updating educational concepts and expanding academic horizons.

In the enterprise immersion stage, teachers are encouraged to go deep into the front lines of enterprises, participate in technology R&D and project management, understand enterprise needs and technology trends, enhance practical and innovative capabilities, and cooperate with enterprise experts to carry out project R&D and technology transformation.

In the project practice stage, interdisciplinary fusion experimental projects are designed in collaboration with real enterprise projects, completed by teachers leading students, enhancing teachers' project management and team collaboration capabilities, and promoting students' mastery of interdisciplinary integration capabilities.

Additionally, a dual mentorship implementation framework was designed, with on-campus mentors responsible for theoretical teaching and academic guidance, and enterprise mentors responsible for practical guidance and career planning, promoting communication and collaboration between universities and enterprises, and jointly driving the cultivation of teachers' interdisciplinary integration competencies.

3. Empirical Research Design

This study adopts a mixed-methods approach, combining quantitative evaluation and qualitative analysis, to comprehensively explore the cultivation paths and effects of interdisciplinary integration competencies of laboratory teachers in the context of AI+ engineering education. The following is the specific empirical research design.

3.1 Research Methods

Quantitative Evaluation - This study uses a teacher competency evaluation scale to quantitatively evaluate the interdisciplinary integration competencies of laboratory teachers. The scale is designed based on the interdisciplinary integration competency dimensional model, including three dimensions: technological integration capabilities, pedagogical innovation capabilities, and collaborative transformation capabilities, with multiple specific indicators under each dimension. By means of pre-test and post-test, data on the competencies of laboratory teachers before and after participating in the cultivation path are collected for comparative analysis.

Table 1

Teacher Competency Evaluation Scale

Dimension	Indicator
Technological Integration Capabilities	AI Toolchain Application Capabilities
	Digital Modeling Capabilities for Engineering Problems
Pedagogical Innovation Capabilities	Project-Based Learning Design Capabilities
	Virtual-Real Fusion Experiment Development Capabilities
Collaborative Transformation Capabilities	University-Enterprise Project Matching Capabilities
	Technology Achievement Teaching Transformation Capabilities

Qualitative Analysis - In addition to quantitative evaluation, this study also conducts qualitative analysis of the interdisciplinary integration competencies of laboratory teachers through teaching case text analysis and in-depth interviews. Teaching case text analysis mainly focuses on the interdisciplinary integration competencies exhibited by laboratory teachers during the project practice process, including project design, implementation, and achievement transformation. In-depth interviews focus on understanding laboratory teachers' views and feelings about the interdisciplinary integration competency cultivation path, as well as the challenges and gains they encountered during the cultivation process.

3.2 Experimental Intervention Plan

In this study, laboratory teachers were randomly divided into experimental and control groups, with different cultivation paths adopted for intervention.

Experimental Group: A hybrid cultivation path of "AI+ Engineering Workshops + Enterprise Project Practice" was adopted. First, systematic interdisciplinary integration competency training was provided to laboratory teachers through AI+ Engineering Workshops, covering AI technology, engineering practice, and pedagogical methods. Then, laboratory teachers were organized to go deep into the front lines of enterprises to participate in the R&D and implementation of real enterprise projects, applying their learned knowledge in practice.

Control Group: A traditional technical training path was adopted, mainly focusing on the enhancement of laboratory teachers' AI technical skills through online courses, lectures, and seminars.

3.3 Variable Control

To ensure the accuracy and reliability of the experimental results, this study strictly controlled variables for the experimental and control groups. Specifically, factors such as teachers' teaching experience and disciplinary backgrounds were controlled to ensure that the experimental and control groups had similar backgrounds and characteristics before intervention.

3.4 Data Analysis

Competency Development Trajectory Analysis - By comparing the competency scores of teachers in the experimental and control groups in the pre-test and post-test, the effects of different cultivation paths on the enhancement of interdisciplinary integration competencies of laboratory teachers were analyzed. The growth rates of experimental group teachers in the three dimensions of technological integration capabilities, pedagogical innovation capabilities, and collaborative transformation capabilities were compared.

ANOVA Analysis - The ANOVA method was used to explore the significance of differences in competency enhancement among laboratory teachers with different disciplinary backgrounds after participating in the cultivation path. Through data analysis, the commonalities and differences in the interdisciplinary integration competency cultivation process among laboratory teachers with different disciplinary backgrounds were understood, providing a basis for subsequent optimization of cultivation paths. Through the above empirical research design, this study will comprehensively explore the cultivation paths and effects of interdisciplinary integration competencies of laboratory teachers in the context of AI+ engineering education, providing strong support for engineering education reform and the professional development of laboratory teachers.

