Curriculum and Teaching Methodology (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/curtm.2025.080123
ISSN 2616-2261 Vol. 8 Num. 1

Application of PBL Teaching Method in the "Mechanical Measurement and Control Comprehensive Experiment" Course

Chi Yulun[1,a,*], Xie Liang[1,b], Song Linlin[1,c], Zhu Wenbo[1,d]

[1]College of Mechanical Engineering, University of Shanghai for Science and Technology, Shanghai, 200093, China
[a]chiyulun@163.com, [b]243391624@st.usst.edu.cn, [c]sll970323@163.com, [d]teacherzwb@usst.edu.cn
**Corresponding author*

Keywords: PBL teaching method, Comprehensive experiment of mechanical measurement and control, Instructional design, Application practice

Abstract: Under the background of new engineering, the course "mechanical measurement and control comprehensive experiment" is a multidisciplinary comprehensive experiment course, and the traditional teaching mode can hardly achieve the teaching goal. Therefore, the application practice of PBL (Problem-based learning) teaching method in the teaching course "mechanical measurement and control Comprehensive experiment" is proposed. Through vertical design: set questions before class, exploration learning in class and feedback summary after class, horizontal design: teacher activities, student activities, assessment and evaluation, combined with the online and offline links provided by the school, such as one-network learning platform, tutoring and question answering, self-study and guidance, 288 mechanical major students in 2021 were studied on teaching application. The practical results show that: The introduction of PBL teaching method into the course of "Mechanical Measurement and Control Comprehensive Experiment" has significantly improved the effect, which can fully mobilize the enthusiasm of students in learning, effectively improve the ability of students to learn independently and solve problems, and also improve the interaction distance between teachers and students. This teaching mode has certain reference significance for other courses to introduce PBL teaching method to cultivate students' inquiry spirit, innovative thinking and cooperation ability.

With the development of modern intelligent manufacturing technology, the demand for mechanical testing and control technology and talents is growing [1]. In the “new engineering” talent training background, in order to cultivate mechanical testing and control of multidisciplinary cross high-end composite talents, our school for mechanical design and manufacturing and automation students opened the “mechanical testing and control of integrated experiments”, the experimental course focuses on the theory of professional knowledge and engineering practice precision combination, compared with the traditional experimental course of theoretical learning and practical knowledge learning, the course is based on a variety of sensors, sensors and control technology and talents. This experimental course pays particular attention to the precise combination of theoretical expertise and

engineering practice. Compared with the traditional experimental course of theoretical learning and practical knowledge learning, this course is based on the main line of measurement and control of a variety of sensors, emphasizes the cultivation of students to combine theory and practice, the ability to practice under the guidance of theory and improves the practical ability of the students, and cultivates the students' ability to deal with the problems through the application of a variety of sensors in various scenarios, including problem discovery, analysis and solving [2-3]. Therefore, the traditional classroom model is usually teacher-centered, and the course effect is often unsatisfactory through one-way knowledge transfer [4].

PBL (Problem-based learning) teaching method is known as problem-based learning, through the teacher selects and sets some actual problem situations, makes students enter the situation, and guides students to analyze the problems through cooperation, mutual help, sharing, etc., so that the students can acquire key knowledge in the process of analyzing and solving these problems [4-5]. In this course, “Mechanical Measurement and Control Comprehensive Room Experiment”, the research and practice of PBL teaching method is carried out, utilizing the one-network learning platform provided by the school for online pre-course preparation and post-course discussion, carrying out group instructional design and exploratory learning in response to the set problems, and combining tutorials, Q&A and self-study tutorials for offline teacher-student exchanges to cultivate the spirit of inquiry, innovative thinking and collaborative work. The spirit of inquiry, innovative thinking and collaborative ability, improve students' independent learning and problem solving ability, and provide practice and exploration for the new path and new direction of “new engineering” talent cultivation in the context of “Made in China 2025”[5-6].

