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# The integration of knowing and doing in the teaching-learning process of professional courses

**Hui Chen[1,a], Jingruo Tian[2,b], Baolin Wang[1,c], Zhaoqiang Chen[1,d], Chonghai Xu[1,e,*]**

*[1]School of Mechanical Engineering, Qilu University of Technology (Shandong Academy of Sciences), Jinan, China*
*[2]Department of Nutrition and Cuisine, Shandong College of Tourism and Hospitality, Jinan, China*
*[a]chenhui@qlu.edu.cn, [b]tle.right.375@163.com, [c]baolinw@qlu.edu.cn, [d]czq@qlu.edu.cn, [e]xch@qlu.edu.cn*
*[*]Corresponding author*

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***Abstract:*** Engineering education focuses on cultivating students' practical and innovative abilities. It not only requires students to master theoretical knowledge but also to apply that knowledge to solve practical problems, achieving a balance between knowing and doing. However, there is currently an issue in engineering education where there is an overemphasis on knowing and a lack of doing, resulting in students having insufficient skills in integrating knowledge, problem-solving and independent thinking. Students may have acquired the knowledge but struggle with the implementation. To enhance students' ability in practical problem-solving, we propose a teaching model that is project-driven and cooperative-group-based. This model incorporates several formative assessment methods, such as inter-group peer evaluation and individual contribution assessment within the group. It was implemented in the course of "Mechanical Design" at an applied research university. The results show that students' learning interest is significantly increased, with more students participating in innovation competitions, and their practical skills are greatly improved. We hope that this "project-driven & cooperative-group-based" teaching model proposed in this paper can provide a useful reference for the teaching of professional courses in engineering education.

## 1. Introduction

With the continuous improvement of education levels, the number of graduates from Chinese universities has been increasing in recent years. The number of graduates from Chinese universities exceeds 11.5 million in 2023. At the same time, according to the "Guidelines for the Development of Manufacturing Talent" jointly released by the Ministry of Human Resources and Social Security and the Ministry of Industry and Information Technology of China, there is a talent gap of over 30 million people in China's top 10 key areas of manufacturing by 2025, with a gap rate as high as 48%. In terms of talent supply and demand, it has created a structural contradiction where graduates face difficulties in finding employment, while at the same time, enterprises experience an exacerbated shortage of talent [1, 2]. Similar talent supply-demand contradictions can be found in different degrees in other countries as well [3, 4]. This situation highlights the practical dilemma caused by the predominance of scientific theory in engineering education, which deviates from engineering practice.

In the teaching process of professional courses, the integration of knowing and doing refers to closely combining theoretical knowledge with practical operations, enabling students to apply the theoretical knowledge they have learned to real-world problems and deepen their understanding and mastery of theory through practice. Through the integration of knowing and doing, students can not only acquire rich theoretical knowledge in professional courses but also transform it into practical skills, preparing them for future career development. This can cultivate students' innovative abilities, problem-solving skills, and teamwork capabilities, making them outstanding talents in the industry.

In order to enhance students' innovation and practical abilities and better adapt to industry demands, we have introduced a "project-driven & cooperative-group-based" teaching model in the undergraduate course of "Mechanical Design" for students majored in mechanical engineering. Through group members' joint discussions and teacher review, we strictly control the quality of design projects and select projects of moderate difficulty that align well with the course content. Based on the characteristics of the course, the design projects are broken down into various modules to facilitate a teaching process of "learning while practicing," avoiding the disconnection between theory and practice caused by learning theory first and then practicing. Additionally, formative evaluation such as inter-group peer evaluation and member peer evaluation intra-group were introduced. After a semester of practice, it was found that the completion rate of design projects was high, students' learning outcomes significantly improved, and their enthusiasm and participation increased noticeably.

## 2. The main issues need to be addressed

The current state of engineering education worldwide is facing a significant challenge: the lack of basic job skills and innovation abilities among graduates. This problem is multifaceted and needs to be addressed comprehensively to ensure that engineering students are prepared for the demands of the modern workforce. The main issues are reflected in the following aspects:

(1) While their foundational knowledge is solid, they lack the ability to integrate knowledge and solve practical problems, and their systematic and independent thinking are insufficient.