4. Data Analysis and Findings

4.1 Competency Development Trajectory Analysis

By comparing and analyzing the competency evaluation data of laboratory teachers in the experimental group before and after the experimental intervention, we clearly observed the development trajectory of their interdisciplinary integration competencies. The study found that after undergoing the hybrid cultivation path of

"AI+ Engineering Workshops + Enterprise Project Practice," laboratory teachers in the experimental group showed significant improvements in the three dimensions of technological integration capabilities, pedagogical innovation capabilities, and collaborative transformation capabilities. Among these, the improvements in technological integration capabilities and pedagogical innovation capabilities were particularly evident, indicating that through systematic training and real project practice, laboratory teachers can effectively integrate AI technology into engineering education and innovatively design interdisciplinary experimental projects.

4.2 ANOVA Analysis

To explore the significance of differences in competency enhancement among laboratory teachers with different disciplinary backgrounds after participating in the cultivation path, we used the ANOVA method for analysis. Table 2 shows the ANOVA analysis results of competency enhancement differences among laboratory teachers with different disciplinary backgrounds in each dimension.

Table 2

ANOVA Analysis Results of Competency Enhancement Differences Among Laboratory Teachers with Different Disciplinary Backgrounds

Dimension	Disciplinary Background	Mean Difference	Standard Error	t-value	p-value
Technological Integration Capabilities	Engineering Background	0.65	0.12	5.42	<0.01
	Science Background	0.58	0.13	4.46	<0.01
	Liberal Arts Background	0.42	0.15	2.80	0.01
Pedagogical Innovation Capabilities	Engineering Background	0.72	0.11	6.55	<0.01
	Science Background	0.64	0.12	5.33	<0.01
	Liberal Arts Background	0.48	0.14	3.43	<0.01
Collaborative Transformation Capabilities	Engineering Background	0.38	0.10	3.80	<0.01
	Science Background	0.32	0.11	2.91	<0.01
	Liberal Arts Background	0.24	0.13	1.85	0.07

Note: The mean difference is the difference between post-test scores and pre-test scores. $p<0.05$ indicates a significant difference, and $p<0.01$ indicates an extremely significant difference.

From the ANOVA analysis results, it can be seen that laboratory teachers with different disciplinary backgrounds showed significant differences in competency enhancement in the dimensions of technological integration capabilities and pedagogical innovation capabilities, both reaching extremely significant levels ($p<0.01$). In the dimension of collaborative transformation capabilities, although laboratory teachers with engineering and science backgrounds also showed significant improvements, the improvement rate of laboratory teachers with liberal arts backgrounds was relatively smaller, and the level of significance was slightly lower (p=0.07). This may be related to the lower initial level of interdisciplinary integration competencies of laboratory teachers with liberal arts backgrounds and the higher requirements of collaborative transformation capabilities for engineering and technical knowledge.

4.3 Analysis of Typical Teaching Cases

To gain a deeper understanding of the specific practices and innovations of laboratory teachers in the process of interdisciplinary integration competency cultivation, we conducted a text analysis of some typical teaching cases. Table 3 shows the innovation point coding of AI+ Engineering experimental projects developed by some teachers.

Table 3

Innovation Point Coding of AI+ Engineering Experimental Projects Developed by Teachers

Project Name	Innovation Point Code	Description
Digital Twin Experiment for Bridge Health Monitoring	I1	Applying digital twin technology to simulate bridge health status
	I2	Combining AI algorithms for real-time monitoring and early warning
Intelligent Manufacturing Production Line Optimization Experiment	I3	Utilizing AI to optimize production processes and improve production efficiency
	I4	Introducing IoT technology to achieve device interconnection and data sharing
Smart City Traffic Management Experiment	I5	Optimizing traffic flow based on big data and AI analysis, optimizing traffic signal control
	I6	Designing a smart transportation system simulation platform for scheme verification and optimization

Through the analysis of these typical teaching cases, we can see that laboratory teachers exhibited high levels of innovation and practical capabilities in the process of interdisciplinary integration competency cultivation. They were not only able to effectively integrate AI technology into engineering experimental projects but also combine knowledge and methods from other disciplines to design experimental projects that were innovative and practical, thereby enhancing students' interdisciplinary integration capabilities and innovative thinking.

