IOSR Journal of Research & Method in Education (IOSR-JRME)
e-ISSN: 2320–7388, p- ISSN: 2320-737x Volume 12, Issue 6 Ser. II (Nov. – Dec. 2022), 48-53
www.iosrjournals.org

Exploration on the Practical Teaching Mode of Mechanical Design Oriented to Solve Complex Engineering Problems

YANG Huadong, ZHANG Xia, HUA Guangru, DUAN Wei
(Department of Mechanical Engineering, North China Electric Power University, Baoding 071000, China)

Abstract: *In order to overcome the shortcomings of the traditional practical teaching of "Mechanical Design" in the cultivation of students' ability to solve complex engineering problems, this paper analyzes the complex engineering problems from the technical and non-technical levels under the guidance of the complex system theory and the complexity theory of the design process. On this basis, a multi-research teaching mode of "problem-driven-project teaching-case analysis-IPD (Integrated Product Development)" is constructed based on constructivism theory. This teaching mode is applied to the practical teaching of "Mechanical Design", and the implementation strategies and evaluation methods are put forward. Two years of teaching practice show that it can improve students' ability to analyze, solve and innovate complex engineering problems.*

Key words: *complex engineering problem; research teaching;constructivism; practical teaching*

Date of Submission: 15-11-2022 Date of Acceptance: 01-12-2022

The Excellent Engineer Training Program [1] of the Ministry of Education in China aims to cultivate students' innovation ability and the ability to solve complex engineering problems. The solution of complex engineering problems requires both technical ability and non-technical ability such as critical thinking ability [2-4]. In traditional engineering education, the cultivation of core technical ability is emphasized, while the training of non-technical ability is neglected. Therefore, in the reform of higher engineering education in the new era, it is necessary to improve students' ability to solve complex engineering problems and reform the teaching mode of the course.

Mechanical Design is an important basic professional course for mechanical undergraduates. The knowledge objective of the course is to enable students to master the design method of universal mechanical parts, and the ability objective of the course is to equip students with the preliminary ability of innovative design of mechanical systems. In order to achieve this goal, in addition to adopting the diversified research-based teaching model [5-7] based on the modern constructivism education thought in course teaching and improving students' ability to solve complex engineering problems, it is also necessary to reform the teaching model in practice. Therefore, how to train students to have solid theoretical knowledge, outstanding practical ability and problem-solving ability under the new situation, achieve the "coupling of knowledge and practice" [8-9], and then train students' good innovation ability and scientific literacy is an urgent problem to be solved in current higher education, and also a problem to be explored in practical teaching.

This paper first analyzes the connotation of complex engineering problems, then puts forward a multi-research teaching model to improve the ability of solving complex engineering problems, and then applies this model to the practical teaching of Mechanical Design, and explores its implementation strategy.

1. Analysis of complex engineering problems

To explore the strategies for improving students' ability to solve complex engineering problems, we need to comprehensively analyze the connotation of complex engineering problems. The "complexity" of engineering problems includes technical and non-technical aspects [10-14].

1.1 Technical complexity

Modern mechanical systems are characterized by intelligence, integration and flexibility, and the development trend of mechanical systems is high efficiency, high precision, limit function and high quality [15]. Therefore, in order to meet the complex functional requirements of users and the needs of operation under extreme working conditions, the structure and function of mechanical systems show the characteristics of complex systems such as nonlinearity, time-varying, strong coupling and openness. Based on the complex system theory and the complexity theory of the design process [16], the design of mechanical system should start from the functional perspective, study the nonlinear, time-varying and decoupling methods of the functional structure, and obtain the functional solution and design scheme. In addition, the complexity at the technical level is also reflected in the fact that the design of modern mechanical systems requires

multidisciplinary knowledge, designers need to have a system view and a scientific view, modern design methods, and understand the impact of modern manufacturing technology (especially additive manufacturing technology) on design methods and technologies. The complexity of the above technical level poses a challenge to the teaching of mechanical design. The practical teaching of mechanical design should be reformed based on the characteristics of modern mechanical system design, guided by the solution of complex engineering problems, and adopted multiple research-based teaching methods.

1.2 Non-technical complexity

Engineering problems involve the coordination between human, machine and environment, so they include complex non-technical elements as well as technical elements. Traditional engineering education focuses on the cultivation and improvement of students' technical ability. However, for the cultivation of outstanding engineers, in addition to the improvement of technical ability, the improvement of non-technical ability should also be considered. Non-technical factors including economic factors, environmental factors, social factors and cultural factors, such as for mechanical system design, the need to consider and design activities related to market analysis, demand analysis, environmental impact and economic analysis, which requires the students to have a systematic analysis, dialectical thinking ability and organization and communication skills, etc.

