Comprehensive Measures for Enhancing the Innovative Capabilities of Mechanical Engineering Professionally-Oriented Graduate Students through Tripartite Collaboration between Local Government, Universities, and Enterprises

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Abstract. Based on an in-depth analysis of the current status and trends of graduate education in China, this paper addresses the issue of inadequate innovative capabilities among graduate students, which makes it difficult to meet the needs of society and enterprises. It proposes to develop a 'Four-integration' curriculum system, the establishment of 'Three-collaboration' laboratories and platforms, and the construction of a 'progressive' practical innovation system. After the implementation of these reforms, compared to graduate students of the same major and grade, the proportion of those with qualified comprehensive innovation scores increased by 25.7%. The quantity and quality of innovative achievements, such as papers, projects, and competitions, have also seen significant improvements. This result demonstrates the effectiveness of the proposed measures for cultivating innovative capabilities among professional degree graduate students.

Keywords: Tripartite Collaboration between Local Government; Universities and Enterprises; Curriculum System; Professionally-Oriented Graduate Students; Innovative Capabilities.

1 Introduction

The Development Plan for Professionally-Oriented Graduate Education (2020-2025) aims to expand enrollment to two-thirds by 2025, marking a new era of scale, quality, and deep industry-education integration. [1] Universities have explored unique training systems for graduate students' innovative capabilities.

In response to the needs of the times, major universities in China have explored and constructed graduate training systems for innovative capabilities with their own characteristics. Xu Jing [2] and other scholars explored and practiced professional-oriented training for graduate students in control engineering, focusing on training modes and

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mechanisms through production-education integration. Li Wei [3] and Ke Qinfei [4] advocate university-enterprise cooperation and the dual mentor system, enhancing the complementarity between theoretical and practical courses and promoting deep integration among industries, universities, and research institutes. Li Sha's [5] team, based on the multi-disciplinary mentor group model, has injected new vitality into the training of master's students. Nieves Arranz [6] and Lambert [7], et al., believe that the establishment of positive collaborative relationships between universities and companies can effectively improve the employment rate of higher education students. Relying on the concept of "open training and chain education," Li Qi's [8] team built a comprehensive education and innovation system, enhancing the practical and innovative skills of control engineering graduates. Huang Fei [9] and others, leveraging the traits of Hefei University of Technology, proposed the "two integrations, three collaboration, and six combination" training mode for innovative practical skills, benefiting professional graduate education reform.

This paper, based on the research of many domestic scholars, combined with the characteristics of talent training for professional-oriented graduate students at Huzhou University, and in consideration of the challenges faced in the training of graduate practical abilities and innovative capabilities, especially the difficulty in meeting the actual demand for talent, puts forward a training mode that is grounded in local industry characteristics and relies on the collaborative innovation among local governments, universities, and enterprises. This model aims to optimize the curriculum system by deepening university-enterprise cooperation. It seeks to build a practical innovation platform, enrich graduate training resources, and cultivate more high-quality engineering science and technology talents who meet the market demand.

2 Problems and Challenges

2.1 Urgent Curriculum Optimization for Innovative Graduate Student Cultivation

In professional graduate education, the rationality of the curriculum structure is crucial for enhancing comprehensive quality and fostering innovation. Current challenges include a disconnect between theory and practice, a lack of interdisciplinary courses, and detachment from industry, all of which limit students' knowledge acquisition and problem-solving abilities. In industries such as intelligent logistics and environmental protection, an interdisciplinary vision and ability are urgently needed. However, existing courses fall short in meeting these demands, necessitating urgent reforms to spark innovation.

2.2 Lack of Innovation in Research Projects Hinders Grad Students' Innovative Capabilities

Huzhou's intelligent logistics, environmental protection equipment, ecological equipment, and other fields are developing rapidly. However, the current innovative capabilities training system for professional-oriented graduate students is still inadequate. It

lacks the driving force and innovative capabilities necessary for independent exploration in scientific research activities, making it difficult to meet the urgent demand for innovative talents in the industry.

