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Evaluation of "Foundation of Thermal Engineering" Based on Engineering Certification and OBE

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Abstract: In order to meet the requirements of current engineering certification and OBE concept of talent training, a trinity teaching link of basic thermal theory teaching, experiment and course design is constructed for the course of " Foundation of thermal engineering ", and the teaching content of "Engineering Thermodynamics" and "Heat Transfer" is integrated according to the graduation requirements of mechanical design majors for mastering basic theoretical knowledge and solving problems. It proposes the in-depth course objectives from understanding basic concepts and laws to building models to solve and analyze related phenomena, engineering problems and influence laws, determines the assessment requirements and achievement evaluation methods, and gives continuous improvement measures. An output-oriented thermal engineering basic course evaluation system is helpful to the cultivation of students' innovation and practical ability, and to realize the integration with international education.

Keywords: Engineering Certification; Thermal Engineering Fundamentals Course; Goal Achievement Evaluation

1. Introducing

In nature and engineering practice, heat transfer and thermal state change between materials all the time. Researchers constantly explore and explore the internal mechanism and law of heat transfer and heat from this dynamic process, forming the basic theory of thermal engineering. It also guides the analysis of heat transfer phenomenon and thermal process, the formulation of heat transfer process and the design of heat transfer equipment such as air conditioning and heat exchanger. For undergraduates majoring in mechanical design, who will be engaged in the design, manufacture and maintenance of mechanical equipment in the future, having the ability of heat transfer, thermal theoretical analysis and calculation plays a very important role in forming a complete professional theoretical knowledge system and broadening the scope of knowledge.

At present, China's university education is in line with international standards, engineering certification is implemented to ensure the quality of engineering education of international counterparts, and international mutual recognition of engineering education and engineer qualifications is realized [1-3]. In the process of implementation, the mechanical design professional qualification evaluation, and require the professional to establish an effective continuous improvement mechanism, to achieve the continuous improvement of education quality, so as to promote the construction of disciplines, to promote the curriculum system and knowledge structure to constantly improve, upgrade and improve the quality of talent training purposes. According to the concept of results-based Education (OBE) in Chinese universities, teaching activities should focus on "student output", emphasizing the determination and evaluation of students' expected learning Outcomes, and paying more attention to the cultivation of students' innovation and practice abilities [4-6]. Therefore, in the context of the new situation, how to integrate engineering certification needs with the OBE concept and guide the efficient development of teaching activities is the key to improving teaching quality and aligning with international standards [7,8]. This article focuses on the professional course of "Fundamentals of Thermal Engineering", which is closely related to the field of mechanical design and also has the characteristics of chemical machinery. It

studies a series of teaching elements, objectives, evaluation methods, techniques, and improvement measures that meet the requirements of engineering certification and OBE, in order to better serve the teaching of this course.

2. Theory and Practice Complement Each Other to Build a Solid Thermal Engineering Foundation

The course "Thermal Engineering Foundation" contains theoretical and experimental teaching links, supporting the course design, forming a trinity, theory and practice complement each other's teaching system. This course has a total of 32 class hours, including 28 theoretical hours and 4 experimental hours, and two experiments. It conforms to the requirements of general education accounting for a considerable share in the talent training program, reducing the class hours of professional courses, increasing elective courses and practical links, which is conducive to enhancing students' natural science theory and humanistic literacy, training students' hands-on ability and broadening their professional knowledge.

The teaching content of this course includes "engineering thermodynamics" and "heat transfer" two modules, each arranged 14 class hours. Among them, Engineering Thermodynamics mainly introduces the basic concepts and laws of thermodynamics, the thermophysical properties of commonly used working fluids, basic thermodynamic processes and typical thermodynamic cycle analysis methods. "Heat Transfer" primarily introduces the fundamental principles and solutions for thermal conduction, convective heat transfer, and radiative heat transfer, as well as techniques to enhance or reduce heat transfer. In contrast, the content of "thermodynamics" is more abstract and theoretical, while "heat transfer" focuses on the application of knowledge and can carry out heat transfer analysis and heat transfer calculation, and has stronger application [9,10]. Therefore, the tasks of course design mostly revolve around the design of "heat transfer" layout heat exchange equipment, emphasizing the combination of theory and application.