1. Introduction to PBL pedagogy and current status of research

PBL (Problem - based learning) teaching method was founded in the 1860s by Howard Barrows, an American professor of neurology, and was initially proposed in order to develop a teaching method for medical students, which advocates a problem-oriented self-study learning style, with real-life problems as the vehicle to facilitate students' learning of concepts and principles, and is an active learning teaching method [7]. According to the teaching process of PBL, the first link is to set up the problem for the teaching case, divide the students into several groups according to 2-4 people, then set up a group leader for each group to conduct group learning and discussion, and let students explore and solve the problems through cooperation and communication. In this process, the teacher guides and finally conducts the results demonstration and summary to improve students' ability to comprehensively think about the problem, analyze the problem, and finally solve the problem [8].

Currently, PBL is widely used in non-medical courses such as nursing, pharmacy, biology, physical sciences, electrical and electronic engineering, international trade, etc., and is often combined with CBL (Case based learning) and 3-Turns (Turn up, Turn away, Turn back) to carry out problem- or project-based discussion-based and Inspired teaching emphasizes placing students in complex and meaningful problem situations or projects to develop their independent learning ability, innovation potential and teamwork spirit [9-10]. Yan Chunlan et al [11] explored the application practice of PBL teaching method in the course of Microbial Physiology Course from the aspects of implementation process, application principles, and implementation effects, which laid the foundation for the effective application and innovative practice of PBL teaching method in the course. Wei Yongqing et al [12] proposed the use of PBL teaching method for the implementation process of project-based teaching for the problem setting in the course of “Power Electronics Technology”, and the practice shows that the application of PBL teaching method in project-based case teaching can effectively improve the problem-solving skills and higher-order thinking ability of learners. Zhao Ximin et al [13] proposed a practical reform strategy based on PBL teaching method in the context of new liberal arts from four

perspectives: extending content, innovating method, reengineering process, and reconstructing evaluation, which provides reference for the practical teaching reform under the construction of new liberal arts in colleges and universities. Zhu Bo et al [14] organically integrated information technology and PBL teaching method, constructed and implemented the teaching system for three links before, during and after class, and the results showed that this teaching mode can significantly improve the teaching effect, improve students' independent self-learning ability, cooperative practice ability, and help to cultivate students' independent scientific research ability, which is helpful for the construction of first-class undergraduate specialties. Then, this PBL teaching method is rarely used in the mechanical measurement and control comprehensive experiment, in order to solve the problem of the experimental classroom is purely teacher-oriented, students passively accept knowledge, the lack of sufficient space for thinking and analysis, the interface between theory and practice is insufficient, students are difficult to apply theoretical knowledge to specific experimental operations [15]. In this paper, the PBL teaching method is adopted for the course "Mechanical Measurement and Control Comprehensive Experiment" to carry out practical research and provide reference for the teaching practice of other science and engineering experimental courses.

