Education Insights

Article

Innovation, Reform, and Practice of Teaching Mechanical Principles under the Context of New Engineering Disciplines

Hongchao Wang [1,*], Ziyu Wang [2], Lin Wan [1], Haichao Bai [1], Gang Che [1] and Xia Han [1]

[1] College of Engineering, Heilongjiang Bayi Agricultural University, Daqing, 163319, China
[2] College of Information and Electrical Engineering, Heilongjiang Bayi Agricultural University, Daqing, 163319, China
* Correspondence: Hongchao Wang, College of Engineering, Heilongjiang Bayi Agricultural University, Daqing, 163319, China

Abstract: In response to the challenges in the teaching of Mechanical Principles, such as difficulties in understanding the principles, the disconnect between theory and practice, and the lack of systematic integration of ideological and political education, this paper proposes a "One Core, Three Integrations" teaching model. This model is designed in the context of New Engineering Education and focuses on foundational theoretical learning. It integrates online and offline teaching resources, classroom implementation, and competition training, aiming to achieve synergy across these three pathways. The model incorporates micro-courses and simulation resources, promotes inquiry-based interactive classrooms, integrates competition training into teaching, and establishes a full-cycle evaluation system. The goal is to effectively transform abstract theories into engineering practice capabilities. This teaching model has been piloted at the College of Engineering, Heilongjiang Bayi Agricultural University. Initial feedback from the practice suggests improvements in students' hands-on abilities and classroom engagement, demonstrating its potential for broader application.

Keywords: mechanical principles; teaching model; practice; competitions

Published: 18 September 2025

Copyright: © 2025 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

With the Ministry of Education's implementation of a series of policies aimed at deepening undergraduate teaching reform and building first-class courses, higher education institutions are increasingly required to improve the quality of talent cultivation [1-3]. Policy directions represented by the "Four New" initiatives and the "Double Ten Thousand Plan" emphasize that the curriculum system must serve national strategies, focus on industry frontiers, and strengthen the cultivation of practical and innovative abilities. These policies clearly call for the elimination of "watered-down" courses and the development of "golden courses." Against this backdrop, university curriculum reforms are shifting from being "teacher-centered" to "student-centered," with an emphasis on the simultaneous advancement of knowledge transmission, skill development, and value guidance. This macro educational transformation presents new and higher demands for core mechanical courses: they must balance theoretical depth and academic rigor while enhancing engineering applicability and educational impact, thereby providing students with a solid knowledge and competence foundation for entering engineering practice [4-6].

As a foundational core course for mechanical engineering majors, the course on Mechanical Principles plays a critical role in the professional curriculum system. It not only systematically imparts basic structural principles, motion laws, and methods of mechanical analysis but also serves as an essential platform for cultivating engineering design thinking, modeling capabilities, and innovative awareness. However, there are still several bottlenecks in current teaching practices. The highly abstract nature of the course content leads to difficulties in student comprehension. Traditional classrooms and experiments are disconnected from engineering practice, limiting the transformation of knowledge into practical ability. Furthermore, the integration of ideological and political education with the course content remains incomplete, preventing the formation of a continuous educational process throughout the teaching [7-9].

Based on the analysis of these issues, this paper proposes and implements the "One Core, Three Integrations" teaching model, with a focus on foundational theoretical learning. This model incorporates a three-way collaboration of "resources-classroom-competition and training" to construct a closed-loop system that connects knowledge mastery to engineering applications, and ability development to value formation, through layered teaching resources, blended inquiry-based classrooms, and competition-driven practical components.

2. Pain Points in the Teaching Process

2.1. Difficulty in Understanding Fundamental Principles

Students commonly face a dual challenge when studying Mechanical Principles, which involves both abstract concepts and complex formula derivations. From determining the degrees of freedom in mechanisms, analyzing velocity and acceleration, to force and power calculations, and understanding the working principles of typical mechanisms, students often struggle to form a cognitive loop between "physical visualization-mathematical expression-engineering explanation." The underlying causes of these difficulties are inadequate support from prerequisite knowledge (such as higher mathematics, linear algebra, engineering drawing, theoretical mechanics, and basic programming and simulation tools), static classroom representations, and a lack of dynamic visualization and interactive derivation. Furthermore, the learning path lacks sufficient differentiation to accommodate the varying starting points of students [10]. The immediate consequences are errors in understanding concepts and performance in classroom assessments, such as misjudging degrees of freedom, confusion in the use of instantaneous centers, overlooking key elements in force analysis, and the ability to run simulations but being unable to explain parameter choices or the resulting differences. More critically, this cognitive gap carries over into subsequent courses and final-year projects, weakening students' ability to model, analyze, and optimize in real-world engineering scenarios.