(2) Many top-performing students excel in exams but lack training in practical teamwork. They have weak dialectical thinking and a lack of a questioning spirit.

(3) They have poor communication and expression skills, low confidence in oral communication, insufficient written communication skills, and lack training in writing of technical document.

This reflects the inadequacy of the current teaching model in engineering education in addressing the demands of enterprises in the context of rapid scientific and technological development. Firstly, slow textbook updates and relatively outdated knowledge systems in textbooks cannot keep up with the rapid emergence and acceleration of new technologies and, therefore, cannot meet the practical needs of modern enterprises. Additionally, the current teaching model in engineering education is relatively singular, lacking innovation and flexibility. With the rapid development of science and technology, the demands in the engineering field are constantly changing. Many engineering education courses still adhere to traditional teaching models, which lack current teaching content and methods. As a result, students face challenges in applying their knowledge flexibly to solve new engineering problems.

Secondly, compared to higher vocational education, undergraduate engineering education focuses more on theoretical teaching, with limited and shallow practical components. Students lack opportunities for practical training and their participation and enthusiasm in practice are not high. In many engineering majors, students only have the opportunity for real practical experience during their final graduation projects. Other practical components, such as course experiments, have proven to be less effective. However, at the point of graduation projects, many students may feel a severe lack of the ability to integrate knowing with doing, conduct literature searches and analysis. As students approach the end of their undergraduate studies, relying solely on the final graduation design is insufficient to compensate for the lack of practical experience. With recent curriculum system reforms, the emphasis on theoretical teaching has increased, showing a trend towards the scientificization of engineering.

Moreover, there are also certain shortcomings in interdisciplinary integration in engineering education. The solution to modern engineering problems often requires the comprehensive application of knowledge from multiple disciplines and courses. However, course instructors often focus too much on teaching their own courses and overlook integration with other courses. This isolated teaching model restricts the cultivation of students' interdisciplinary thinking and makes it difficult to develop comprehensive engineering talents.

Established in 1997, the Olin College of Engineering in the United States has implemented a revolutionary "curriculum + project" training model, which has propelled it to the forefront of the engineering education field. Students engage in project-based learning, which enhances their autonomous learning and practical skills, while also improving their interdisciplinary thinking, innovation and entrepreneurship abilities, and ethical principles in engineering. Project-based learning offers numerous advantages in engineering education. Firstly, it is outcome-oriented and student-centered, significantly boosting student engagement in the learning process. This approach aligns well with advanced teaching methods and concepts such as OBE and the BOPPPS, which have been proven to enhance student learning outcomes. Secondly, project-based learning greatly enhances students' awareness of innovation and practical skills, aiding in the development of systematic and dialectical thinking skills to integrate their knowledge effectively.

The success of Olin College of Engineering has inspired universities around the world to introduce project-based teaching reforms [5]. However, challenges exist, such as low alignment between projects and course content, low student engagement and completion rates, and an incomplete assessment system. "Mechanical Design" as a core course for undergraduate students majoring in mechanical engineering, plays a crucial role in the training of undergraduate talents in the field of mechanical engineering. Design inherently involves the integration of various elements. It is characterized by strong comprehensiveness and practical aspects, requiring the integration of abstract theoretical knowledge from prerequisite courses into a specific machine. Hence, compared to other professional courses, "Mechanical Design" is more suitable for project-based learning. Therefore, many universities have explored and practiced project-based learning for "Mechanical Design" [6-8]. Through research and literature review, it has been found that project-based teaching for "Mechanical Design" and similar courses still face the following issues in practice:

(1) There is a certain disconnect between projects and courses. This is manifested in the lack of close synchronization and coordination between the teaching process and the project completion process. At the same time, the integration of project and curriculum knowledge is not tight, lacking the reconstruction of teaching content for project-based learning. Therefore, the promotion and support role of projects in course teaching is limited.

