Research and Application Prospects of Engineering Thermodynamics Instruction based on PDCA Management Cycle

Muxing Zhang[1a*], Xuemei Chen[1b], Shanguo Zhao[2c]

[a]muxingzhangnk@hotmail.com,[b]xuemeichen@njust.edu.cn
[c]brozhao@126.com

[1]Nanjing University of Science and Technology, Nanjing, China
[2]Jiangsu Maritime Institute, Nanjing, China

Abstract. Engineering thermodynamics is a vital discipline in engineering education, playing a crucial role in the professional development and competence of engineering students. However, the current instructional practices face several challenges, including abstract content, limited integration with practical applications, and a reliance on a single teaching method. This study investigates the existing issues in engineering thermodynamics instruction and proposes the implementation of the PDCA (Plan-Do-Check-Act) cycle work method to enhance teaching effectiveness. The proposed approach involves four stages: establishing clear teaching objectives and designing instructional plans, employing diverse teaching methods with a focus on practical aspects, regularly evaluating teaching outcomes, and incorporating improvements based on evaluation results. The ultimate objective is to optimize students' learning outcomes and overall competence. By bridging the gap between theory and practice, diversifying teaching methods, and incorporating regular evaluation and improvement, instructors can create an engaging and effective learning environment that equips students with the knowledge, skills, and confidence to excel in the field of engineering. Results shown that the quantities of passed grades in Engineering Thermodynamics has increased in 11.10% after applying PDCA method for 2 years.

Keywords: Engineering Thermodynamics; Undergraduate Education; PDCA Cycle Work Method; Instructional Innovation

1 Introduction

Engineering thermodynamics is a fundamental course within the discipline of engineering, and it holds significant importance for the professional competence and overall development of engineering students. However, in teaching practice, there are several issues associated with the instruction of engineering thermodynamics, such as overly abstract content, lack of integration with practical engineering applications, and a reliance on a singular teaching method[1][2]. This paper analyzes the current status and problems of engineering thermodynamics instruction and explores the introduction of the PDCA (Plan-Do-Check-Act) management cycle method to improve teaching effectiveness[3]. The proposed approach encompasses four stages: clarifying teaching objectives and designing instructional plans, utilizing various teaching methods and emphasizing practical components, regularly evaluating teaching outcomes, and making

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improvements to instructional methods and content based on evaluation results. The ultimate goal is to enhance students' learning outcomes and overall competence.

1.1 Current Status and Issues in Engineering Thermodynamics Instruction

Table 1. Summary of key knowledge points and corresponding teaching objectives and instructional methods[4]

Knowledge Point	Teaching Objectives	Teaching Methods
Fundamental concepts of thermodynamics	Understand basic concepts such as temperature, pressure, heat, enthalpy, and entropy, and their relationships	Lectures, example analysis, problem-solving, group discussions, practice exercises
The First Law of Thermodynamics	Understand the principle of energy conservation, grasp mathematical expressions and applications for energy transfer and transformation	Lectures, example analysis, experimental demonstrations, mathematical derivations, real-world problem-solving
The Second Law of Thermodynamics	Understand the principle of thermodynamic irreversibility, master the principle of entropy increase and mathematical expressions of entropy	Lectures, example analysis, experimental demonstrations, mathematical derivations, case studies
Thermodynamic properties of ideal gases	Understand the state equation, thermodynamic properties, and calculation methods for ideal gases and basic processes	Lectures, example analysis, problem-solving, experimental demonstrations, computational exercises
Heat transfer	Understand the basic concepts and modes of heat transfer, grasp mathematical models and relevant parameters for heat transfer processes	Lectures, experimental demonstrations, example analysis, problem-solving, computational exercises

The current situation of engineering thermodynamics education presents some common characteristics. The teaching content is extensive and abstract, involving the basic principles of thermodynamics, cycles, and cycle processes, etc. as details listed in Table 1. These abstract concepts and theories may be complex and difficult for students to comprehend. Moreover, traditional teaching methods rely heavily on teacher lectures, lacking interaction and opportunities for student participation. In addition, there are also limitations in teaching resources and experimental conditions, which cannot meet the practical needs and demands of students.

1.2 Definition and Principal of PDCA Management Cycle

The PDCA cycle, also known as the Deming cycle or the Plan-Do-Check-Act cycle, is a four-step iterative problem-solving and continuous improvement method. The PDCA cycle is widely used in various industries and disciplines, including engineering, management, and education[5]. The four steps of the PDCA cycle are as showed in Fig.1.

