Short communication

Strategies for Reforming Graduate Engineering Education: A New Model in the "Made in China 2025" Era

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ABSTRACT

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| The "Made in China 2025" initiative emphasizes the need for mechanical engineering graduates with strong practical and innovative skills. Currently, graduate mechanical engineering education faces challenges such as the disconnect between thesis topics and engineering practice, and insufficient university-industry collaboration. To address these issues, this paper proposes a novel educational model—"one core, two centers, and five-ability cultivation." This model focuses on practice and innovation, with school and industry supervisors as the two focal points. It aims to develop five key abilities in students: knowledge application, communication, project summarization, innovation, and progress control. The effectiveness of this model was validated through a pilot study involving graduate students, enterprise supervisors, and academic supervisors. The results showed significant improvements in students' practical and innovative abilities, problem-solving skills, and teamwork capabilities. By optimizing training objectives, developing a parallel evaluation system, and strengthening university-industry collaboration, this model seeks to enhance students' overall quality and better serve the national manufacturing strategy. The successful implementation of this model provides valuable insights for reforming graduate engineering education and has important implications for aligning educational practices with industry demands. |

*Keywords: Educational Reform; Graduate Students in Mechanical Engineering; One Core, Two Centers, and Five-Ability Cultivation; Made in China 2025; University-Industry Collaboration*

1. INTRODUCTION

The "Made in China 2025" initiative underscores the need for mechanical engineering graduates with robust practical and innovative skills. Graduate education plays a crucial role in fostering students' research abilities and innovation skills[1-4]. It equips students with advanced knowledge and prepares them for academic and professional pursuits[5-7]. By providing rigorous training and research opportunities, graduate education helps students develop critical thinking and problem-solving abilities, which are essential for their future careers. Additionally, it contributes to the advancement of various fields by promoting cutting-edge research and intellectual growth[8, 9].

Liu et al.[10] proposed integrating medicine and engineering in graduate education to enhance students' abilities in medical technology innovation. Chandralekha Singh[11] advocated for modernizing physics graduate education to address 21st-century challenges, highlighting the need for quality education and guidance for underrepresented groups. "Effective Strategies for Quality Management in Graduate Education"[12] stressed the importance of involving all stakeholders to implement effective quality management strategies and align with societal and employment market demands. Xiang et al.[13] suggested incorporating new information technologies into graduate education to boost students' practical and innovative capabilities, proposing a "three-level promotion" training model. Liu et al.[14] analyzed 26,103 engineering job advertisements, identifying problem-solving as the most sought-after professional skill and noting that job ads mentioning Python and MATLAB were associated with higher salaries. Lu et al.[15] found that professional identity, empathy for nature, and consideration of consequences could significantly enhance Chinese undergraduate engineering students' sustainable development awareness. Schellpfeffer et al.[16] analyzed curriculum complexity patterns in undergraduate mechanical engineering, exploring curriculum structure and sequence. Additional studies have explored the impact of various degree fields and combinations on salaries , used regional data to reveal the heterogeneity of master's degree labor market returns, examined the evolution and diversity of specific professional groups like physician assistants as they develop into entry - level master's degree roles, and analyzed the relationship between master's degrees and labor market mismatches in different contexts[17-20]. Collectively, these findings emphasize the comprehensive influence of graduate education on professional and economic outcomes.

This paper proposes a new educational model—"one core, two centers, and five - ability cultivation"—aiming to align graduate engineering education with "Made in China 2025" goals. It will discuss the model, its implementation strategies, and its potential impact on graduate education.

2. Graduate Education Models at Home and Abroad

In recent years, graduate education models have evolved to keep up with the changing demands of industry and academia. This section compares graduate education models in China and other countries, highlighting their strengths, weaknesses, and unique features.

In China, postgraduate education has achieved considerable development. The Ministry of Education has always taken the lead in carrying out reforms to improve the quality of educational programs and make them more in line with practical needs. The "New Engineering" initiative emphasizes the combination of interdisciplinary research and industry practice, aiming to cultivate innovative and application-oriented engineering talents. Many universities have implemented a dual-mentor system, where academic mentors and industry mentors work together to narrow the gap between theoretical knowledge and practical application. However, challenges still exist. A key issue is the need to integrate industry practice more systematically into the curriculum. Although some universities maintain very close ties with the industry, others have encountered significant challenges in effectively implementing such collaborations. A more diverse range of assessment methods is required to provide a comprehensive assessment of students' practical and innovative capabilities.

Countries like the United States and Germany have mature and distinctive postgraduate education models. The model in the United States places more emphasis on students' innovation ability, interdisciplinary knowledge, and independent research capabilities. Generally, postgraduate courses in the United States offer a large number of rich elective courses and research opportunities, which enables students to explore different interest directions and develop their professional knowledge. Unlike the American model, the German model places greater emphasis on practical training and establishing strong connections with the industry. The "dual-track education" it adopts combines vocational training with academic education, enabling students to gain practical experience in the real-world working environment during the learning process. This model is relatively effective in cultivating graduates that meet the needs of the industry.