2.3 Mismatch in Job Demand and Talent Supply; Highlighting High-Tech Talent Shortage Prominent

Huzhou's distinct industries urgently need professionals with deep expertise, practical experience, and strong innovative capabilities. Yet, current graduate training emphasizes academics over practical innovation, reducing graduates' job market competitiveness. Internships and training are ineffective due to low student engagement and a lack of practical problem-solving skills, hindering their swift integration and value addition in enterprises.

3 Reform Measures and Means

The government guides policies, invests resources, evaluates, and supervises; universities build a solid theoretical foundation; and enterprises provide practical platforms. Huzhou University has collaborated with all parties to establish a platform for university-enterprise collaborative education, optimize courses, construct practice bases, and form a multi-dimensional innovation and training system, as illustrated in Fig 1, with the aim of comprehensively enhancing the innovative capabilities of graduate students.

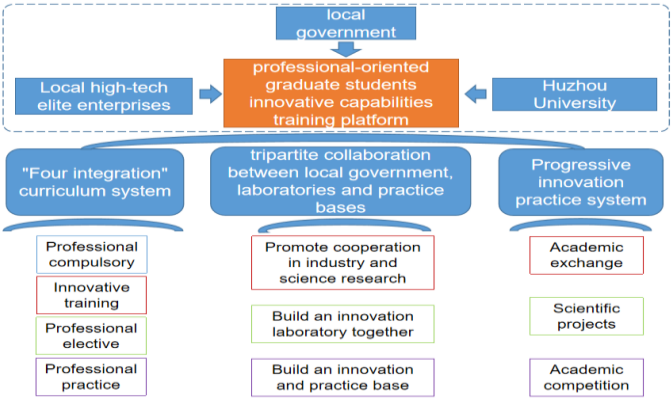

Fig. 1. Innovation ability training general approach

3.1 University-enterprise Cooperation to Jointly Build the 'Four-Integration' Curriculum System

Huzhou University partners with local enterprises to create a curriculum that is tailored to the needs of local industries. The Engineering College focuses on intelligent logistics, energy conservation, environmental protection, and ecological agriculture, and has formed research teams while optimizing the curriculum into four modules: compulsory

courses, innovative training, electives, and practical sessions. It emphasizes the "Four-integration" concept, with a particular focus on innovation training. Deep cooperation between the university and enterprises integrates resources, enabling students to lead local technological innovation after mastering theoretical knowledge.

Targeting Huzhou's intelligent logistics industry, a curriculum system integrating core concepts and cutting-edge practical practices is constructed. The Modern Industry College specializing in intelligent logistics equipment was founded to provide a comprehensive learning platform. The curriculum stays up-to-date, offering cutting-edge courses such as "Intelligent Logistics System Optimization" and "Internet of Things Technology Application". These courses are assessed in stages, emphasizing the integration of theory and practice, and fostering innovative capabilities. It aims to cultivate high-quality, professionally oriented graduate students with a solid theoretical foundation, proficient in technology application, and capable of leading the industry's development.

Our curriculum in energy-saving and environmental protection focuses on research and development (R&D) and application, partnering with EKO to offer courses such as "Resource Recycling" and "Intelligent Monitoring". It analyzes principles, emphasizes practical applications, and enables students to participate in cutting-edge R&D projects, such as the treatment of organic waste heat. We supervise, incentivize, regularly evaluate, and invite experts to assess, thereby ensuring that the quality meets market demands. This curriculum aims to cultivate professionals with cutting-edge skills for their future careers.

In the field of biological and ecological equipment, the curriculum system is carefully constructed, closely centering on the innovation of ecological technology and management modes. It aims to cultivate compound talents who possess both scientific literacy and practical abilities. The university actively integrates academic resources from top scientific research institutions such as the Huzhou Academy of Agricultural Sciences and Zhejiang A & F University, as well as from leading local enterprises in the agricultural field in Huzhou. Together, they jointly create a series of frontier courses, such as "Ecological Monitoring Technology" and "New Technology in Ecological Equipment," opening a door for students to the world of green science and technology.