(2) There are inconsistencies in project selection, and the "group collaboration" model has not been effectively implemented, resulting in students facing significant challenges when undertaking project tasks individually. As a result, the completion rate of projects is generally low, and student participation rates are also unsatisfactory. The design projects, which were originally meant to be student-led, have ultimately shifted towards being mainly presented in the form of case studies,

failing to fully reflect the students' initiative and practical skills.

(3) In the current implementation of project-based learning, there is an issue with the overly single mode of presentation, making it difficult for students to gain enough satisfaction and sense of achievement during their participation. As a result, students' enthusiasm for participating in projects is not high and often in a passive state. This situation has a detrimental impact on the improvement of teaching quality and fails to fully demonstrate the expected effects of project-based learning.

(4) There are significant shortcomings in the current process management and evaluation system, lacking scientific and rationality, which to some extent affects students' learning motivation and participation. At the same time, we have not effectively implemented incentive measures and still adhere to the traditional assessment model of "one test determines the grade." This has resulted in low acceptance and poor recognition of project-based learning by students.

## 3. Exploration of Teaching Reform

### 3.1. The comprehensive teaching reform plan

In professional course instruction, the integration of knowing and doing involves closely aligning theoretical knowledge with practical application. This approach enables students to utilize theoretical knowledge in solving real-world problems, thereby enhancing their comprehension and proficiency in theory through practical engagement. To foster knowing-doing integration among students, we have introduced a "project-driven & cooperative-group-based" teaching model tailored to the characteristics of the "Mechanical Design". This model involves forming learning groups of 4-5 students randomly, encouraging mutual support to collectively undertake design project and theoretical studies. Departing from the conventional sequence of theory-first learning followed by practical application, we advocate for simultaneous theory learning and design practice to enhance knowledge-practice integration. Engaging in collaborative design project cultivates teamwork skills and bolsters communication abilities among students. The comprehensive teaching reform plan is illustrated in Figure 1.

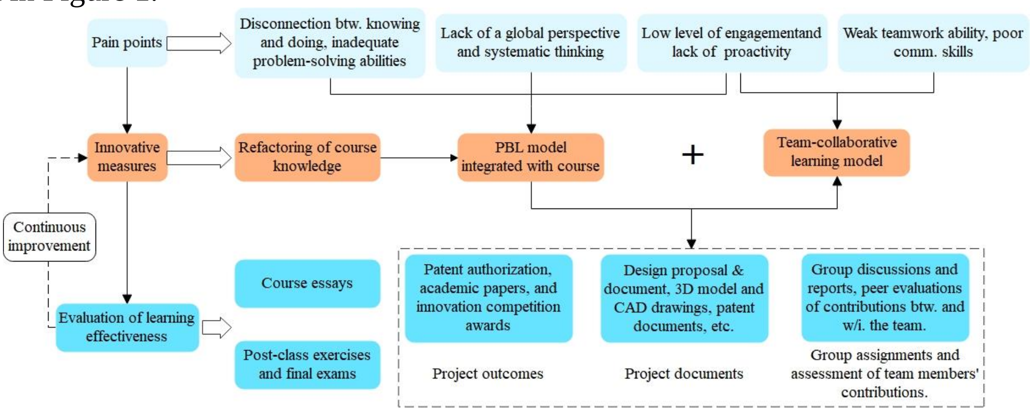


Figure 1: The comprehensive teaching reform plan.

In line with modern educational concepts such as OBE and BOPPPS, we have embraced project-driven & cooperative-group-based teaching methodologies. Our focus is on student-centered development and the fusion of theory and practice. We have reorganized course content and essential concepts, intertwining them into the different phases of project design to deepen students' comprehension of the curriculum through hands-on application. This pedagogical approach not only boosts student engagement and motivation but also elevates the course's complexity, innovation, and challenge. Departing from the conventional mode where a single exam determines grades, we have put in place a comprehensive assessment system that encompasses the entire learning process and project design activities. Drawing on student feedback and performance, we have established a continuous enhancement mechanism driven by formative evaluations. We consistently refine project-based teaching and group management strategies to encourage active student involvement in both theoretical learning and project participation, ensuring the successful execution of design projects.