2.2. Insufficient Integration of Theoretical Teaching and Engineering Practice

In traditional teaching models, classroom interaction is often limited, and teachers find it difficult to effectively stimulate students' independent thinking. As a result, there is a degree of disconnection between teaching and learning. The traditional model has not sufficiently emphasized the importance of fostering students' ability to conduct pre-class literature research or explore practical application scenarios of mechanisms. Overall, the approach is still predominantly focused on theoretical delivery, with students' learning outcomes relying heavily on their ability to understand content during class [11]. However, in the post-class phase, there are insufficient platforms and opportunities for students to engage in engineering applications and practical research. Additionally, due to the relatively limited engineering practice experience of the experimental course instructors and the insufficient hours allocated for laboratory sessions, there has been no deep integration between theoretical teaching and engineering practice. Consequently, the effectiveness of the practical teaching components is suboptimal, making it difficult to systematically improve students' engineering practice capabilities and innovative thinking. Therefore, addressing the core function of professional courses in cultivating students' engineering thinking and innovative abilities has become a critical issue that needs to be overcome in the current curriculum.

2.3. Need for Improvement in the Integration of Ideological and Political Education, and the Enhancement of Educational Impact

The content of the Mechanical Principles course is closely related to daily life and engineering practice. Its knowledge points widely cover various aspects of life and technological applications, providing rich material and significant advantages for integrating ideological and political education (IPE) into the course. This makes it a good carrier for carrying out IPE. However, in previous teaching practices, the focus has often been on the delivery of theoretical knowledge, without systematically integrating elements of moral education and aesthetic education into the classroom [12]. As a result, students lack an aesthetic perception of the geometric representation of mechanisms, and there is a disconnect between the course content and real-life or engineering contexts. This tendency towards a cold, technical teaching approach has failed to fully utilize the course's unique role in holistic education. In the long term, professional identity, a sense of responsibility, and aesthetic judgment have not been sufficiently cultivated, and the comprehensive effect of "educating through culture, aesthetic education, and moral nurturing" needs to be systematically improved.

3. Teaching Innovation Measures

To address the pain points in the teaching process of the Mechanical Principles course, the course team has proposed a gradual integration of innovative teaching elements, based on the cognitive patterns and progressive nature of knowledge systems for engineering students. By promoting teaching innovation through three coordinated pathways-teaching resources, classroom implementation, and competition and training-the course has gradually formed an overall teaching framework aimed at cultivating application-oriented talent. In this context, the course team emphasizes the "student-centered" concept, starting from the learning needs of students, following the inherent logic of the knowledge system in a step-by-step manner, and continuously exploring new teaching elements throughout the process. This approach makes the course more aligned with the reform direction in the background of New Engineering Education.

3.1. Reconstructing Teaching Resources to Support Layered Learning with "Fit" Resources

In terms of teaching resources, the teaching team, after a thorough analysis of the learning progress of students at the College of Engineering, Heilongjiang Bayi Agricultural University over the years, adheres to a student-centered approach. The team systematically summarizes teaching experiences and actively explores educational models that suit application-oriented undergraduate institutions, ultimately constructing an innovative teaching model centered around "One Core, Three Integrations." This model aims to "stimulate interest in learning, foster a sense of national pride, achieve the coordination of moral and intellectual development, and cultivate exceptional talent." The model is systematically designed from the levels of problems, measures, and goals, integrating diverse teaching strategies and resources to break through the bottlenecks of traditional teaching, such as "difficulty in enhancing interest, challenges in fostering innovation, and inadequate integration of moral and aesthetic education." Specifically, the "One Core, Three Integrations" teaching model includes the following three aspects of integration:

(1) Integration of Teaching Resources - Developing Micro-courses to Strengthen Resource Support

In response to the learning characteristics and cognitive patterns of engineering students, the course team has created a multi-level teaching resource system based on the core principles of "basic concepts-working principles-motion and power analysis-graphical and analytical methods-engineering applications." This system includes self-recorded instructional videos, annually updated teaching slides, an online question bank, and a mechanism model library to help students systematically acquire core knowledge in a targeted manner. By utilizing information technology, the team incorporates mechanism motion simulations and dynamic graphical displays to enhance the intuitiveness and depth of teaching content, improving the visualization and perceptibility of resources.