The PDCA cycle is a continuous and iterative process, meaning that once the "Act" step is completed, the cycle begins again with the "Plan" step. This allows for ongoing improvement and refinement of processes, products, or services. The PDCA cycle promotes a systematic approach to problem-solving, encourages learning from experience, and fosters a culture of continuous improvement within organizations or educational contexts[6].

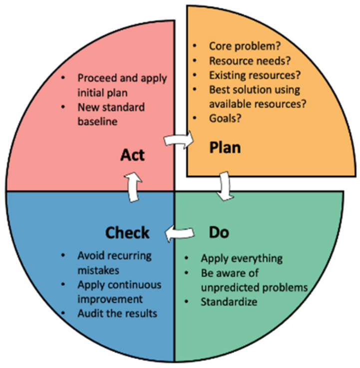

Fig. 1. Principal of PDCA Management Cycle

2 Study on the Application of the PDCA Cycle in Engineering Thermodynamics Instruction

2.1 Development of an Instructional Model for Engineering Thermodynamics based on the PDCA Cycle

Applying the PDCA management cycle method to course instruction can help improve teaching quality and student learning outcomes. The following are the steps and methods for applying the PDCA cycle to course instruction:

2.1.1 Plan Phase

Define teaching objectives: Clearly specify the teaching objectives of the course, including knowledge, skills, and attitudes.

Develop a teaching plan: Design appropriate teaching content, methods, assessment methods, and scheduling to ensure that the teaching plan aligns with the teaching objectives.

2.1.2 Do Phase

Instruction implementation: Conduct classroom teaching according to the teaching plan, using various teaching methods and resources to actively engage students and facilitate knowledge acquisition and skill development.

Teaching evaluation: Collect timely feedback and performance data from students, including classroom discussions, assignments, quizzes, etc., for subsequent checking and assessment.

2.1.3 Check Phase

Student learning assessment: Analyze students' learning outcomes, check if the expected teaching objectives are achieved, and assess students through quizzes, assignments, projects, etc., to gather feedback and evaluations.

Evaluation of teaching methods: Assess the effectiveness of teaching methods, understand students' acceptance and comprehension of teaching methods, and gather feedback through questionnaires, teaching observations, etc.

2.1.4 Act Phase

Instructional improvement: Identify issues and deficiencies in teaching based on the evaluation results and student feedback, develop improvement measures, including adjusting teaching content, improving teaching methods, and providing better learning resources.

Course updates: Timely update course content and teaching materials based on improvement measures and student needs, keeping up with the latest developments and providing a better teaching experience and learning outcomes.

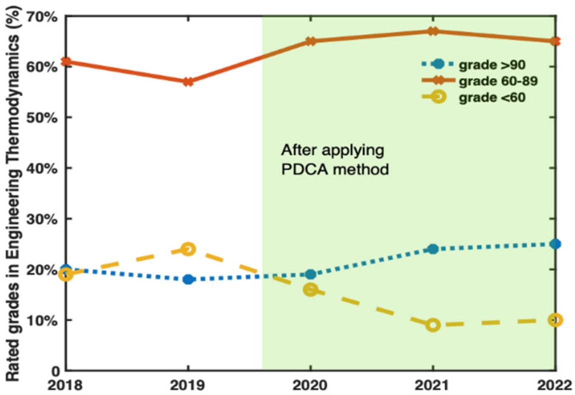

Fig. 2. Rated grades distribution variation of Engineering Thermodynamics

From Fig.2, it can be inferred that PDCA cycle had been efficiently applied in the instruction of Engineering Thermodynamics since students' grades were largely improved.

2.2 Specific Application Strategies of the PDCA Cycle in Engineering Thermodynamics Instruction

Applying the PDCA management cycle as showed in Fig.3 to the course instruction, specifically the observation of the critical state of carbon dioxide and the P-V-T relationship experiment, can help students better grasp the experimental operation methods for critical temperature, pressure, and other variables.

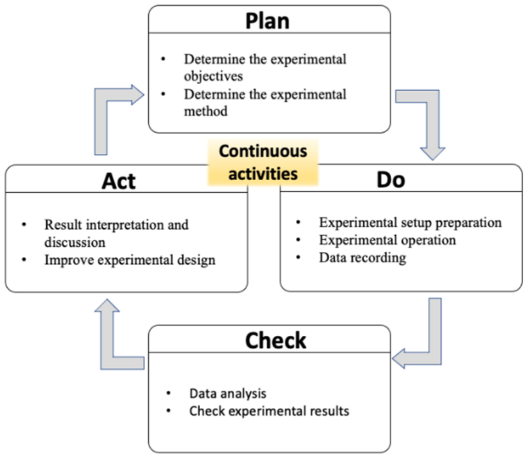

Fig. 3 Framework of application of PDCA Cycle in Engineering Thermodynamics Instruction

2.2.1 Plan Phase

Determine the experimental objectives: Clearly define the research questions and objectives related to the critical state and the P-V-T relationship of carbon dioxide.