### 3.2. Evaluation for Learning Effectiveness

Establishing a multidimensional, multi-stakeholder, whole-process, non-standard academic evaluation system that spans the entirety of the teaching process fosters a positive learning environment characterized by active dialogue and constructive interaction between teachers and students, thereby enhancing curriculum quality. Common methods for evaluating learning effectiveness include summative evaluation through final exam scores and formative evaluation through student homework and reports. Building upon these conventional approaches, we have made enhancements by increasing the proportion of open-ended questions without standard answers in the end-of-term exam and empowering students as evaluator in the process of formative evaluation. This approach reduces teacher involvement and strengthens a student-centered teaching philosophy.

Figure 2 illustrates the breakdown of students' overall course assessment score. The final grade consists of two main components: 70% based on summative evaluation derived from final exam results and 30% from formative evaluation reflecting student performance throughout the semester. In the summative evaluation, questions on students' understanding of fundamental concepts and terms contribute 40% to the total score, while open-ended questions assessing students' comprehensive comprehension of knowledge and critical thinking skills constitute 30% of the score. The student self-assessment grade, involving peer assessment inter-group and intra-group during the course and project design process, makes up 20% of the total score. Lastly, post-class exercises and essays make up 10% of the total score.

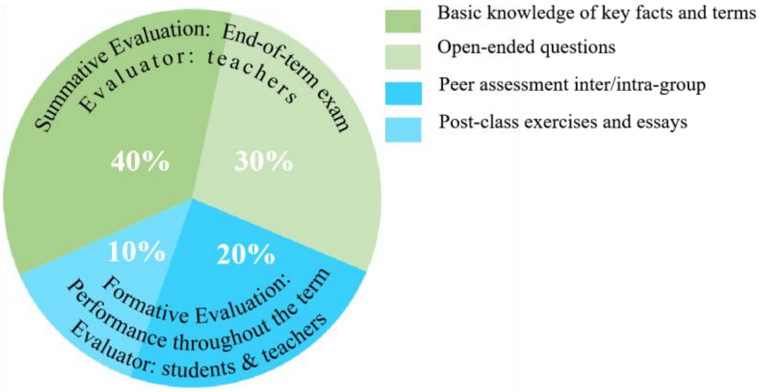


Figure 2: Breakdown of students' overall course assessment score.

### 3.3. Formative evaluation involving students as evaluators

Formative evaluation primarily takes place during the teaching process, aiming to enhance the effectiveness of teachers' instruction and students' learning by providing timely feedback. The feedback can be utilized to adjust teaching methods and enhance learning outcomes. Involving each group and its members as evaluators in the evaluation process can boost student engagement and motivation. Various measures have been implemented to further foster teamwork spirit, ensure full engagement of all group members, and prevent individual members from slacking off. For instance, throughout the course, several group presentations were organized for the entire class to demonstrate each group's achievements. Additionally, after class, group units engaged in discussions with teachers to address any project design challenges encountered. Furthermore, upon completion of the course, group units participated in project design defenses for evaluation by peers. Displayed in Figure 3 are snapshots from the teaching process, highlighting that such activities not only enhance the presentation and communication skills of group members but also promote improved communication and mutual understanding among groups.


Figure 3: Snapshots from the teaching process: (a) The group collaborates with teachers to discuss design plans; (b) The group delivers a project summary to the entire class, with teachers posing questions and other groups providing evaluations; (c) and (d) Group members present updates on the design progress to the entire class during classroom sessions.

Building on this foundation, an evaluation mechanism has been established that involves both inter-group and intra-group assessments among group members. The evaluations are comprehensive and consider the performance of each group and individual student in project design, presentation, and teamwork. Teachers only intervene in the evaluation process when necessary to prevent biases and ensure fairness. The assessment process combines quantitative and qualitative measures, taking into account both the individual contributions of group members and the collective performance of the entire group. Inter-group evaluations require each group to provide objective assessments of other groups, encouraging critical thinking and teamwork. Intra-group member evaluations prompt group members to reflect on their own performance and identify areas for enhancement. To maintain objectivity and fairness in the evaluation outcomes, clear evaluation standards are defined to establish a structured and trackable process. Furthermore, fostering open communication and idea exchange among group members aids in mutual understanding. Timely feedback on evaluation results is provided to each group and its members to help them identify strengths and weaknesses, facilitating continuous improvement in their learning journey.