Integration of Classroom Models - Inquiry-based Interaction to Expand Teaching Space

Breaking through the boundaries of traditional classrooms, the team relies on multimedia classrooms and experimental training environments to create an interactive classroom model driven by students, projects, and case studies. By combining engineering examples with computer simulations, the team actively promotes the "One Core, Three Integrations" teaching model. Modern information technology is used to facilitate independent, flexible, and reinforcement-based learning, strengthening students' engagement and practical skills.

Integration of Competition and Training Platforms - Promoting Learning through Competitions to Foster Research and Learning Synergy

The team has systematically built a mechanical innovation design studio, introducing advanced manufacturing technologies such as 3D printing to expand the practical teaching platform. The team actively organizes students to participate in various competitions, including the National Mechanical Innovation Design Competition, 3D Design Competition, Advanced Drawing Competition, and Innovation and Entrepreneurship Competition. By deeply integrating competition themes with course content, the team implements a model of "promoting innovation through competitions, promoting teaching through competitions, and promoting learning through competitions." These competitions not only test students' ability to apply professional knowledge but also provide feedback on the quality of talent cultivation, driving continuous improvement of courses and professional programs. Excellent competition results are transformed into teaching cases and training materials, creating a virtuous cycle of "learning-practice-competition-feedback."

3.2. Constructing a Classroom and Evaluation System That Covers the Entire Teaching Process

In response to the foundational knowledge and learning status of students at the College of Engineering, Heilongjiang Bayi Agricultural University, the teaching model for the Mechanical Principles course is undergoing a systematic reconstruction. The traditional teacher-centered, single-point lecture model is being expanded into a "five-ring interconnected" full-process teaching chain. This includes pre-class reading and preparation of mechanical mechanism materials, in-class self-learning presentations, teacher-student interactions, and quizzes, as well as post-class application of engineering examples and computer simulation exercises. The goal is to strengthen students' internalization and integration of basic theoretical knowledge, achieving full-process integration of teaching and learning.

(1) Building a Blended Teaching Model with Online and Offline Integration

Relying on provincial-level first-class undergraduate course resources and the customized online courses, model libraries, case libraries, and ideological and political education (IPE) material databases developed by the teaching team, a variety of teaching resources are systematically integrated. This forms a flipped classroom teaching model based on the "five-ring interconnected" approach, promoting the mutual enhancement of online independent learning and offline in-depth interaction.

(2) Strengthening Independent Learning and Fostering Professional Interest

During the pre-class phase, students independently complete concept review, data collection, and exploration of typical application scenarios based on teacher guidance. They then write literature review reports and present their findings in class. This mechanism not only stimulates students' initiative but also hones their skills in information integration and expression. Classroom teaching incorporates interactive elements to ensure full student participation, achieving synchronous thinking between teachers and students, and fostering a resonant teaching experience.

(3) Establishing a Comprehensive and Diverse Evaluation Mechanism

The original evaluation system is being reformed to adjust the grading structure of the Mechanical Principles course. The previous grading breakdown of 10% for daily performance, 20% for assignments, 10% for validation experiments, and 60% for the final exam is optimized to include: 10% for online and offline assignments, 10% for attendance and online tests, 10% for literature or project proposals, 10% for practical or experimental activities, 10% for classroom participation, and 50% for the final exam. This new mechanism places greater emphasis on process evaluation and practical ability assessment. It advocates for non-standardized exam questions, promotes the development of corresponding question banks, encourages students to think divergently, and focuses on assessing the flexible application of knowledge.