2. Course design of "Mechanical Measurement and Control Comprehensive Experiment" based on PBL methodology

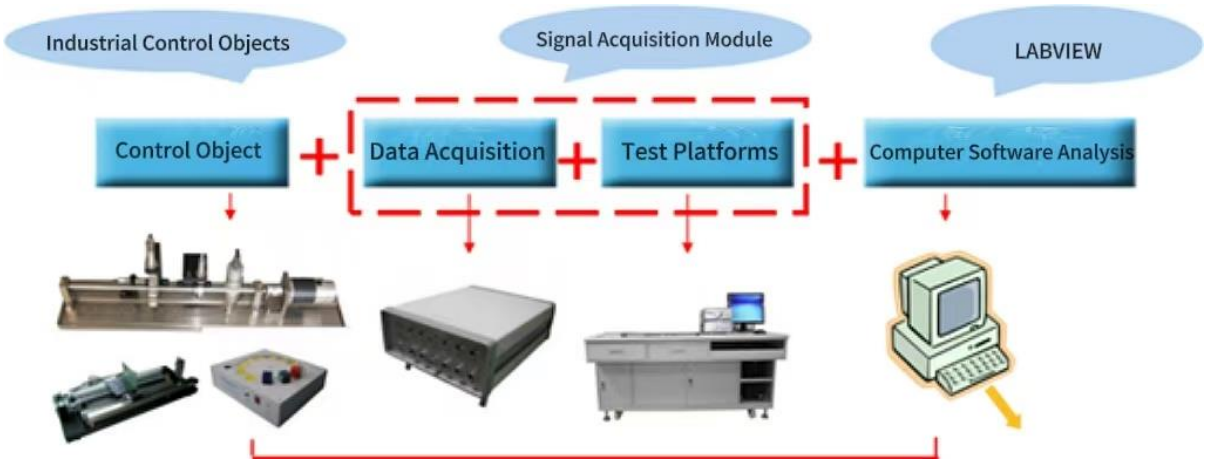

Figure 1: Mechanical measurement and control comprehensive experimental teaching platform.

According to the 2023 version of the training program formulated by our school, the comprehensive experiment of mechanical measurement and control is a professional practice course for all majors of mechanical class. As shown in Figure 1, this experimental course adopts modular experimental equipment, industry-standard sensors and computer software to build the experimental test platform. This teaching platform allows students to contact with the actual industrial application objects, to build their own industrial models and redesign these models, which aims to combine the theoretical knowledge and engineering practice, and train students' scientific thinking and innovation ability. Due to the strong comprehensiveness of the experimental course, not only need the theoretical knowledge of multiple disciplines, but also need to operate a variety of experimental instrumentation as a support, with a typical combination of theory and practice, the course involves machinery, sensors, signal processing, software analysis and other disciplines, the experimental module has a relative independence of the principle of the instrumentation used in the large gap between the purely through the teacher to explain - experimental operation - to complete the report, it is difficult to stimulate students to seek for the best. Completion of the report, it is difficult to stimulate students' desire for knowledge and exploration, resulting in great difficulty and poor learning results [16]. The PBL

teaching method is student-centered and problem-oriented, teacher guides their students to solve problems by group discussion and collecting the information independently. Utilizing the one network learning platform, tutorials and self-study tutorials teaching links, at the same time, combined with the course nature and teaching objectives of the comprehensive experimental course of mechanical measurement and control, the PBL teaching can effectively solve the problem of the experimental teaching and meet the requirements of cultivating students' independent learning ability and innovation ability [17].

In order to effectively implement the PBL teaching method to cultivate application-oriented talents, as shown in Figure 2 below, the PBL course of the comprehensive experimental course of mechanical measurement and control is designed vertically and horizontally, in which the vertical design includes: pre-set problems before the class, exploration and learning in the class and feedback and summary after the class; and the horizontal design includes: teacher activities, student activities and assessment and evaluation of the three parts. This course combines the online teaching with the function of online learning, the experimental course design to preset engineering application problems as the teaching center, guiding students to discuss the knowledge involved in the problem and group division, in the process of classroom implementation of the preset practical analysis and testing problems as a guide to the group discussion and exploratory learning, and gradually cultivate the students' sense of theoretical connection to practice in discussion and learning, in the teaching process, the teacher mainly plays the role of inspiration and guidance, and the teacher plays the role of inspiration and guidance, and the teacher plays the role of inspiration and guidance, and the teacher plays the role of inspiration and guidance. In the teaching process, the teacher mainly plays the role of inspiration and guidance, while the students, as the main body of learning, participate in the whole process of exploration, thinking and learning and discussion, and finally combined with a network of smooth learning group results report and summarize the problem, through the school set up tutorials and self-study tutorials on the students' doubts or difficulties in close communication and discussion to further consolidate the relevant theoretical knowledge and practical experience.