Based on the analysis of complex engineering problems, it can be seen that the practical teaching of mechanical design course should start from the complexity of technical level and non-technical level.Based on the theory of complexity subject and the educational thought of modern constructivism, this paper adopts the multi-research teaching model combining problem-driven, project teaching, case analysis and IPD to degrade and decouple the complexity of complex problems, so as to improve students' comprehensive analytical ability and cultivate excellent mechanical design engineers.

2. Problemdriven, project-based teaching, case-analysis and IPD combined with a diversified research-based teaching model

2.1 Practical teaching system of mechanical design course

The practical teaching of mechanical design course includes experiment teaching and course design.Through the statistical analysis of the practice of mechanical design courses in 30 universities in China, it can be found that most of the experimental teaching hours are 6-8 hours.The experimental teaching content includes belt drive, shafting structure design, transmission performance analysis and reducer disassembly and assembly. The teaching content of mechanical design course design is mainly the design of two-stage reducer. The teaching of these practical links is helpful for students to master and tamp the knowledge points of mechanical design. However, the above practice content lacks the improvement of students' system view and modern design ability, so the improvement of students' complex engineering problem solving ability needs to be improved.

In view of the problems existing in the current curriculum practice teaching, the reformed practice teaching system is shown in Figure 1. Facing the real problems in the real world, practical teaching takes the project as the main line to break through classroom teaching and practical teaching (experimental teaching and course design), and cultivate students' systematic and scientific outlook.

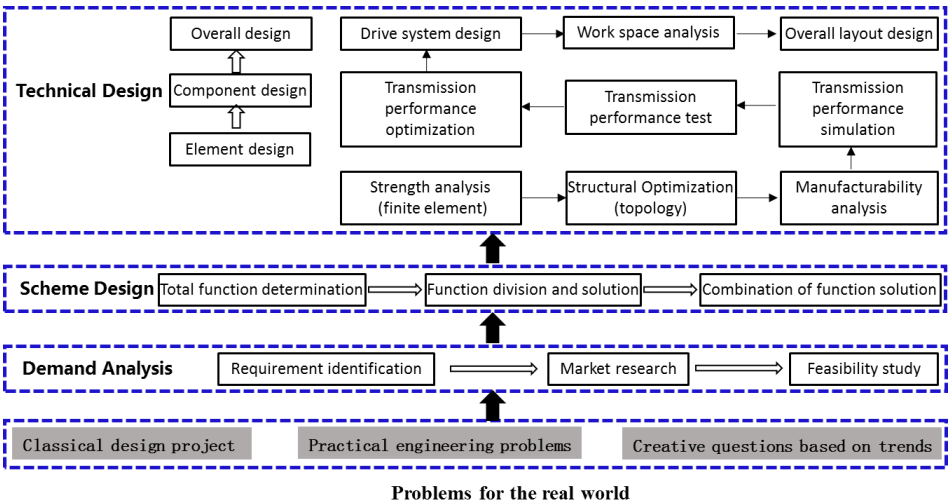

FIG. 1 Practical teaching system of mechanical design

2.2 Multi-research teaching mode of mechanical design practice

In view of the problems existing in practice teaching, from the perspective of constructivism, taking students' learning as the center, strengthening students' active inquiry, this paper puts forward a pluralistic integrated research teaching model. Research-based teaching model includes research-based teaching and research-based learning. From the perspective of teaching, students can become the leading role of the class through reasonable teaching design and implementation of teaching strategies. After years of teaching practice, a combination of "problem-driven, project-based teaching, case analysis and IPD" is proposed.

(1) The connotation of the diversified research-based teaching model

In order to solve the teaching problems in the case of differences in learning basis, the method of online and offline mixed teaching is adopted. Corresponding online resources are recorded for students with different learning basis, supplemented by online discussion and answering of basic questions, so as to make up for the differences in students' original knowledge basis.

Problem-driven teaching is an effective teaching model for classroom interaction, and the choice of questions is particularly important. In practice teaching, theoretical problems with certain depth and breadth or complex engineering problems requiring interdisciplinary knowledge coordination should be selected. According to the characteristics of knowledge points, the teaching is organized by means of group discussion, teachers' difficulty to promote questions step by step, role transformation and so on, so as to change passive acceptance into active exploration.

