Application of PDCA Cycle in Quality Management of Mechanical Experiment Teaching in Colleges and Universities

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**Abstract.** Under the background of Emerging Engineering Education, the traditional experiment teaching cannot meet the needs of diversified and innovative talents in the present society, and the subversive reform is needed. In the reform of experimental teaching, process control is always the difficult point in quality management. Taking the mechanical experiment teaching quality as the research object, the application of PDCA cycle in quality management of mechanical experiment teaching is discussed. First of all, on the basis of the analysis of the mechanical talents training target, the experimental targets are determined and the experimental projects are designed. And then, mechanical experiment teaching model based on BOPPPS is proposed, the influencing factors of the experiment teaching quality are analyzed. Finally, the improvement plan is established to enter the next cycle. The mechanical experimental teaching quality would be continuously improved through PDCA cycle.

**Introduction**

Since February 2017, the Ministry of Education has actively promoted the construction of Emerging Engineering Education (abbreviated as EEE) to cultivate diversified and innovative outstanding engineering talents, which takes high moral values establishment and people cultivation as the fundamental task of education in respond to change and shape the future for the construction concept using inheritance and innovation, crossover and integration, coordination and sharing as the main way [1]. The connotation of EEE is to promote the reform of new-type engineering talents training mode for sustainable competitiveness in view of the changes of advanced technologies, new industries and social forms [2,3]. In order to meet the requirements of the society for professional and technical personnel at the present stage, colleges and universities have put forward new objectives for personnel training and carried out a series of teaching reforms.

As a bridge combining theoretical knowledge with practical activities, experimental teaching is particularly important for mechanical students. The mechanical specialty knowledge is complex, and experimental teaching can greatly improve students’ understanding and memory of professional knowledge, exercise their practical ability and cultivate creative thinking [4,5]. Meanwhile, high-quality experimental teaching is conducive to stimulating students’ interest in experimental practice and laying a good foundation for further deepening scientific and technological innovation competition and scientific research projects of college students. However, at the present stage, the mechanical experimental teaching cannot meet the requirements of modern society for mechanical talents, and the reform of experimental teaching is the general trend [6]. In order to improve the effect of experiment teaching and guarantee the quality of experiment teaching, PDCA (Plan, Do, Check, Action) quality loop is introduced to control the process of experiment teaching reform, so as to achieve the goal of continuous improvement [7].

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Overview of PDCA Quality Management

PDCA theory is put forward by the famous American quality management expert Deming, also known as "Deming Ring" [8]. It is a logical working procedure that can make any activity carry out effectively. The meanings of P, D, C and A are as follows:

P (Plan)—“Plan” including defining the guidelines and objectives of the activities and making the plans of the activities;

D (Do)—“DO” means to realize the goal and plan through concrete operations;

C (Check)—“Check” is to evaluate the effectiveness of the plan and find out what is done well and what is not done well;

A (Act)—“Act” is to process the results of the inspection. The good aspects should to be confirmed and promoted, and a standardization scheme should to be formed; The bad aspects should to be improved, and outstanding issues should to be put into the next PDCA cycle.

The main characteristics of this cyclical scientific management method are that each cycle is not cyclical at the original level, but achieves a part of the results, makes further progress, while improving the level of a hierarchy.

The Practice of PDCA Cycle in Mechanical Experiment Teaching

The mechanical specialties offered by our university include mechanical design and manufacture and automation, material forming and control engineering, mechanical engineering, industrial engineering, process equipment and control engineering, electrical engineering and its automation, marine engineering, etc., providing excellent talents for automobile, ship, electrical appliance, material, transportation and other industries.

Mechanical experiment is an indispensable part of learning for students majoring in machinery. Through experiments, theory and practice are combined to deepen students' understanding of knowledge and enhance their practical and innovative abilities. In order to improve the experimental effect, PDCA cycle is applied to the quality management of mechanical experimental teaching. P represents the experimental plan stage, the requirements of the experimental implementation process should be established, the standards and plans of the experimental implementation process should be defined, D represents the experimental implementation stage, the related work according to the requirements and plans would be carried out, and the experimental effect is evaluated. A and C stages are to process the results and feedback.
The implementation process should be determined; C represents the experimental inspection stage. The quality of the experiment is determined to meet the requirements through self-inspection by the research group, department inspection and school review, A represents the experimental improvement stage, measures should be taken to correct the deviation and prepare to enter the PDCA cycle of the next phase of the mechanical experiment teaching (as shown in Fig. 1).