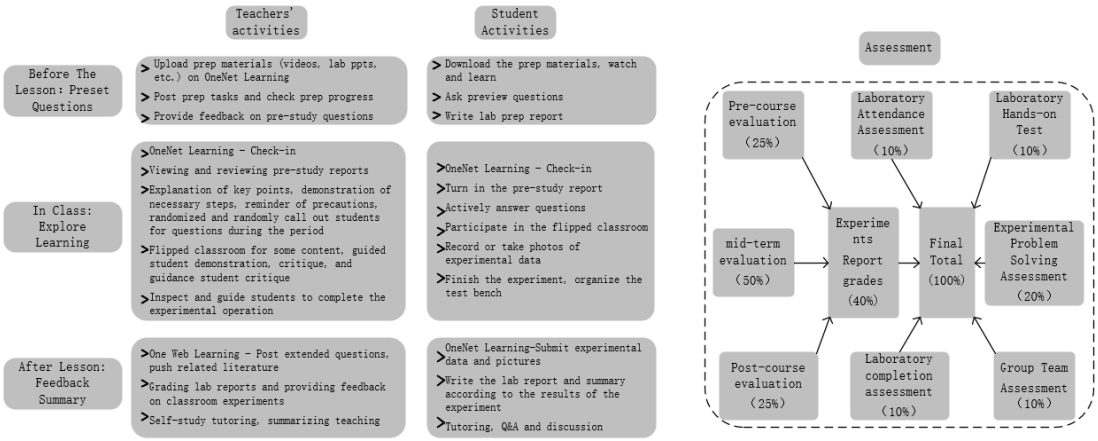

Figure 2: Framework diagram of PBL teaching model for comprehensive experiment of mechanical measurement and control.

3. Practice of "Mechanical Measurement and Control Comprehensive Experiment" Course Based on PBL Teaching Methodology

The practice of this course is to take 288 undergraduate third-year students majoring in Mechanical Design, Manufacturing and Automation in the class of 2021 in University A as the practice object, divided into 24 experimental teaching classes, the odd-numbered classes as the experimental class of the PBL teaching method in Fig. 2 (12 classes of 144 students), and the even-numbered classes as the

control class (12 classes of 144 students), and the control class adopts the traditional teaching method, i.e., the professor lectures on the experimental content, students operate according to the experimental requirements, and finally write and submit the experimental report. Each experimental teaching class can hold 12 students, during the class, these students are divided into four groups (each group of three people, of which one is the leader), the leader is responsible for the division of tasks and communication with the teacher. The specific implementation process of the experiment is shown in Figure 3 below, during this class, the students will learn how to use the LabVIEW virtual instrumentation software to design and develop different control systems for different sensors, the whole content of this course mainly divided into: LabVIEW basic, temperature measurement, rotational speed measurement, light intensity measurement and control and simulation of production lines and other 10 teaching units, each unit has 4 hours. By comparing the actual situation and feedback results of the experimental class of the PBL teaching method (odd-numbered classes) and the traditional teaching control class (even-numbered classes), we evaluate and summarize the implementation effect of the PBL teaching method.

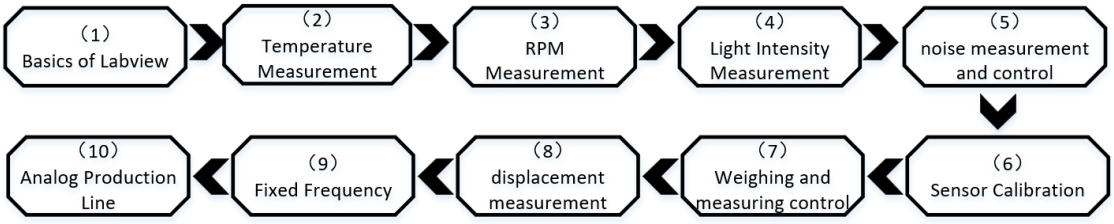

Figure 3: Comprehensive experimental teaching content of mechanical measurement and control.