Taking the "Digital Twin Experiment for Bridge Health Monitoring" as an example, this experimental project innovatively applies digital twin technology and AI algorithms to monitor and alert the health status of bridges in real-time. Through this experimental project, students can not only grasp the basic knowledge of bridge engineering but also understand the application of digital twin technology and AI algorithms in bridge health monitoring, thereby enhancing their interdisciplinary integration capabilities and innovative thinking. During the iterative process of the experimental project, laboratory teachers also continuously introduced new technologies and methods to optimize and improve the experimental project, further enhancing its practicality and innovation.

5. Conclusions and Recommendations

5.1 Research Conclusions

Effectiveness of University-Enterprise Collaborative Cultivation Path: Through comparative experiments between the experimental and control groups, this study verified the significant effect of the university-enterprise collaborative cultivation path in enhancing the interdisciplinary integration competencies of laboratory teachers. After undergoing the hybrid cultivation of "AI+ Engineering Workshops + Enterprise Project Practice," laboratory teachers in the experimental group showed extremely significant improvements in the dimensions of technological integration capabilities and pedagogical innovation capabilities, and significant improvements in the dimension of collaborative transformation capabilities. This indicates that the university-enterprise collaborative cultivation path can effectively promote laboratory teachers to integrate AI technology into engineering education, innovate teaching modes, and enhance their ability to cooperate with enterprises in project R&D and technology transformation.

Differences Among Teachers with Different Disciplinary Backgrounds: ANOVA analysis results showed that laboratory teachers with different disciplinary backgrounds exhibited significant differences in competency enhancement. Laboratory teachers with engineering and science backgrounds showed extremely significant improvements in the three dimensions of technological integration capabilities, pedagogical innovation capabilities, and collaborative transformation capabilities, while laboratory teachers with liberal arts backgrounds also showed significant improvements in technological integration capabilities and pedagogical innovation capabilities, but the improvement rate in collaborative transformation capabilities was relatively smaller. This suggests that differentiated cultivation strategies need to be formulated for teachers with different disciplinary backgrounds during the cultivation process.

Challenges and Opportunities of Collaborative Transformation Capabilities: Despite the improvements of laboratory teachers in the experimental group in the dimension of collaborative transformation capabilities, the overall improvement rate was relatively small, especially for teachers with liberal arts backgrounds. This reflects that collaborative transformation capabilities have higher requirements for engineering and technical knowledge and require the support of real enterprise projects. Therefore, in the future cultivation process, it is necessary to further strengthen the introduction mechanism of real enterprise projects and enhance laboratory teachers' ability to cooperate with enterprises in project R&D and technology transformation.

5.2 Practical Recommendations

Construct a Dynamically Updated AI+ Engineering Education Resource Library: In response to the rapidly developing characteristics of AI technology, it is recommended to construct a dynamically updated AI+ Engineering Education Resource Library to provide laboratory teachers with the latest technical materials, teaching cases, and training courses, helping them update their knowledge structures in a timely manner and keep pace with industrial development.

Establish a Long-Term Incentive Mechanism for Teacher Enterprise Training: To encourage laboratory teachers to actively participate in enterprise training and project practice, it is recommended to establish a long-term incentive mechanism, such as providing training subsidies, priority promotion opportunities, and recognition awards, to stimulate teachers' enthusiasm and participation.

Develop a Performance Evaluation System for Interdisciplinary Teaching Teams: The cultivation of interdisciplinary integration competencies requires the collaboration and support of interdisciplinary teaching teams. Therefore, it is recommended to develop a performance evaluation system for interdisciplinary teaching teams to objectively evaluate their contributions to the cultivation of interdisciplinary integration competencies and provide corresponding rewards and support accordingly.

Strengthen the Introduction Mechanism of Real Enterprise Projects: In response to the challenges of enhancing collaborative transformation capabilities, it is recommended to strengthen cooperation and exchanges with enterprises, establish a stable enterprise project cooperation mechanism, and provide laboratory teachers with more opportunities to participate in real enterprise projects. At the same time, encourage laboratory teachers to actively seek enterprise cooperation opportunities, transform scientific research achievements into teaching resources, and promote the deep integration of industry, academia, and research.

In summary, this study verified the effectiveness of university-enterprise collaborative cultivation in enhancing the interdisciplinary integration competencies of laboratory teachers by constructing an interdisciplinary integration competency dimensional model and designing a university-enterprise collaborative cultivation path. In the future, it is necessary to further improve the cultivation mechanism, formulate differentiated cultivation strategies for teachers with different disciplinary backgrounds, and strengthen the introduction mechanism of real enterprise projects to continuously promote the enhancement of interdisciplinary integration competencies of laboratory teachers.

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