Experimental Planning Phase

The experiment plan is the first step in the process control of mechanical experiment. Firstly, the training objectives of mechanical specialty under the background of the EEE should be defined. Based on this, the experiment objectives should be determined, and the experiment projects should be designed. Then, sufficient experimental conditions should be prepared.

Define the Training Objectives of Mechanical Talents. Mechanical specialty training goal of our university aims at training engineering technical talents, those have solid natural science and social science knowledge, have admirable moral character and the social responsibility, have a certain international view, have solid foundation of theoretical knowledge and the application ability in the field of mechanical specialty, have good ability of engineering practice and modern engineering tool using ability, and have the team cooperation spirit and the Leadership potential [9].

The graduates will achieve the following knowledge and abilities:

Engineering Knowledge. The ability to apply mathematics, natural science, engineering fundamentals, and special knowledge to solve complex engineering problems in the field of machinery;

Problem Analysis. The ability to use the basic principles of mathematics, natural science and engineering science to identify, express, and analyze complex engineering problems of mechanical specialty from the work of literature research to acquire effective conclusions;

Design/Development Solutions. The ability to determine design solutions to complex engineering problems, units (components) or processes which meet specific needs, and embody innovation in design, social, health, safety, Legal, cultural and environmental factors;

Research. The ability to conduct research based on scientific principles and scientific methods to solve complex problems in mechanical specialty field, including the design of experiments, analysis and interpretation of data, and the work from information synthesis to reasonable and effective conclusions;

Use Modern Tools. The ability to develop, select and use appropriate technologies, resources, modern engineering tools and information technology tools for complex mechanical engineering problems, including predictions and simulations of complex engineering problems, and to understand their limitations;

Engineering and Society. The ability to analyze the impact of professional engineering practices and complex engineering solutions on social, health, safety, legal and cultural issues, and to understand the responsibilities that should be undertaken, based on the contextual knowledge of the project;

Environment and Sustainable Development. The ability to understand and evaluate the impact of engineering practices on complex engineering issues on environmental and social sustainability;

Professional Specifications. Qualifications of the humanities and social sciences, social responsibility, understanding and adhering to engineering ethics and norms, fulfill their responsibilities in engineering practices;

Individuals and Teams. The ability to assume the roles of individuals, team members and principals in a multidisciplinary team;

Communications. The ability to communicate effectively with industry peers and the public on complex engineering issues, including writing reports and design presentations, presenting statements, articulating or responding to directives, obtaining a certain international perspective, capable of communication and exchange in cross-cultural context;

Project Management. The ability to understand and master engineering management principles and economic decision-making methods in a multidisciplinary environment;
Lifelong Learning. The ability to maintain sustainable self-development with the sense of self-learning, lifelong learning and continuous learning [10].

Set Goal and Design Experiment. The goal of experimental teaching is to improve students' knowledge, ability and quality through experiments, so as to meet the social requirements for mechanical talents under the background of EEE [11,12]. Mechanical experiments can be divided into demonstration experiments, verification experiments, comprehensive experiments and design and research experiments.

Demonstrative experiment belongs to the direct teaching. The basic way is that teachers demonstrate the experimental process, guide students to observe, think, analyze the experimental principles and draw conclusions. Demonstrative experiments focus on broadening students' cognition, such as hydraulic cognitive experiment, port machine cognitive experiment, etc;

Verification experiments refers to experiments conducted to verify the validity of a hypothesis based on a certain understanding of the basic parameters of the subjects, with emphasis on cultivating and improving students' ability to understand knowledge. The experiments involved include: length measurement, surface roughness measurement, straightness error measurement of guide rail, circular runout measurement, welding joint organization analysis, etc;