In the field of biological and ecological equipment, the curriculum focuses on innovating ecological technology and management, aiming to cultivate talents with scientific literacy and practical skills. The university integrates resources from top institutions such as the Huzhou Academy of Agricultural Sciences and Zhejiang A&F University, as well as from local enterprises, in order to create courses like "Ecological Monitoring" and "New Technology in Ecological Equipment," thereby opening doors for students to the world of green science and technology.

3.2 In-depth Cooperation to Build "Three-Collaboration" Laboratories and Practice Bases

Professional-oriented graduate education is the cradle of high-level applied talents, and the enhancement of innovative capabilities is linked to national competitiveness. The

traditional model emphasizes theory over practice, leading to a lack of employment opportunities for graduates. The government, universities, and enterprises collaborate to increase practical opportunities and foster innovation in problem-solving. This initiative promotes the transformation of scientific research achievements, assists enterprises in making technological innovations, and achieves a win-win situation for all three parties.

(1)Three parties cooperate to establish a practice base. Enterprises collaborate with universities to construct training bases for graduate internships and training programs. They devise practical teaching plans to ensure that internships remain industry-relevant, thereby helping students master crucial skills. Both entities exchange talents, optimize resources, and further deepen their cooperation. Teachers remain informed about industry trends, while enterprise personnel spark innovations, jointly enhancing the practical abilities of students.

(2)Three parties cooperate to promote industry-university-research collaboration. Enterprises collaborate with universities to establish training bases for graduate internships and training programs. They devise practical teaching plans to ensure that internships remain industry-relevant, thereby helping students master crucial skills. Both entities exchange talents, optimize resources, and further deepen their cooperation. Teachers remain informed about industry trends, while enterprise personnel spark innovations, jointly enhancing the practical abilities of students.

(3)Three parties cooperate to promote industry-university-research cooperation. Local governments, universities, and enterprises should cooperate to train graduate students, apply for projects, integrate industry, academia, and research, and involve students in cutting-edge research. This resolves industrialization issues, accelerates the transformation of achievements, and provides practical learning opportunities. They will build an innovation platform to enhance socio-economic development and promote this model widely to cultivate top talents.

Through deep cooperation, the construction of labs and practice bases will enhance the innovative capabilities of graduate students, promote industry-university-research integration, and foster regional development. This model will be expanded to more fields, thereby contributing to the training of high-level, application-oriented talents.

3.3 Build a Progressive Innovative Practice System by Means of Projects and Competitions

In order to improve the abilities of professional-oriented graduate students, a progressive innovative practice system has been designed, including regular reporting, multidimensional academic exchanges, discipline competitions, and scientific research project practice.

(1)Research reporting mechanism within the team. Within the supervisor's research group, a regular reporting system for graduate research projects is implemented to ensure that each graduate student can timely share their research progress, challenges, and solutions encountered. In the process of preparing the report, graduate students take the initiative to consult literature, sort out research ideas, conduct experiments or data analysis, thereby continuously promoting the research process.

(2)Interdisciplinary exchanges and academic activity participation. Graduate students are encouraged to cross disciplinary boundaries and participate in academic presentations, salons, and other related activities. These expose them to the latest research, trends, and expert lectures, stimulating their research interest and innovation. Participation enhances their academic expression and writing skills, laying a solid foundation for their future research.

(3)Discipline competition and comprehensive quality improvement. Taking the scientific research competition as the driving force and promoting students to improve their abilities and surpass themselves in the competition is an effective way to improve the research innovation capabilities and practical ability of postgraduates. Furthermore, Internet +, Challenge Cup, Mechanical Design Innovation Competition, etc., can enhance the practical ability and knowledge application ability of graduate students, and promote the improvement of scientific research and innovative capabilities.