3. Curriculum Objectives are Multi-level and Closely Related to Graduation Requirements

Mechanical design students to lay a solid foundation in professional theory and practice is the premise of becoming a qualified and excellent engineer in the future. In the graduation requirements, focusing on the training of engineering knowledge and problem analysis ability, Thermal Engineering Foundation mainly supports corresponding indicators: (1) Master the basic knowledge of engineering, and be able to select or establish models and solve complex engineering problems in the engineering field; (2) Be able to use the basic principles of mathematics, natural science and engineering science to identify and judge the key factors and links of complex mechanical engineering problems. Combined with the course content, the teaching objectives of "Fundamentals of Thermal Engineering" are gradually deepened from accurate understanding of concepts and basic theorems to model building and application analysis: (1) Students are required to understand the basic concepts and laws of engineering thermodynamics and heat transfer, and master the theoretical knowledge of thermal engineering; (2) Ability to apply fundamental principles of thermal engineering comprehensively, select or develop thermodynamic and heat transfer models for complex engineering issues, and solve them effectively;(3) Be able to use differential, integral and other mathematical knowledge, as well as the basic principles of physics, engineering thermodynamics and heat transfer, determine analytical methods, identify and explain thermodynamic and heat transfer phenomena in the field of mechanical engineering; (4) Can use thermal knowledge to decompose the thermal process and heat transfer process in complex mechanical engineering problems, and qualitatively analyze the main influencing factors and influencing laws.

Taking heat transfer as an example, this part contains the meaning of three basic heat transfer modes and related thermodynamic properties, involving Fourier's law, Newton's cooling formula and blackbody radiation law, requiring the use of these knowledge to explain the thermal phenomenon in daily life, such as whether the house uses hollow brick or solid brick insulation effect is better? In

autumn and winter, which side of the leaves is more prone to frost; To expedite the cooling of the porridge, should I stir it with chopsticks or stir the cold water outside the bowl. In order to solve the engineering problem, it is necessary to decompose the complex heat transfer process into several links, and establish a series parallel model for heat transfer calculation, such as the heat dissipation of steam pipeline, the heat transfer area in the heat exchanger calculation. In addition, the influence factors of heat transfer process are analyzed comprehensively to determine the influence law of main control factors. If the heat transfer coefficient of the total heat transfer process has a number of influencing factors, respectively from improving the heat transfer coefficient inside and outside the tube, can be used to improve the flow rate, the use of large specific heat capacity of the fluid and other measures, can also change the direction of the flow of the two media, increase the fin to increase the total heat transfer coefficient, but the truly feasible solutions should be analyzed on a case by case basis.

4. Comprehensive Curriculum Evaluation Methods and Reasonable Requirements

4.1 The Comprehensive Assessment Method of "Homework + Experiment + Exam"

The course assessment is closely focused on the four course objectives from the three aspects of homework, experiment and final exam, and the target scores account for 20%, 10% and 70% respectively. The usual homework mainly evaluates students' understanding and mastery of the knowledge points of each chapter. There are four assignments in total, and each assignment is scored according to the percentage system. The average score of each assignment is taken as the final score of the usual homework, and the final score is multiplied by 20% to be included in the overall grade of the course. The weight coefficients for the four assignments are all 0.25, and the final grade multiplied by 10% will be included in the overall course evaluation score.

This course is equipped with two experiments: the determination of vapor saturation pressure and latent heat of vaporization, and the experiment of nozzle aerodynamic characteristics. Through comprehensive experimental operation and the written experimental report, the average of the two results is calculated according to the percentage system.

The final exam mainly examines the basic concepts of engineering thermodynamics and heat transfer, thermal process analysis, application of the first and second laws of thermodynamics, analysis of the influencing factors of three heat transfer modes and heat transfer calculation, etc., with a full score of 100.

4.2 Evaluation Requirements

4.2.1 Homework

The requirements of the four homework are: (1) understand the meaning of the first law of thermodynamics, and use the first law to calculate the heat and work exchanged between the working medium and the outside world; (2) Understand the different expressions of the second law of thermodynamics, analyze the thermodynamic process in mechanical equipment, and judge whether it can be realized; (3) Master the convection heat transfer analysis method and calculate the convection heat transfer; (4) Master the characteristics of radiation heat transfer, draw the network diagram, and calculate the radiation heat transfer.

4.2.2 Experimental requirement

Experiments on saturated vapor pressure and latent heat of vaporization require students to be able to correctly operate pressure gauges, atmospheric pressure gauges, pressure regulators and thermometers to observe boiling phenomena on metal surfaces. The P-T relationship curve of saturated steam can be drawn by measuring the relationship between temperature and pressure of saturated steam.

The experiment of nozzle aerodynamic characteristics tested the ability of students to observe the relationship between gas pressure and flow of the scaled and gradually shrunk nozzle. It required students to draw pressure curves of different sections and flow-back pressure curves, analyze the phenomenon of under-expansion and over-expansion of gas, and determine the influence of working conditions on the flow process of the nozzle.