4. Evaluation and assessment of experimental courses based on PBL teaching method and improvement measures

Mechanical measurement and control comprehensive experiment is an independent professional comprehensive experimental course in school, 2 credits, need to master the basic idea of data acquisition, learn the principles of various sensors and application methods and analysis and processing of the collected signal. According to Figure 2 of the PBL teaching method design needs to be evaluated and assessed in Figure 3 of the experimental content. In the past, the traditional experimental teaching assessment, the teacher according to the classroom performance and experimental reports to give the usual grades and report grades; while the PBL teaching process is divided into the pre-course - preset questions, the class - exploration and learning and post-course - feedback summary of the three phases of the student-centered, problem-oriented, so the PBL experimental evaluation assessment focuses more on the hands-on ability of the students, answering the questions, group teamwork and so on, as shown in Table 1 , the assessment points of this experimental course are: 1) whether they can put forward the key problems and difficult problems of the experimental content according to the pre-class preliminaries, 2) whether they can learn independently according to the purpose of the experiment and build the experimental test system during the experiment, and whether they can identify the reasonableness of the design, and 3) whether they have the comprehensive ability of discovering problems and analyzing and solving problems after the experimental class. In these aspects, teachers can make comprehensive judgments through offline and online pre-class preview, in-class teaching and post-class feedback, and design PBL specific evaluation indexes: attendance (10%), hands-on ability (15%), answering questions (17%), teamwork (18%), completion (10%) and experiment report (30%), using these quantitative indexes teachers based on the students in the one-network unimpeded learning platform Using these quantitative indicators, teachers give objective grade results based on the students' comprehensive

performance before, during and after the class.

Table 1: Evaluation and Assessment of Mechanical Measurement and Control Comprehensive Experiments with PBL Teaching Methodology.

Goal:	Highlights of assessment	Comprehensive Evaluation Methods and Scale of Achievement(%)					
		Attendance	practical	Q&A	Teamwork	Completion	Report
	1) The formulation of key questions and difficult problems 2) Study to build a test System and determine design rationality independently 3) To develop the ability to discover, analyze and solve problems	10%	15%	17%	18%	10%	30%
Total:		100%					

Mechanical measurement and control comprehensive experiment has a strong engineering applicability, most of the students do not have relevant engineering practice background, traditional teachers from the knowledge transfer teaching to carry out, often ineffective. After the introduction of PBL teaching method into this experimental course, the students' interest in learning has been significantly increased, and the interaction between teachers and students has also been enhanced. In PBL teaching, although the teaching effect is remarkable, some problems have emerged, especially in the three aspects of teacher activities, student activities and assessment and evaluation in the horizontal design of Fig. 2, which need to be taken to improve the measures in the subsequent teaching.

5. Conclusion

Under the background of “new engineering” talent cultivation of the Ministry of Education, experimental teaching is facing new opportunities and challenges. The “Mechanical Measurement and Control Comprehensive Experiment” is a core practical course that involves the intersection of multiple disciplines, and plays a crucial role in enhancing students' comprehensive practical innovation ability. In this paper, by introducing the PBL experimental teaching method, the vertical design of the course: before class - preset questions, during class - exploration and learning and after class - feedback and summarization, which improves students' independent thinking and teamwork ability; the horizontal design of the course: teaching activities, student activities and evaluation and assessment, which improves the equality and interactivity between the teachers and the students, and the teaching and discussion of the learning effect is obviously improved; through a network of free learning, tutoring and Q&A and self-study tutoring, the online and offline teachers are able to improve the students' ability of comprehensive practice and innovation, and to enhance the students' ability to learn. Self-study counseling online and offline multi-dimensional learning and communication between teachers and students, effectively consolidate students' theoretical knowledge and practical experience, promote the distance between teaching and students, and improve students' independent hands-on ability. The PBL teaching mode can effectively stimulate students' learning autonomy, enthusiasm and innovation, effectively improve the shortcomings of the traditional teaching mode, and play an important role in cultivating “new engineering” application-oriented and innovative talents.