4 Evaluation Method for Cultivating Graduate Students' Innovative Abilities

In order to scientifically and effectively evaluate the effectiveness of cultivating innovative abilities among professional degree graduate students, we considered various dimensions. Among these, the effectiveness of the 'Four-Integration' curriculum system reform is primarily evaluated through students' academic performance, which serves as a measure of their mastery of industry knowledge. The achievements of the "Three Collaborations" laboratory and platform construction are mainly reflected in students' performance during corporate internships, progress in research projects, and patent outcomes. The implementation effect of the progressive innovative practice system can be demonstrated through students' published papers at academic conferences, competition awards, and the submission of reports.

Given the differences in the training focuses of graduate students across different academic years, we regard course grades, various reports, and participation in academic conferences as their professional achievements, while research projects, academic competitions, paper publications, and patent applications are considered their innovative practice achievements. Meanwhile, in order to accurately reflect the varying contributions of each achievement in cultivating graduate students' innovative abilities, we have assigned different weights to each achievement, based on factors such as importance, influence, and difficulty. The comprehensive testing method for evaluating graduate students' innovative abilities is detailed in Formula 1.

$$\begin{aligned} T &= T_1 \times w_1 + T_2 \times w_3 \\ w_1 &+ w_2 = 1 \end{aligned} \tag{1}$$

In the above formula 1, T_1 represents the score of specialized courses with a weight of w_1, and T_2 represents the score of innovative practice with a weight of w_2, respectively.

T_1 represents the professional score with a maximum of 100 points. The professional

score for the second year of graduate study is calculated based on the weighted average score of all courses taken in the first academic year. The weighted average score is calculated according to formula 2.

$$T_1 = \sum(S \times C) / \sum C \tag{2}$$

In formula 2, S represents the exam scores of each course, and C represents the corresponding credits for each course.

The professional score for the third year of graduate study is calculated based on the assessment results of the opening Report, mid-term report, enterprises professional practice report, and other relevant tasks completed during the second academic year. The calculation method is shown in formula 3.

$$\begin{aligned} &T_1 = S_{OR} \times w_{OR} + S_{MR} \times w_{MR} + S_{ER} \times w_{ER} \\ &w_{OR} + w_{MR} + w_{ER} = 1 \end{aligned} \tag{3}$$

In formula 3, S_{OR} represents the score of the opening report with a weight of w_{OR}, S_{MR} represents the score of the mid-term report with a weight of w_{MR}, and S_{ER} represents the score of the enterprise professional practice report with a weight of w_{ER}.

T_2 represents innovative practice with a maximum score of 100 points. The scoring criteria for different levels of papers, patents, projects, and competitions are shown in Table 1. For innovative practice achievements involving multiple contributors, the scores will be allocated to the participating students based on their ranking order, with the score assigned to a student with a lower ranking not exceeding that of a student with a higher ranking. The calculation method is shown in formula 4.

$$T_2 = S_{PP} + S_{PT} + S_T + S_C \tag{4}$$

In formula 4, S_{PP}, S_{PT}, S_T, and S_C represent the innovative practice scores for papers, patents, projects, and competitions, respectively. When T_2 exceeds 100 points, it will be calculated as a maximum of 100 points.The details can be found in Table 1.

Table 1. The scoring criteria for different perspectives

Item	Thesis						Competition						Patent			Project			
	SCI			EI	Core	Else	National			Provincial			IN*	UM*	SC*	NA*	Pr*	CL*	SL*
	1	2	3,4				1	2	3	1	2	3							
S*	60	50	40	30	20	10	60	50	40	30	20	10	60	30	10	60	40	20	10

S*-Score,IN*-Invent ,UM*-Utility model ,SC*-Software copyright , NA*-National , Pr*-Provincial ,CL*-City Level ,SL*-School Level

5 Main Construction Achievements

To evaluate the effectiveness of the graduate student innovation capability cultivation measures proposed in this paper, we collected data on academic performance, academic papers, academic competitions, and professional research and project outcomes from

152 graduate students of the same major and grade in the Engineering College for both 2022 and 2023. The distribution of comprehensive scores for student innovation capability for these two years is detailed in Table 2. The data in the table indicates that, after the implementation of the reforms, the comprehensive innovation scores of students in 2023 significantly improved, with the pass rate increasing by 25.7% when compared to 2022. This demonstrates that the implementation of various innovation initiatives has honed students' innovation capabilities.