Table 1 clearly presents the comparison of the postgraduate education models of mechanical engineering in China, the United States and Germany. Each country's model has its own unique advantages, but there are also areas that need improvement. The Chinese model adopts a dual-mentor system, combining theory with practice, but it faces some challenges in fully integrating industry practice. The American model emphasizes innovation and interdisciplinary knowledge, and also offers a variety of elective courses and research opportunities. The dual-track education model in Germany closely combines vocational education and academic education, enabling students to have rich practical experience. These comparisons highlight the different approaches of postgraduate engineering education. And it provides some ideas for developing more effective models under the background of "Made in China 2025".

**Table 1. Comparison of Graduate Education Models in Mechanical Engineering**

| **Feature/Model** | **China** | **United States** | **Germany** |
| --- | --- | --- | --- |
| **Education Model** | Dual - supervisor system combining theory and practice | Emphasizes innovation and interdisciplinary knowledge | Dual education system combining vocational training with academic education |
| **Course Structure** | Combination of theory and practice courses, but with insufficient practical courses | Rich elective courses and research opportunities | Integration of vocational training and academic courses |
| **Practical Teaching** | Insufficient practical courses and limited internship opportunities | Abundant practical opportunities and research projects | Extensive practical teaching with long - term corporate internships |
| **Assessment Mechanism** | Assessment mechanism not well - developed | Diversified assessment mechanism | Assessment mechanism equally emphasizing practice and theory |

3. Problem Analysis and Model Proposal

**3.1 Problems and Challenges**

China's graduate mechanical engineering education is growing rapidly, showing the country's focus on boosting the manufacturing sector. Yet, the current situation has its own set of challenges and characteristics.

Firstly, Chinese universities have seen a significant rise in graduate mechanical engineering programs at both master's and doctoral levels, with growing annual enrollment. This expansion has diversified mechanical engineering education, encompassing undergraduate, graduate, and vocational levels, and covering fields like mechanical design, manufacturing automation, and materials control engineering. While this aims to satisfy the manufacturing industry's demand for specialized talent, it has also pressured program quality and relevance. Despite the growing number of such programs, there's still a need to optimize the educational structure to match industry demands. This requires not just expansion, but also quality improvement and enhanced adaptability to foster innovative and applied talents.

Secondly, while the quality of education has been on the rise, there's still potential for further enhancement. In certain universities, the curriculum structure and teaching approaches are deemed somewhat antiquated, favoring theoretical knowledge over practical application. Furthermore, the incorporation of emerging technologies such as artificial intelligence into the curriculum has been sluggish, with a scarcity of digital - related elective courses. This lack of innovation in curriculum design and teaching methods might dampen student engagement and leave them ill - equipped to handle real - world engineering challenges. With many courses centering predominantly on lectures, there's a risk of failing to spark student interest or foster active participation. Consequently, students might exhibit a deficiency in the motivation to explore and innovate, skills that are vital for modern manufacturing engineers.

Lastly, practice is crucial in engineering education. But in some universities, practical teaching is underdeveloped. Due to social and economic factors, engineering education content is often disconnected from actual practice. Engineering graduate students have limited internship opportunities. Some schools lack practical training bases and enough supervisors. Without sufficient practical opportunities, students can't fully develop their ability to apply theory to real - world problems, which is a major issue in engineering education. This lack of substantial practical opportunities may hinder students' transition from theory to practice, potentially impacting their employability and work efficiency.

Figure. 1 shows the theory - practice distribution in a Chinese university's mechanical engineering curriculum. Theoretical courses take up 60%, while practical courses account for 40%. This shows the need for a more balanced mix of theory and practice in teaching to suit the "Made in China 2025" goals.



**Figure 1. The Distribution of Theory and Practice in the Mechanical Engineering Curriculum of a Chinese University**

In summary, China's graduate mechanical engineering education has advanced significantly, yet several challenges must be addressed to better synchronize with the "Made in China 2025" strategy and produce high-quality engineering talents that meet modern manufacturing demands. These challenges involve enhancing the connection between coursework and practical application, strengthening university-industry-research collaboration, increasing the practical relevance of research outcomes, and devising more comprehensive assessment mechanisms. Tackling these issues will be vital for the future progress of China's graduate mechanical engineering education.

**3.2 "One Core, Two Centers, and Five - ability Cultivation" Model**

To address the aforementioned challenges, this paper suggests the "one core, two centers, and five - ability cultivation" model. Tailored to align graduate engineering education with the "Made in China 2025" initiative, it aims to cultivate graduates who can satisfy the demands of modern manufacturing.