Project teaching is based on the educational thought of constructivism and driven by project tasks. It adopts "learn by doing" and "do by learning". Learning subjects conduct independent inquiry through a series of practical activities in real situations. Through the design team collaboration, discussion, questioning, to solve the difficult problems encountered, so as to complete the knowledge construction. Based on the characteristics of the mechanical design course, with the project as the traction, students can solve practical design problems through self-study and independent literature review, and improve the ability of problem analysis, problem solving and innovation.

(2) Integration of multiple research-based teaching models

Based on the cognitive law of students and the learning characteristics of students in the Internet environment, this paper puts forward a multi-element integrated teaching model to realize the coupling of knowledge and practice. It adopts multiple integration modes, including space-time integration, online and offline integration, curriculum ideological and political integration, diversified research teaching integration, discipline competition and research teaching integration, and industry-university-research integration. It follows the educational thought of "learn by doing, do by learning" and integrates "theory" and "practice" to achieve the coupling of knowledge and practice.

Combined with the demand of enterprises for innovative talents in the frontier of science and technology and the ability to solve complex engineering problems under the new situation, a new teaching model is proposed to solve the disjunction between knowledge and practice. Basic idea is to face the real world of the true problem, through diverse teaching method, in the form of project driven, change traditional teaching methods lack of students' autonomous exploration and analysis of the shortcomings, guides the student through teamwork, analysis and explore actively, and to master the correct method, process and method, so as to improve their ability of analyzing and solving practical problem.

3. The implementation strategy of the multi-research teaching model in practical teaching

3.1 Creation of complex engineering problems

According to the characteristics of the mechanical design course, the connection relationship between the knowledge points of the prior and subsequent courses is considered as a whole, and the project is used throughout the teaching process under the guidance of the design idea based on the whole life cycle. The molecular task content of the project department was taken as the experimental topic to carry out experimental verification. The complete design process of the project is the task of curriculum design, and the practical links composed of experiment and curriculum design can achieve the objectives of knowledge, ability and quality of the curriculum.

The creation of the project title (that is, the complex engineering problem mentioned in this paper) meets the connotation requirements of the complex engineering problem in Section 1, while considering students' design experience, design cycle, etc. Complex engineering problems should have the following characteristics:

(1) Typicality, the selected project should have all the characteristics of modern typical electromechanical integration equipment, with the complexity of the technical level. Through the completion of this project, students can master the basic processes, methods and the use of relevant tools of modern machine design and manufacturing.

(2) Practical, the selected project should be combined with the actual needs of the current society to solve the practical problems encountered in current life, or the actual scientific research project from the teacher, stimulate students' interest, and improve students' ability to analyze and solve problems, with non-technical complexity.

(3) Moderate difficulty, because this project is for students in the process of study, according to the product design process of the lecture, step by step to complete the design of the product, considering the students' time is limited, so we should choose the topic of moderate difficulty, can stimulate the student participation enthusiasm, inspire students to think deeply. At the same time, students can feel confident to complete the project through their own efforts. The title of the practical teaching project of Mechanical Design is shown in Table 1.

Table 1 Project title

Number	Title
1	Design of automatic nail making machine for woodworking
2	Design of chestnut peeling machine
3	Design of auto lift machine
4	Design of automatic barrier crossing device for transmission line
5	Design of ice removal device for transmission line

3.2 Implementation Strategy

The implementation strategy of multiple research teaching in the practical link teaching of Mechanical Design is shown in Figure 2. Firstly, the design stage is divided according to the integrated product development process. In each design stage, based on the modern design idea of the whole life cycle, detailed design tasks are arranged. The experiments involved include the feasibility verification of the system design scheme, the simulation analysis of the transmission system performance, the transmission system performance test and the overall assembly scheme design of the system. The content of the experiment is different from the previous experiment. Because the design topics selected by each group are different, the specific experiment plan is drawn up by the design team instead of given by the teacher, so the ability of analyzing and solving problems independently can be cultivated. At the same time, in the discussion of experimental program, the teacher through the introduction of cases, for students to teach the experimental program, route setting is not reasonable caused by the serious consequences, so as to cultivate students a good system view and rigorous scientific view.

