Short communication

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" plan particularly emphasizes that graduates majoring in mechanical engineering need to have strong practical and innovative abilities. Currently, the existing education model is facing some challenges, such as the disconnection between thesis topics and engineering practice, and the insufficiency of school-enterprise cooperation. Here, a teaching model of "one core, two centers, and five types of ability cultivation" is proposed. This teaching mode places considerable emphasis on practice and innovation. It regards school and industry management as two key aspects. This teaching mode aims to cultivate five crucial abilities in students, namely the ability to apply knowledge, communication skills, project summary skills, innovation skills, and progress control skills. This teaching mode will rely on optimizing the training objectives, establishing a parallel evaluation system and strengthening school-enterprise cooperation, etc., to strive to improve the comprehensive quality of students, so as to serve the national manufacturing strategy. |

*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. Liu et al.[1] proposed integrating medicine and engineering in graduate education to enhance students' abilities in medical technology innovation. Chandralekha Singh[2] 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"[3] stressed the importance of involving all stakeholders to implement effective quality management strategies and align with societal and employment market demands. Xiang et al.[4] 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.[5] 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.[6] found that professional identity, empathy for nature, and consideration of consequences could significantly enhance Chinese undergraduate engineering students' sustainable development awareness. Schellpfeffer et al.[7] 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[8-11]. 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, However, some other universities have found it very difficult to carry out effective cooperation in industry-university-research collaboration. More diverse assessment methods are still needed to comprehensively evaluate students' practical ability and innovation ability.

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** |
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| **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. Graduate Education Models at Home and Abroad

**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. As shown in Figure 2, the model emphasizes practice and innovation, with school and enterprise supervisors as the two focal points. It focuses on developing five key abilities in mechanical engineering graduate students: knowledge application, communication, project summarization, innovation, and progress control. By promoting collaboration between academic and industry supervisors, this integrated approach offers students a comprehensive education that combines theoretical knowledge with practical skills, better preparing them for the demands of modern manufacturing.



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

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**

To meet the demands of the industry, the training objectives must highlight practical and innovative skills. Postgraduate courses need to incorporate real-world engineering projects into the curriculum to integrate theory with practice. Universities can collaborate with enterprises to create capstone projects for students that they need to complete before graduation. These projects should reflect real engineering problems, allowing students to apply the knowledge they have learned in practical environments. Additionally, interdisciplinary courses should be added, which can broaden students' knowledge base and enable them to have a deeper understanding of engineering systems. Universities can also refer to the dual-track education system in Germany and strengthen close ties with the industry. Ensure that the course content can keep pace with the trend of technological development.

**II. Developing a Parallel Evaluation System**

This article suggests that a dual-track evaluation system can be implemented. This system should combine the feedback from the academic community and that from industry supervisors. When academic supervisors evaluate students, they can use traditional evaluation methods to see how well students have mastered theoretical knowledge and whether their research skills are good. From another aspect, Industry managers can gain a clearer understanding of students' practical skills, problem-solving abilities, and teamwork skills based on their performance during internships and in participating in projects. When students are interning at a manufacturing company, the enterprise supervisor can assess their ability to operate machinery, whether they can solve technical problems, and whether they can work efficiently in the team. Such a comprehensive assessment method can help students develop a relatively comprehensive set of skills and also enable them to adapt to the working environment more quickly.

**III. Strengthening University - Industry Collaboration**

Establishing long-term cooperative relationships between universities and industries is crucial for improving the quality of postgraduate education. If joint research centers or laboratories are set up, students can participate in real-world research and development projects under the guidance of industry experts. Moreover, enterprise internships can be established to enable students to gain practical experience in manufacturing and engineering processes. By cooperating with car manufacturers, students can be provided with internship opportunities in areas such as car assembly, quality control or supply chain management. This can help students understand how the industry operates and cultivate their relevant skills. Universities and enterprises can also work together to develop teaching materials and courses, thus ensuring that education meets industry standards. Regular exchanges and seminars between academia and industry can combine theory with practice and enhance students' educational experience.

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, we 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. This model corresponds to the "Made in China 2025" strategy. 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.

Consent (where ever applicable)

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

Ethical approval (where ever applicable)

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References

1. Liu, L., et al., *Exploring a new model for graduate education at the intersection of medicine and engineering.* Asian Journal of Surgery, 2024. **47**(7): p. 3256-3257.

2. Singh, C., *2024 Jackson Award for Excellence in Graduate Physics Education lecture: Physics graduate education for the 21<SUP>st</SUP> century.* American Journal of Physics, 2024. **92**(12): p. 918-923.

3. Lee, G.J. and M.-S. Kim, *A Study on the Effective Strategies for Quality Management of Graduate Education.* The Journal of Economics and Finance of Education, 2024. **33**(4): p. 135-161.

4. Xiang, F., et al., *A Novel Training Path to Promote the Ability of Mechanical Engineering Graduates to Practice and Innovate Using New Information Technologies.* Sustainability, 2024. **16**(1).

5. Fleming, G.C., et al., *What engineering employers want: An analysis of technical and professional skills in engineering job advertisements.* Journal of Engineering Education, 2024. **113**(2): p. 251-279.

6. Lu, L.L., et al., *The Effects of Professional Identity, Empathy with Nature,and Consideration of Future Consequences onSustainability Consciousness among ChineseUndergraduate Engineering Students.* International Journal of Engineering Education, 2024. **40**(5): p. 1076-1089.

7. Schellpfeffer, S.E., *An Analysis of Curricular Complexity Patterns in Undergraduate Mechanical Engineering Programs Using Federally Reported Data*. 2024.

8. Cabrera, G.M. and P. Mariel, *Master's degree studies and its impact on vertical and horizontal mismatch in Spain.* Economia Politica, 2024. **41**(3): p. 687-716.

9. Lin, Y.-Y., *How Does Graduate Education Play a Role? The Effects of Master's and Bachelor's Degree Fields and Their Combinations on Salaries*. 2024.

10. Minaya, V., J. Scott-Clayton, and R.Y. Zhou, *Heterogeneity in Labor Market Returns to Master's Degrees: Evidence from Ohio.* Research in Higher Education, 2024. **65**(5): p. 775-793.

11. Young, P.A., et al., *Diversity of PA cohorts during the evolution to an entry-level master's degree.* Jaapa-Journal of the American Academy of Physician Assistants, 2024. **37**(2): p. 5-6.