References

[1] Jia Jianfeng; Ge Yijing; Sun Xinbo. Teaching Mode Design of the Innovation and Entrepreneurship Course in Vocational Colleges Based on PBL [J]. Journal of Vocational Education, 2021, 37(2): 67-72.

[2] Zhang Junli; Ma Jinjin; Shi Wenzhong. Research on the Reform of Instrumental Analysis Experimental Teaching Method Based on the Integration of Production and Teaching [J]. Journal of Higher Education, 2021(6): 140-143.
[3] Duan Pei. A Study of Project-Oriented Practice Teaching in the Context of the New Liberal Arts [J]. Journal of Higher Education, 2023, 9(12): 68-73.
[4] Sheng Juan; Ni Xiaolei. Research on the Construction and Application of SPOC Blended Teaching Mode under the Background of "Internet Plus": Taking the Engineering Project Management Course of Applied Undergraduate as an Example [J]. China Training, 2021, (3): 78-79.
[5] YAN Xianchun; CAO Xiuli; BU Xin et al. Exploration and application of PBL combined flipped classroom teaching model in medical molecular biology experiment teaching [J]. Journal of Biology, 2022, 39(1): 115-117, 122.
[6] Bodagh N, Bloonfield J, Patrick B et al. Problem - based learning: a review [J . British Journal of Hospital Medicine (Lond), 2017, 78(11): 167-170.
[7] Yin Qi. Exploration of the Application of PBL Teaching Method in the Teaching of "International Trade Studies". [J], Gansu Education Research, 2024, 4(36):78-81.
[8] Yu Yao; Xiao Wenjun; Zhang Xiaoyun. Application of PBL Teaching Method in "Electrical and Electronic Technology" Teaching [J]. China Southern Agricultural Machinery, 2024, 04:195-198.
[9] Zhao Yong-fu; Wang Ling; Liu Hui. Teaching Reform and Practice of Instrumental Analysis Course Based on PBL Teaching Method [J]. Journal of Zhengzhou Normal Education, 2024, 13(2): 38-41.
[10] Chen Dongyi; Wang Wu; Lin Jianxin et al. Application of 3-Turns Teaching Method in Promoting Deep Learning in Community of Practice [J].Research and Exploration in Laboratory, 2024, 04(43): 155-158.
[11] Yan Chunlan; Pei Guofeng; Cheng Guojun et al. The Application of Problem Project-Based Learning Methodology in Teaching Microbial Physiology Course [J]. Journal of Microbiology, 2024, 04:1-8.
[12] Wei Yongqing; Yu Fei; Huang Yaxin et al. Application of PBL Teaching Method in the Course of Power Electronics Technology [J]. Journal of Electrical and Electronic Education.2024, 1(46): 110-114.
[13] Zhao Ximin; Ding Liang; Guo Jun. Exploration of Practice Teaching Reform Based on "PBL" in the Context of New Liberal Arts: Taking the Course of Film and Television Dubbing Art as an Example [J]. Journal of Gansu Normal Colleges, 2023, 06(28): 123-127.
[14] Zhu Bo; Wang YuanXiu; Liu Huijun et al. Design and Practice of PBL Teaching Model in Biochemistry Laboratory Teaching [J]. Journal of Higher Education 2024, 01: 123-127.
[15] Ye Weijia; Shen Chenlu; Gao Bicong et al. Application of PBL Combined with CBL Teaching Method in Clinical Teaching of Oral Mucosal Diseases[J]. China Higher Medical Education, 2024, 01: 98-100.
[16] Chi Yulun; Ying Xiaoang; Liu Jianguo. Online and Offline Mixed Teaching Practice of Mechanical Measurement and Control Comprehensive Experiment under the COVID-19[J]. Experiment Science and Technology, 2021, 19(6): 1-5.
[17] Zeng Xiaosong, Tan Qiong. About "Active Practice" Experimental Teaching of University [J]. Research and Exploration in Laboratory, 2011, (7): 279-281.