3.3. Integration of Competitions and Mechanical Art: Balancing Practical Implementation and Educational Impact

The teaching team systematically reviews the typical applications of mechanical principles in ancient agriculture, industry, and modern technology, and creates a teaching resource library integrated with ideological and political education (IPE). By showcasing China's ancient technological achievements and modern industrial advancements, the team guides students to appreciate the wisdom of ancestors, enhance their national pride, and gain a deep understanding of the core role of mechanical engineering in national development. This process aims to strengthen students' professional beliefs and inspire them to dedicate themselves to the construction of the new era. In the teaching process, emphasis is placed on showcasing the dynamic beauty and artistic value of mechanical mechanisms. Through dynamic diagrams and other forms, abstract and tedious mechanical principles are transformed into visual and aesthetic experiences. Students are guided to understand the composition and working principles of mechanisms from the perspective of the fusion of art and structure. They are also encouraged to use software like SolidWorks (SW) or ADAMS for simulation analysis and innovative design, fostering a sense of accomplishment and motivation for exploration through aesthetic education. In teaching practice, strict standards and a pursuit of excellence are emphasized. For example, when drawing mechanism motion diagrams, students are required to strictly adhere to national standards and use drafting tools such as rulers and compasses, cultivating a sense of discipline and a meticulous craftsmanship spirit. Simultaneously, students are encouraged to repeatedly refine and continuously optimize their design works, focusing on the details and fostering creative thinking. This approach strengthens scientific literacy that values excellence and encourages innovation.

4. Teaching Effectiveness

4.1. Teaching Outcomes

The "One Core, Three Integrations" teaching model has significantly stimulated students' initiative and classroom engagement. Before class, students build a basic understanding through textbook reading and micro-lesson preparation. By completing pre-class assignments focused on "problem-concept-case," students establish an initial cognitive framework for key knowledge points. During class, dynamic graphics and simulation demonstrations enhance students' intuitive understanding of the working principles of mechanisms. Group investigations and peer evaluations are organized around typical units such as "four-bar mechanisms, cam-follower systems, gear transmissions, and link mechanisms," which encourages students to internalize knowledge through progressively structured tasks. Post-class activities, such as simulation experiments and competition training, help students convert theory into actionable engineering skills. Accompanied by process-oriented evaluations and digital learning feedback, students are empowered to analyze their own progress and make timely improvements, thereby enhancing overall learning motivation and effectiveness.

Classroom interaction has become more frequent, and the majority of students report that dynamic visual materials assist in understanding abstract content and enable them to model and analyze mechanisms independently. Some student groups have even completed sensitivity analysis and optimization designs for mechanism parameters based on simplified assumptions. This has also led to increased enthusiasm for participating in technological innovation activities. Additionally, significant progress has been made in cultivating students' professional ethics and engineering culture. By reviewing ancient and modern mechanical applications and integrating them into the teaching resources, the course narrative emphasizes "engineering problems as the guide, with the history of national science and technology as the background," which enhances students' recognition of national technological history and engineering culture. The course also integrates topics such as safety regulations, standardization, and green manufacturing, fostering students' awareness of correct engineering values and social responsibility.

4.2. Teaching Achievements

After implementing the teaching reforms, students have achieved excellent results in various provincial, ministerial, and university-level academic competitions. The teaching team has actively guided students to participate in practical and innovative activities, with over ten awards won in A-level provincial and higher competitions, covering areas such as mechanism innovation design, virtual prototyping, intelligent manufacturing, and engineering simulation. The team has also guided students to lead and complete two provincial-level student innovation and entrepreneurship projects and one university-level project, while encouraging students to deeply engage in two faculty-led provincial and ministerial research projects, showcasing their strong engineering practice and innovative capabilities.

On the faculty side, significant improvements in teaching design and mentoring abilities have been observed. The team has made notable progress in both teaching reform and research, successfully securing two Ministry of Education industry-university-research collaborative education projects, one provincial-level research project, and publishing a total of ten teaching and research papers. Several faculty members have won first prizes in university-level teaching competitions, demonstrating excellent professional ethics and continuous development. These achievements not only reflect the teaching model's impact on improving students' practical abilities but also provide empirical support for the future optimization of the course. On the one hand, a stable mechanism of "learning through competition, research-driven teaching, and evaluation-driven reform" has been established. On the other hand, a replicable classroom organization paradigm and resource development pathway have been formed.

4.3. Promotion and Application

By integrating classical mechanism applications and the history of mechanical development into the course and combining them with competition practice, a distinctive course feature has gradually emerged. The related teaching model has been applied in the Mechanical Design, Manufacturing, and Automation program, receiving positive feedback and effectively serving as a demonstration model. The teaching team has actively engaged with industry, participating in production practices and offering technical guidance. As a core course within the professional curriculum, "Mechanical Principles" has been jointly submitted for industry-university-research education reform projects with enterprises, establishing a cooperative mechanism for exchange and mutual benefit between the university and industry. Students are now able to apply the theories learned in class to real-world industry practices, with the variety of internship bases continuously expanding, thus further deepening and broadening the integration of industry and education. To support the development of the Engineering College's discipline construction, talent cultivation, and accreditation work, the team actively engages in experience exchanges and collaborations with other universities in areas such as talent development, faculty construction, teaching research, and professional program development. By sharing effective practices, the team aims to contribute to the high-quality development of higher education.