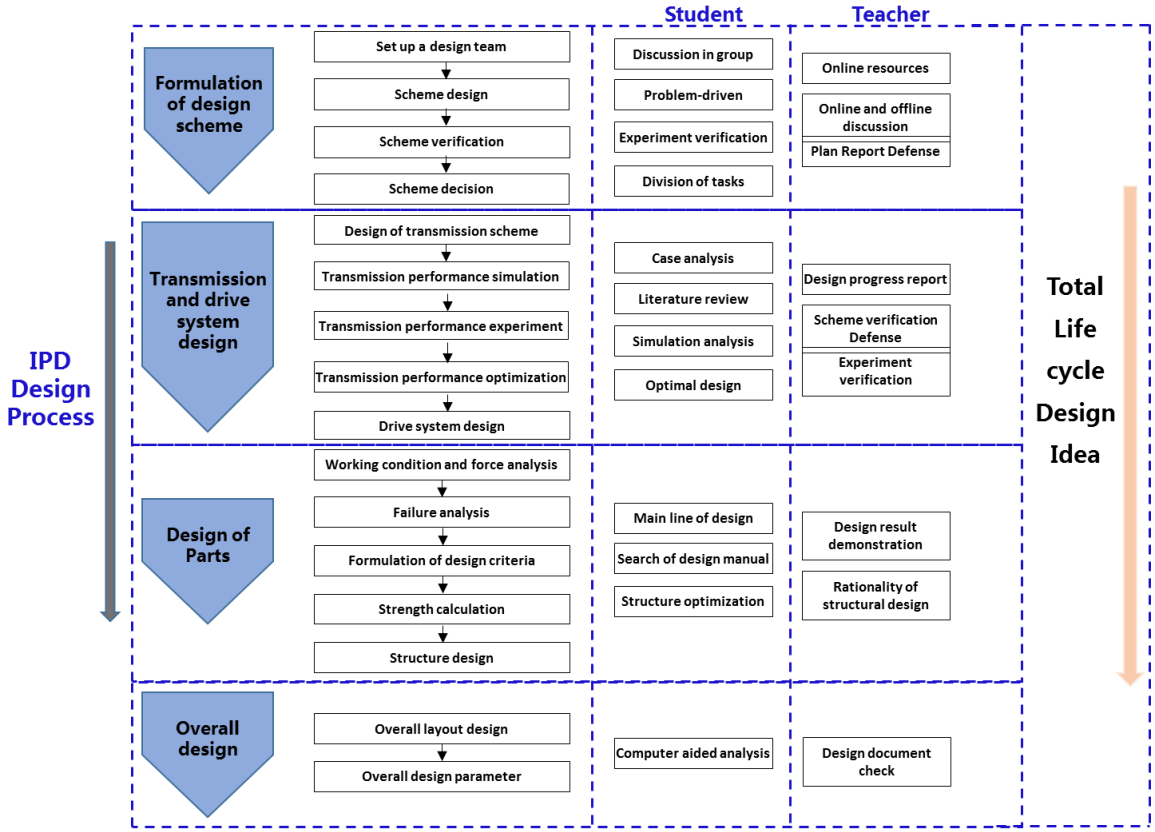

FIG. 2 Research practice teaching implementation strategy

Simulation experiments and physical experiments can prove the rationality and feasibility of the design scheme, and the course design aims to cultivate students' ability to use and internalize knowledge.The new teaching mode changes the original curriculum design topic and content.At present, the design problem of the two-stage reducer is a very typical one which makes students' ability to design mechanical parts be well trained. However, it is not enough to train their ability to solve complex engineering problems and the application of modern design methods in the design of mechanical systems. Therefore, the project topics as shown in Table 1 are proposed to enable students to complete all the design links according to the design process of the enterprise, while strengthening the application of modern design methods and advanced manufacturing technology, especially the impact of the emergence of additive manufacturing technology on the design method. Therefore, the content of simulation and structural topology optimization are added to the system design part, so as to improve the high order and complexity of the design task and improve the innovation ability of students.

4. Multiple evaluation methods

For the experimental and course design practice teaching links, the traditional single evaluation method is changed to adopt multiple evaluation methods (as shown in Table 2).Through the combination of process assessment and final assessment, we can comprehensively evaluate the students' learning situation.

Table 2 The composition of student evaluation

Evaluation item	Description	Proportion
Research inquiry	Group discussion	10%
Experimental scheme	Experimental report and performance	20%
Design scheme and structure	Creativity Feasibility Reliability Presentation Team cooperation	50%
Design report	Standardization of format Integrity	20%

Total	**100%**

The research inquiry mainly evaluates the research reports and case analysis group discussions on the non-standardized problems after class raised by enterprise experts, tests students' ability to read and write scientific and technological literature, and solves practical problems based on problem investigation. The design scheme and structure are evaluated by peer evaluation, school instructor and enterprise instructor.