Through the implementation of inter-group evaluation and intra-group evaluation, a comprehensive and objective assessment of each group and its members' performance is enabled. This approach not only stimulates the enthusiasm and creativity of group members but also enhances teamwork collaboration. Additionally, it cultivates a sense of responsibility and teamwork spirit among group members, providing a strong foundation for their future learning and work. Ultimately, integrating these evaluation results into final grades accurately reflects the performance of group members throughout their learning process.

The inter-group evaluation score is determined collectively by group members to assess other groups. Subsequently, the score is weighted by the number of evaluators in each group and calculated as the weighted average, representing the final score for the evaluated group, as depicted in Formula 1.

$$X_n = \frac{\sum_{i=1}^{z} x_{in} R_i}{\sum_{i=1}^{z} R_i \text{-} R_n} \tag{1}$$

The final score $X_n$ of group $n$ is influenced by the total number of groups ($z$), the score provided by group $i$ to group $n$ ($x_{in}$), and the number of members in group $i$ ($R_i$). Group $n$ does not assign a score to itself, resulting in $x_{nn}$=0. Ratings are assigned based on each group's performance during project completion, with a maximum score of 100 points. Biased scoring practices, including favoritism or uniform scores for all groups, are explicitly prohibited to uphold fairness and impartiality.

After conducting inter-group evaluations, intra-group evaluations of each group member are carried out. In this stage, group members collectively determine the contribution percentage $P_{\text{indn}}$ of each member based on their regular performance. The final formative evaluation score, $S_{\text{indn}}$, for each student is calculated by considering both the inter-group evaluation score of their group and their contribution percentage within the group ($P_{\text{indn}}$), as demonstrated in Formula 2.

$$S_{\text{indn}} = \frac{X_{\text{n}} \frac{P_{\text{indn}} R_{\text{i}} * X_{\text{n}}}{100}}{\text{MAX}(\frac{P_{\text{indn}} R_{\text{i}} * X_{\text{n}}}{100}, \text{indn} = (1, R_{\text{i}}))} * 20\% \tag{2}$$

Table 1: The intermediate data and calculation results of the formative evaluation scores for students in Groups 1-4.

| Student No. | Group No., $n$ | Number of group members, $R_i$ | Group score, $X_n$ | Contribution rate, $P_{\text{indn}}$ (%) | Individual score, $S_{\text{indn}}$ |
|---|---|---|---|---|---|
| 1 | 1 | 4 | 91.78 | 25 | 13.11 |
| 2 | | | | 20 | 10.49 |
| 3 | | | | 20 | 10.49 |
| 4 | | | | 35 | 18.36 |
| 5 | 2 | 5 | 86.28 | 19 | 13.11 |
| 6 | | | | 20 | 13.80 |
| 7 | | | | 18 | 12.42 |
| 8 | | | | 18 | 12.42 |
| 9 | | | | 25 | 17.26 |
| 10 | 3 | 5 | 87.23 | 21 | 15.26 |
| 11 | | | | 21 | 15.26 |
| 12 | | | | 24 | 17.45 |
| 13 | | | | 22 | 15.99 |
| 14 | | | | 12 | 8.72 |
| 15 | 4 | 5 | 86.25 | 17 | 11.73 |
| 16 | | | | 22 | 15.18 |
| 17 | | | | 17 | 11.73 |
| 18 | | | | 19 | 13.11 |
| 19 | | | | 25 | 17.25 |

Although the formative evaluation, which assesses both groups and individual students, only contributes to 20% of the total scores, significant score variations exist among students due to differences in their performance throughout the term, as indicated by the calculation setup above. Taking the 19 students in Groups 1-4 as examples, the calculation results and intermediate data for the formative evaluation are presented in Table 1. For Group 1, the group evaluation score is 91.78, with students A, B, C, and D having contribution percentages of 25%, 20%, 20%, and 35% respectively. As a result, their formative evaluation scores are 13.11, 10.49, 10.49, and 18.36 correspondingly. Due to differences in contribution percentages within the group, students B, C, and D have evaluation score variations as high as 75%, leading to a 7.87-point difference in their total scores. This system underscores the significance of formative evaluation and self-assessment among students, boosts student engagement, underscores the relationship between individual and group scores, and fosters student unity and collaboration.