5. Conclusion

This paper, under the context of New Engineering Education, addresses the pain points in teaching Mechanical Principles and proposes and implements the "One Core, Three Integrations" teaching model. The model, through layered micro-courses, visualized simulations, the "five-ring interconnected" blended classroom flow, and competition-driven training practices, effectively promotes the transformation of theoretical knowledge into engineering practical skills, while enhancing students' professional identity and craftsmanship spirit. The promotion of this teaching model has effectively guided students to deepen their understanding of knowledge, stimulate critical thinking, and gradually develop the ability for self-directed learning and continuous innovation. This practice has led to mutual growth and dual enhancement for both students and teachers. In the future, the course team will continue to explore more efficient and scalable innovation paths for teaching Mechanical Principles, actively advancing course reform and contributing to the "Four New" initiatives, laying a solid foundation for cultivating first-class application-oriented talents.

Funding: This work was supported by the Education and Teaching Research Project of Heilongjiang Bayi Agricultural University (NDJY2404) and the Ministry of Education's Industry-University-Research Collaborative Education Project (231003806252500).

References

1. C. G. Lyu, "Quality Evaluation Model of Mobile Internet Innovative Education Personnel Training Based on Fuzzy Analytic Hierarchy Process," In *International Conference on Advanced Hybrid Information Processing*, October, 2021, pp. 383-393.
2. H. M. Zhang, "Analysis of the Teaching Reform Strategy of Mechanical Principles," *Advances in Educational Technology and Psychology*, vol. 5, p. 64, 68, 2021.
3. Q. Dong, E. Wu, and J. Gao, "The Application of Digital Technology in Online and Offline Blended Teaching of Mechanical Principles Course," *Curriculum and Teaching Methodology*, vol. 7, no. 1, 2024.
4. N. Li, "Research on the cultivation of college students' innovation ability," *Adv. Educ. Technol. Psychol*, vol. 7, no. 16, pp. 92-97, 2023.
5. Y. Jia, and C. Li, "Bidirectional Teaching Reform in Theoretical Mechanics: Integrating Engineering Thinking and Personalized Assignments," *Education Sciences*, vol. 15, no. 5, p. 574, 2025.
6. W. Li, C. Meng, X. Lian, Q. He, M. Kong, and Y. Gao, "Six-Link Teaching Methods for Improving the Creative Practical Ability-Taking "Mechanical Principle" as an Example," In *Artificial Intelligence, Medical Engineering and Education*, 2024, pp. 821-828.
7. C. Li, Y. Hou, and J. Yang, "Research on project-driven teaching method of technology of mechanical manufacture based on ability training," *International Journal of Information and Education Technology*, vol. 7, no. 6, pp. 474-478, 2017.
8. L. Ding, R. Chabay, and B. Sherwood, "How do students in an innovative principlebased mechanics course understand energy concepts?," *Journal of research in science teaching*, vol. 50, no. 6, pp. 722-747, 2013. doi: 10.1002/tea.21097.
9. H. A. N. Tielin, M. A. Kai, H. U. Yifeng, and W. A. N. G. Yan, "Teaching reform and practice of mechanics of materials courses in the context of new engineering sciences," *Mechanics in Engineering*, vol. 46, no. 5, pp. 1096-1107, 2024.
10. X. Zhang, C. Liu, Y. Chen, and M. Pang, "Research on Teaching Mode Innovative Reform of College Physics Under the New Engineering Background," In *2024 5th International Conference on Education, Knowledge and Information Management (ICEKIM 2024)*, August, 2024, pp. 87-98.
11. S. Pace, "Teaching mechanical design principles on engineering foundation courses," *International Journal of Mechanical Engineering Education*, vol. 28, no. 1, pp. 1-13, 2000. doi: 10.7227/ijmee.28.1.1.
12. A. Silva, M. Fontul, and E. Henriques, "Teaching design in the first years of a traditional mechanical engineering degree: methods, issues and future perspectives," *European Journal of Engineering Education*, vol. 40, no. 1, pp. 1-13, 2015. doi: 10.1080/03043797.2014.903227.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). The publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.