In Figure 2, the "one core, two centers, five - ability cultivation" model is depicted as a cohesive framework designed to address the challenges in graduate engineering education. The model's core emphasis on practice and innovation reflects the growing demand for engineering graduates who can apply their knowledge to real-world problems effectively. By having school and enterprise supervisors as the two focal points, the model ensures that students receive guidance from both academic and industry perspectives. This dual supervision approach not only enriches the educational experience but also narrows the gap between theoretical knowledge and practical application. The five key abilities—knowledge application, communication, project summarization, innovation, and progress control—are integral to the model, representing essential skills that mechanical engineering graduate students need to excel in modern manufacturing. These abilities are developed through a structured yet flexible curriculum that encourages active learning and collaboration. The model's holistic approach aims to equip graduates with the comprehensive skill set required to thrive in the dynamic and competitive manufacturing industry, aligning with the strategic goals of the "Made in China 2025" initiative.



**Figure 2. The "One Core, Two Centers, Five - ability Cultivation" Model Diagram**

The "One Core, Two Centers, Five - ability Cultivation" model makes unique contributions to graduate engineering education. It focuses on developing five key abilities in students: knowledge application, communication, project summarization, innovation, and progress control. These abilities are carefully selected to meet the demands of modern manufacturing and are integrated into a cohesive framework that ensures students receive a well - rounded education. The model provides a systematic approach to collaboration between academic and industry supervisors, defining clear roles and responsibilities for each to ensure students benefit from both theoretical knowledge and practical experience. Specifically tailored to align with the "Made in China 2025" initiative, it addresses the specific needs of China's manufacturing industry, preparing graduates to contribute to the nation's strategic goals. Additionally, the model incorporates a parallel evaluation system that combines feedback from both academic and industry supervisors, offering a comprehensive assessment of students' abilities from multiple perspectives. This innovative educational framework goes beyond traditional dual - mentor and university - industry collaboration models, emphasizing not only the integration of theory and practice but also the development of students' comprehensive skills and adaptability to meet the dynamic demands of modern manufacturing.

Tackling the key challenges in the current graduate engineering education model and focusing on fundamental skills development, the "one core, two centers, and five - ability cultivation" model offers a workable solution for graduate engineering education reform under the "Made in China 2025" initiative. It has the potential to boost the quality of mechanical engineering graduates and better prepare them for industrial demands.

4. Implementation Strategies

**I. Optimizing Training Objectives and Models**

Industry demands require training objectives to emphasize practical and innovative skills. Current curricula often overemphasize theory. Universities should collaborate with enterprises to create capstone projects reflecting real engineering problems. For example, working with automotive manufacturers on assembly line optimization projects. Interdisciplinary courses should also be added to broaden students' knowledge base.

**II. Developing a Parallel Evaluation System**

Traditional evaluation systems often fail to assess students' practical abilities. A dual-track evaluation system combining feedback from academic and industry supervisors is proposed. Academic supervisors can assess theoretical knowledge, while industry supervisors evaluate practical skills like machinery operation and team collaboration during internships.**III. Strengthening University - Industry Collaboration**

Long-term university-industry partnerships are essential. Joint research centers or laboratories can be established for students to work on real R&D projects. Enterprise internships should be offered in areas like car assembly or quality control. Universities and enterprises should also collaborate on developing teaching materials and courses to ensure education meets industry standards.

When conducting tests on the "One core, Two Centers, and Five Types of ability cultivation" model, postgraduate students majoring in mechanical engineering also participated in this test. Both the company and academic supervisors joined the testing process. Through tracking and evaluation, this paper found that the students' practical and innovative abilities have greatly improved. They have demonstrated the ability to combine theory with practice in internships and projects. Their problem-solving ability has become stronger, and their teamwork ability and communication skills have also improved significantly. Thus, they can cooperate more efficiently with enterprise engineers and team members. And some students, under the guidance of their mentors, Successfully published high-quality academic papers or obtained patent authorization.

6. Conclusion

The "One core, Two Centers, and Five Capabilities Cultivation" model provides a brand-new solution for postgraduate engineering education. It centers on practice and innovation and will utilize all the professional knowledge of academic and industry mentors. It can effectively improve the practical ability and innovation ability of postgraduate students majoring in mechanical engineering. From those successful cases and the positive feedback given by students, it can be seen that this model is a good way to reform postgraduate engineering education and promote students' career development. When conducting research in the future, attention can be paid to the long-term impact of this model on students' professional growth and its possible applications in other engineering fields.

To strengthen graduate engineering education, this paper recommend integrating the "one core, two centers, five - ability cultivation" model into university programs. This model emphasizes combining theory with practice and leverages academic and industry expertise to develop students' practical and innovative skills. Enhancing university - industry collaboration by establishing long-term partnerships can provide students with valuable practical experience and ensure education aligns with industry standards. Implementing a dual evaluation system that incorporates feedback from both academic and industry supervisors will offer a more comprehensive assessment of students' abilities.

Additionally, increasing practical teaching components and promoting interdisciplinary learning can better prepare students to address complex engineering challenges. Updating the curriculum to include emerging technologies and adopting diverse teaching methods will stimulate student engagement and innovation. Future research should explore the long-term impact of this model on students' professional development and its potential applications across various engineering disciplines.

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Authors have declared that the content does not involve any issues of medical ethics.

Ethical approval (where ever applicable)

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