Table 2. The distribution of comprehensive evaluation scores in 2022 and 2023

Distribution	90-100	80-90	70-80	60-70	Below 60
2022	8%	16%	28%	8%	40%
2023	11.40%	20%	31.40%	22.90%	14.30%

In the past two years, there has been an increase in research papers, approved patents, and software copyrights, with discipline competition participation breaking new ground. See Table 3 for details. The achievements include 34 provincial-level or higher awards, 2 provincial practice cases, 4 doctoral admissions, and 1 university-level teaching award. Laboratory and base construction excelled, with the provincial research center and key lab being rated as excellent, the establishment of 1 industry lab, and the approval of 1 provincial training base. Discipline construction also progressed, with the approval of 2 municipal key disciplines and labs. With the support of Huzhou city, the College of Intelligent Equipment was built to high standards, and the College of Semiconductor & Photoelectric Industry was jointly established with the district government.

Table 3. Data of graduate innovation achievements

Year / project	Thesis				Competition		Patent			Project	
	SCI	EI	Core	Else	National	Provincial	Invent	UM*	SC*	Provincial	School Level
2022	19	22	7	8	2	17	12	27	24	1	7
2023	17	41	5	20	10	24	17	41	57	3	14

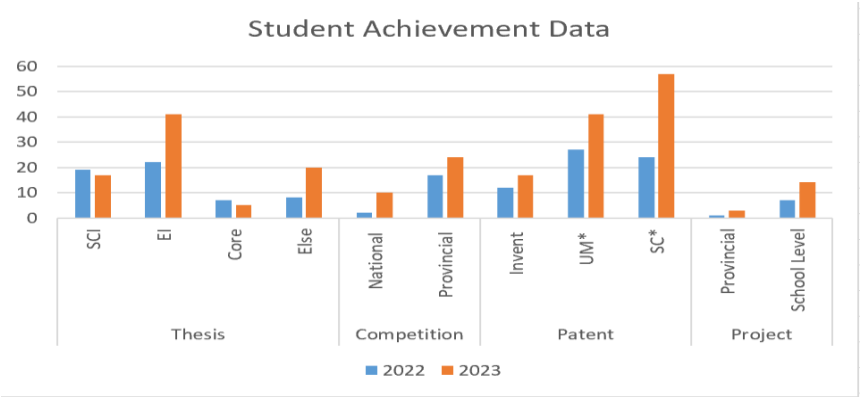

Fig. 2. Student achievement data

After implementing "multiple measures" taken by local governments, universities, and enterprises, the innovative capabilities of graduate students improved. The data presented in Table 3 and Fig 2 show a significant increase in EI (Engineering Index Compendex) and general journal publications, entries and wins in national/provincial competitions, invention patents, utility models (which doubled), and student research projects. This reflects an enhancement in innovative practice, a focus on applied research, and comprehensive innovative capabilities.

6 Conclusion

Huzhou University closely focuses on the local industrial characteristics and sets the goal of cultivating the innovative capabilities of professional-oriented graduate students. Through close cooperation and deep integration among the local government, universities, and enterprises, Huzhou University has carefully constructed the "Four-integration" graduate innovative capabilities training curriculum system. To further strengthen the practical and innovative capabilities of professional-oriented graduate students, the local government, the university, and the enterprise carry out deep cooperation in three key areas: laboratory construction, practice base construction, and industry-university-research cooperation. They jointly build a solid platform to promote the cultivation of graduate students' innovative capabilities. In addition, through the implementation of a series of advanced innovative practice activities, such as regular reporting, academic exchanges, discipline competitions, and scientific research projects, Huzhou University provides all-round and full-cycle training for the innovative capabilities of professional-oriented graduate students. These activities not only stimulate the innovative thinking and exploration spirit of graduate students but also promote their all-round development in scientific research, academics, and practice. They provide high-quality innovative talents for the national and local innovation-driven development strategies.

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