5. Conclusion

The traditional practice teaching mode of mechanical design focuses on the mastery of knowledge and lacks the cultivation of students' ability to solve complex engineering problems. This paper analyzes complex engineering problems from two dimensions of complexity, puts forward a multi-research teaching model, and applies this model to the practice of mechanical design. After two years of teaching practice, it is found that this model can significantly improve the students' ability to analyze problems, solve problems and innovate. At the same time, it can be found that students' scientific literacy has been significantly improved.

Acknowledgement

This research was funded by the Higher Education Teaching Reform Project and Practice of Hebei Province (2020GJJG304), the special project of "Teaching Reform and Practice Research Based on First-class Curriculum Construction" of China Association of Higher Education (2020JXYB06) and the Educational Science Research Project of Mechanical Basic Education Reference Committee of Ministry of Education (2022JXJC-JSXJ-12).

References

[1]. Ministry of Education of the People's Republic of China. Notice on the approval of the First batch of "Outstanding Engineer Education and Training Program" universities [EB/OL].[2010-06-30]. http://old.moe.gov.cn//publicfiles/business/htmlfiles/moe/s3860/201010/109630.html.
[2]. Pang Fenghui, Wang Yaodong. On the Non-technical Ability of Outstanding Engineers [J]. Journal of National Institute of Educational Administration,2012,11:23-26.
[3]. Han Yu, Wang Xiuyan. Research on multi-source representation of occupational norms in non-technical competence of engineering education [J]. Higher Engineering Education Research,2022(02):74-80.
[4]. Chen Jian, Zhu Luchuang, Wang Jie, Wu Jianbo. Research on Curriculum System of Non-technical Ability Training in Engineering Training [J]. Experimental Science and Technology,2020,18(04):74-78.
[5]. Bai Yixian. Constructivist Learning Theory and entrepreneurial engineering talent Training: A case study on the reform of talent training model in British and American universities [J]. Higher Engineering Education Research,2014,4(05):46-51.
[6]. Dong Zengwen, Deng Xiaohua, Zhang Hua. Practice and reflection of research teaching in engineering education [J]. Research of Higher Engineering Education,2013(05):164-167.
[7]. HU Rong. The Application of Constructivism in Higher Engineering Education and teaching [J]. Journal of Changchun University, 2021,31(04):78-82.
[8]. ZHU Shuangxia. Construction and Practice of Mechanical Foundation Series Courses Guided by Coupling of Knowledge and Practice [J]. Light Industry Science and Technology,2020,36(03):125-126+128.
[9]. FeiShaomei, Lu Guodong, GuDaqiang. Research on Higher Engineering Education,2017,4(06):71-75.
[10]. Yang Yigang, Meng Bin, Wang Weinan. How to Solve the Difficulties of "Complex Engineering Problems" in Engineering Education: Based on the Perspective of enterprise technology Innovation [J]. Research of Higher Engineering Education,2017,4(02):72-78.
[11]. Deng Jiaojiao, ZouYanyan. Teaching practice of solving complex Engineering Problems: A study based on complexity degradation [J]. Higher Engineering Education Research,2022(01):62-67.
[12]. Lin Jian. Using Inquiry Learning to cultivate complex engineering problem solving Ability [J]. Research of Higher Engineering Education,2017,4(02):79-89.
[13]. ZouGuangming, liuJiongXiaoHan, wangxingdong, Hou Yu, aftershocks. Practical Teaching system of Mechanical Engineering for Solving Complex Engineering Problems [J]. Laboratory Research and Exploration,2020,39(09):221-226.
[14]. BaoHaitao, Wang Dianlong, Yang Rui, Gao Yuan, Chen Qinghong. Research on Mechanical Foundation Experiment Teaching for Solving Complex Engineering Problems [J]. Laboratory Science,2020,23(04):158-161.
[15]. Zhang Peng, Luo Yang, Yang Tongda, Yu Fei, Liu Weisheng. Review of Complex Systems from the Perspective of Design Process Complexity [J]. Journal of Machine Design,2020,37(8):1-10.
[16]. Li Dandan. Function Analysis and Design process complexity integrated solar dust removal System Research [D]. Tianjin: Hebei University of Technology,2019.

YANG Huadong, et. al. "Exploration on the Practical Teaching Mode of Mechanical Design Oriented to Solve Complex Engineering Problems." *IOSR Journal of Research & Method in Education (IOSR-JRME)*, 12(06), (2022): pp. 48-53.