Comprehensive experiment is designed for a certain mechanical specialty, such as mechanical design and manufacturing and automation, mechanical engineering, etc. Or for a certain course, such as mechanical design foundation, modern testing technology, numerical control technology, sensor principle and application, focusing on training and improving students' integration ability and comprehensive application ability of different knowledge points of the same course. The comprehensive experiments of mechanical class include the design of combined structure of shaft and bearing, the innovative design of mechanism motion, the design of combined structure of shaft and bearing, the measurement of dynamic stress and strain of structure, the milling programming experiment of cam, the turning experiment of handle, the brake experiment, the motion control experiment of robot, etc;

Design and research experiments are designed for the hot and difficult problems in the key courses and practical fields of mechanical specialty, focusing on training and improving students' design and creativity. Such as: turning tool angle measurement design, blanking die disassembly experiment, deep drawing die disassembly experiment, signal analysis experiment, mechanical principle curriculum design, single chip computer principle and interface technology curriculum design, electromechanical transmission and control curriculum design, hoisting machinery metal structure curriculum design, hydraulic components and control system curriculum design, pressing process and die design curriculum design, etc.

Preparation of Experimental Conditions. The experimental conditions include site, hardware and software facilities, teaching resources, etc. They are the indispensable support for experimental teaching and provide favorable conditions for training students' practical skills [13,14]. First of all, it is necessary to establish a perfect open laboratory, which is conducive to giving full play to resource benefits, realizing resource sharing and improving equipment utilization. Secondly, experimental equipment and software system are necessary conditions, which need to update experimental equipment and upgrade experimental software to meet the training requirements of new engineering talents in line with the needs of enterprises. Thirdly, the experimental teaching resources include video of all required and open projects of mechanical experiments, experimental instructions and expanded resources of software, competition works, exercises and examination papers of all kinds of mechanical experiments.

Experimental Implementation Phase

The implementation stage is the second step of PDCA cycle and the key link of experimental teaching reform. After making the plan, teachers need to combine the experimental plan to carry out teaching in order to achieve the goal of teaching reform. Specifically, it includes the determination of teaching content, goal setting, classroom guidance, after-class summary and so on. In order to achieve better experimental teaching effect, the teaching content should be enriched and novel.
Meanwhile, in the classroom, the instructor needs to use heuristic teaching methods to guide students to think and ask questions, and give students enough time to practice.

BOPPPS model is famous for effective teaching, which is a closed-loop teaching activity model that emphasizes students' participation, interaction and feedback in the process of classroom teaching organization [15]. BOPPPS model is mainly composed of six elements: B (bridge-in) classroom introduction, O (objective) classroom goal, P (pre-assessment) classroom pre-assessment, P (participatory learning) classroom participation, P (post-assessment) classroom post-test and S (summary) classroom summary. The introduction of BOPPPS teaching model into experimental teaching fully reflects the student-centered teaching concept, and more importantly, it fits the experimental target [16].

**Classroom Introduction.** The key role of classroom introduction lies in stimulating students' interest. The introduction of mechanical experiment before class can introduce the experimental content through practical cases, story-telling methods and so on, which can trigger students to think and then enter the study with questions.

**Classroom Objectives.** In view of the specific experimental projects, the learning goal of the experiment is emphasized, so that students can clearly understand the purpose of experimental teaching. For mechanical experiments, students need to improve their practical ability, self-learning ability, ability to analyze and solve problems, and stimulate students' innovative thinking in the experimental process.

**Pre-assessment in Class.** Pre-assessment in class is to understand the effect of students' pre-assessment by asking questions before the formal lecture. Therefore, students need to preview knowledge points and teaching videos related to experimental projects through the experimental teaching management platform before class, and complete online pre-assessment [17]. On the one hand, it can improve students' autonomous learning ability, on the other hand, it can let teachers understand students' mastery of knowledge points, so as to make appropriate adjustments to the teaching content in the classroom.

**Classroom Participation.** Participatory learning is to insert questions into the teaching process so that students can participate in interaction and improve learning efficiency. The mechanical experiment teaching usually takes the group as the unit. Students are asked to design experiments around problems and complete the construction, debugging and operation on site. This kind of experiment requires students to be familiar with and master the basic theoretical knowledge, understand the operation method of the experimental equipment, and analyze the problems in the experiment and propose solutions by integrating the knowledge they have learned and previous accumulated practical experience. Participatory learning not only cultivates students' practical ability and cooperative spirit, but also stimulates their creativity.