## 4. Conclusions and Outlook

By implementing the "project-driven & cooperative-group-based" teaching model proposed in this article, significant improvements have been made in students' learning enthusiasm and participation. By integrating course content with project design processes, students are provided with an opportunity to learn and practice simultaneously, promoting the application of knowledge and stimulating students' interest in learning through practice. After a semester of implementation, compared to parallel classes, the class using the proposed teaching model saw an average increase of 5.62 points in final scores. More notably, students' enthusiasm for participating in university innovation and technology competitions significantly increased. Out of 10 groups, 9 groups participated in various competitions, winning 1 first prize at the provincial or ministerial level, 1 second prize, and 7 third prizes. Many students who had never considered participating in competitions changed their minds after getting involved in project design, with 90% of students participating in competitions, far exceeding the rate in parallel classes. Moreover, through systematic engagement in project design, students significantly enhanced their abilities to apply knowledge from various disciplines such as drafting, mechanics, materials science, and mechanical principles. Their skills in writing design documents, compiling professional technical materials, CAD 3D modelling, and 2D drawing also notably enhanced.

There are still many areas that can be improved. In the future teaching reform process, we will attempt to collaborate with other courses, break the boundaries between courses, and carry out teaching reforms based on the entire process of product development and manufacturing, using practice as the carrier. We aim to extend the course projects from the design stage to the actual design, manufacturing, and optimization of products, selecting outstanding projects for actual manufacturing. This approach will organically integrate courses related to drafting, mechanics, design, materials, and manufacturing, and encourage students to apply for patents while constructing a teaching case library. At the same time, we will enhance the proportion of formative assessment with students as the evaluators, such as incorporating more open-ended questions and post-class assignments from final exams into project design. This will increase the students' participation in the teaching process, with teachers playing more guiding and assisting roles, further promoting the integration of knowing and doing for students.

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Development and Teaching Reform Project of Qilu University of Technology (Shandong Academy of Sciences) (Construction and Research of Virtual Simulation Experiment Teaching System for Mechanical Design Course Group in the Background of "New Engineering").

## References

*[1] J. Wang, J.-M. Sun, Talent development in China: current practices and challenges ahead, Advances in Developing Human Resources, 20 (2018) 389-409.*
*[2] F. Guo, Z. Li, A. Zhang, Industrial Internet Enterprises' Talent Acquisition in China, in: International Conference on Human-Computer Interaction, Springer, 2022, pp. 29-40.*
*[3] S. Showkat, T. Wani, J. Kaur, "New Normal" implications for global talent in the wake of economic nationalism and slowdown, Thunderbird International Business Review, 65 (2023) 161-175.*
*[4] J. Biberman, Manufacturing the Digital Revolution: Building a Sustainable Supply Chain for ICT-Driven Development in India, in, ICT India Working Paper, 2022.*
*[5] D. Kokotsaki, V. Menzies, A. Wiggins, Project-based learning: A review of the literature, Improving schools, 19 (2016) 267-277.*
*[6] D. Garcia-Garcia, J. Gomez-Caturla, J. Ivorra-Martinez, L. Quiles-Carrillo, N. Montanes, Use of Problem-Based Learning (PBL) as a methodology for the development of competences in the Mechanical Engineering Degree, in: INTED2022 Proceedings, IATED, 2022, pp. 3658-3665.*
*[7] F.V. Barbosa, P.A. Lobarinhas, S.F. Teixeira, J.C. Teixeira, Project-Based Learning in a Mechanical Engineering Course: A new proposal based on student's views, International Journal of Mechanical Engineering Education, 50 (2022) 767-804.*
*[8] R. Kuppuswamy, D. Mhakure, Project-based learning in an engineering-design course–developing mechanical-engineering graduates for the world of work, Procedia CIRP, 91 (2020) 565-570.*