Determine the experimental method: Select appropriate experimental methods and techniques, such as isothermal compression or isothermal expansion, to observe and measure the pressure, volume, and temperature of carbon dioxide.

2.2.2 Do Phase

Experimental setup preparation: Prepare the necessary apparatus and equipment for the experiment, including high-pressure containers, pressure gauges, thermometers, etc.

Experimental operation: Follow the predetermined experimental procedure. By gradually increasing the pressure or temperature of carbon dioxide, observe the corresponding volume changes to determine the critical state and the P-V-T relationship.

Data recording: Record the pressure, volume, and temperature data during the experiment, ensuring accuracy and stability of experimental conditions.

2.2.3 Check Phase

Data analysis: Analyze the experimental data, including plotting P-V and P-T charts, and observe trends and patterns in the data.

Check experimental results: Based on the data analysis results, check whether the experimental results align with the expected critical state and P-V-T relationship.

2.2.4 Act Phase

Result interpretation and discussion: Based on the experimental results, interpret and discuss the observed critical state and P-V-T relationship, incorporating relevant theories and knowledge for analysis.

Improve experimental design: Provide suggestions for improving the experimental design based on the results and discussions, such as adding more data points or adjusting experimental conditions.

Throughout the entire experiment, ensure the safety of experimental operations and adhere to relevant laboratory protocols. Accurate recording and reliable analysis of experimental results are essential to draw reliable conclusions. If further in-depth research and exploration are required, the above steps can be repeated within the PDCA cycle to progressively refine the experimental design and data analysis.

3 Development Prospects of Engineering Thermodynamics Instruction based on the PDCA Cycle

3.1 Application Methods of the PDCA Cycle in Knowledge Delivery, Practical Operations, and Problem Solving

Introduction of Project-Based Learning: Design course projects that require students to work in groups on tasks such as design projects, research projects, or community service projects. Students are responsible for project planning, goal setting, task allocation, and schedule development, followed by project implementation, teamwork, communication, and final evaluation. Such project-based learning helps students acquire project management skills, including planning, resource management, risk management, and assessment[7][8].

- Instructing Project Management Knowledge
- Provision of Project Management Tools and Resources
- Cultivation of Teamwork and Communication Skills
- Practice-Oriented Internships and Project Assignments

By implementing these methods, project management theory can be effectively integrated into undergraduate education, allowing students to not only acquire knowledge but also develop practical skills and competencies necessary for successful project management.

3.2 Insights and Development Trends of Engineering Thermodynamics Instruction Innovation through the PDCA Cycle

Innovating the instruction of engineering thermodynamics can better adapt to the needs and developments in the field of engineering, enhance students' comprehensive qualities and engineering practical abilities, and lay a solid foundation for their future engineering practice and research[9][10]. Furthermore, educational innovations also contribute to fostering students' innovative thinking and teamwork spirit, promoting the development and innovation in the field of engineering thermodynamics.

- Cultivating students' application abilities
- Introducing modern technological tools
- Interdisciplinary integration
- Practice-oriented approach
- Improving teaching effectiveness

4 Conclusion

Engineering thermodynamics is a fundamental course in higher education for engineering disciplines and plays a significant role in cultivating students' professional competence and comprehensive qualities. However, in teaching practice, there are several issues with the teaching of engineering thermodynamics, such as overly abstract content, a lack of connection to practical engineering applications, and limited teaching methods. The PDCA cycle, also known as the Plan-Do-Check-Act cycle, is a continuous improvement method widely applied in various organizations and industries.

This article explores how to introduce the PDCA management cycle method to improve the teaching of engineering thermodynamics. It involves four stages: clarifying teaching objectives and designing teaching plans, adopting various teaching methods and emphasizing practical activities, regularly evaluating teaching effectiveness, and making improvements based on the evaluation results.

In summary, by introducing the PDCA management cycle method and applying project management experiences, the teaching of engineering thermodynamics can be improved to enhance students' learning outcomes and comprehensive qualities. It allows for the integration of theory and practice, cultivates essential abilities, and instills a lifelong learning mindset, benefiting students' future professional development.

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