**Post-assessment in Class.** Classroom post-assessment is a means to test the teaching effect through students' feedback after the experiment. The main form of post-assessment is to check the completion of students' experimental reports, including the analysis of experimental data, experimental conclusions and experimental experience. According to the post-assessment situation, teachers can timely understand the students' learning effect, find out the students' learning blind spots, find out the teaching contents and arrangements that need to be adjusted and improved, and timely adjust the next teaching content.

**Classroom Summarizing.** Summary is the analysis of the first five links to provide a common opportunity for teachers and learners to reflect on the problems in this teaching or lay an ambush for the next course content; students summarize what they have learned, and do a good job of after-class review.

**Experimental Inspection Phase**

The inspection stage is the third step of PDCA cycle. The emphasis is to evaluate the quality of mechanical experiment teaching. Firstly, the factors influencing the effect of mechanical experiment teaching and their internal relations should be analyzed, and then the evaluation model should be established by using the method of fuzzy comprehensive evaluation to get the evaluation results.
The factors affecting the effect of experimental teaching involve many aspects, including the quality of teachers' teaching and the effect of students' learning, as well as the preparation of experimental teaching conditions and experimental management.

The preparation of teaching conditions mainly includes whether the experimental instruction book and the experimental teaching plan are ready or not, whether the quantity and intact rate of the experimental equipment can meet the experimental requirements or not, whether the overall environment of the laboratory is clean and tidy or not, whether there are potential safety hazards or not, etc.

The quality of teaching refers to whether the teaching content of teachers is full and novel in the course of experiment or not; whether teachers use heuristic teaching methods to guide students to think and ask questions or not [20]; how about the interaction and discussion between teachers and students in the course of experiment; and how about the discipline of experiment;

The effect of learning refers to whether students have the ability to discover and solve problems or not [21,22], whether they have the ability of comprehensive analysis, and the ability of innovative research and development is particularly important in the context of emerging engineering education.

Experiment management refers to whether there is an experimental attendance; the use of experimental equipment records or not; whether the filling of the experimental log is standardized or not; whether the experimental report is detailed or not and so on.

In addition, the factors that affect the quality of experimental teaching are the policies and systems of the school. At present, the school does not pay enough attention to experimental teaching. From the point of view of the allocation of school hours, experimental hours are constantly compressed, teachers cannot explain more theoretical knowledge in a short time, and students do not have enough time to study in depth. In addition, schools should formulate incentive mechanisms to encourage experimental teachers to fully open laboratories, design open experimental projects, and provide extra-curricular guidance to students who have spare time. Therefore, all parties involved in experimental teaching need to carry out evaluation and assessment, and then re-formulate plans, implement, inspect and process according to the assessment results, and make continuous improvement by using PDCA cycle.

**Experimental Improvement Phase**

Improvement phase is the last step of PDCA cycle and the essence of process control. It is not only the promotion of this PDCA cycle, but also the precondition of the next PDCA cycle. In the improvement stage, teachers analyze and organize the evaluation of the quality of mechanical experiment teaching according to the inspection stage. For the factors with high evaluation, PDCA cycle in the next stage will continue to maintain and develop, and form a standardized plan. For the factors with lower evaluation, the existing problems are analyzed and improvement plans are proposed. For the implementation effect of improvement measures, the next PDCA teaching practice process to test, modify and constantly improve; unsolved problems are put to the next PDCA cycle.

**Conclusion**

Mechanical experiment teaching is the key content of practical teaching. The quality of mechanical experiment teaching affects the quality of training mechanical talents. Teaching quality is a dynamic and continuous improvement process. Introducing PDCA quality loop into mechanical experiment teaching, dividing a complicated experiment teaching process into four interrelated stages: planning, implementation, inspection and improvement, and through multiple PDCA cycles, is a developmental, whole-process and continuous improvement of mechanical experiment teaching. In this process, the school invests more resources, experimental management becomes more orderly and efficient, teachers' teaching content and teaching methods are constantly innovated to meet the needs of students' development, students are promoted from knowledge, ability, literacy and other aspects, to achieve the goal of experimental teaching more quickly, and a set of universal mechanical experimental teaching program is extended to more colleges and universities.
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