4.2.3 Final examination

The final examination requirements include: (1) master the basic concepts of thermodynamics and heat transfer, the first and second laws of thermodynamics, and the basic meanings of the three heat transfer laws, with accurate discussion and concise language; (2) Master the basic mathematical model establishment and calculation method of thermal process and heat transfer process, be able to use the first law to calculate the heat and work exchanged between the working medium and the outside world, and be able to calculate the heat conduction, convection and radiation heat transfer, and the calculation results are correct; (3) Skilled use of the theoretical knowledge of thermal engineering to explain thermodynamic phenomena and heat transfer phenomena, analyze the characteristics of thermal process and heat transfer process, accurate discussion, concise language, and comprehensive analysis; (4) Apply the theoretical knowledge of thermal engineering to decompose the heat and heat transfer process, determine the influencing factors and laws, and propose measures to strengthen or weaken heat transfer, with comprehensive, accurate and clear analysis.

5. Evaluation and Analysis of Achievement Degree

The supporting relationships of different assessment methods, such as final exam, homework and experiment, on course objectives are shown in Table 1.

Table 1. The Supporting Relationship between Assessment Methods and Curriculum Objectives

Assessment method	Target score	Assessment rules	Course objective			
			1	2	3	4
homework	20	Each assignment is scored according to the percentage system, and the average score of each assignment is taken as the final score of the usual homework, and the final score is multiplied by 30% to be included in the total grade of the course. The weight coefficient is the same for each job.	5	5	5	5
experiment,	10	Each experiment is scored according to the percentage system, and the average of the two scores is multiplied by 30% to be included in the total course score. The weight coefficient of both experiments is 0.5.		5		5
final exam	70	The full score of the test paper is 100 points, and the score of the paper is multiplied by 70%.	11	28	10	21
Total: 100			16	38	15	31

The degree of achievement of course objectives in different assessment links is calculated according to the following formula:

$$n_i = T_{1i} \times 0.7 + T_{2i} \times 0.2 + T_{3i} \times 0.1 \quad i=1, 2, 3, 4 \quad (1)$$

$$m_i = T_{1i} \times 0.7 + T_{2i} \times 0.2 + T_{3i} \times 0.1 \quad i=1, 2, 3, 4 \quad (2)$$

Then the degree of achievement of goal i is

$$p_i = \frac{n_i}{m_i} \quad (3)$$

In the formula, ni represents the evaluation value of curriculum objective i; T1i~ T3i respectively represent the scores of exam papers, homework and target i in the experiment; mi represents the target value of course objective i; T1i~ T3i respectively represent the scores set for target i in exam papers, homework and experiments.

Taking the assessment results of 31 students in a class as an example, the degree of achievement of course objectives is shown in Table 2.

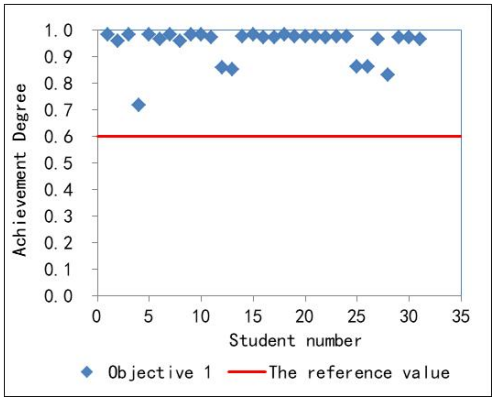
The degree of achievement of the course goal can be obtained by calculating T1i~ T3i of each student's exam, homework and experiment scores, as shown in Figure 1.

When the course goal value is ≥0.60, the course teaching goal is "achieved". As can be seen from Figure 1, the achievement degrees of goals 1 to 4 are 0.72 to 0.95, 0.63 to 0.97, 0.38 to 0.98, and 0.46 to 0.98, respectively. All 31 students in the class have achieved goals 1 and 2, which reflects that the students have a good understanding of the basic concepts and theorems of thermal engineering, and have mastered the model building and solving methods of heat conduction and convective heat transfer. For goals 3 and 4, one and four students "did not achieve", respectively. Mainly in the heat pump energy conversion and the total heat transfer process

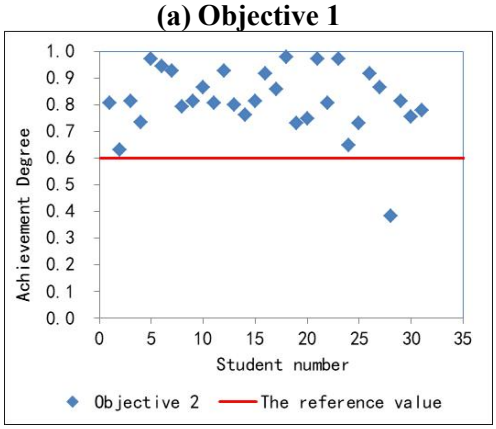
of the mapping analysis method is relatively poor, the heat and heat transfer process of the influence factors and law analysis is not complete.

Table 2. Calculation Table of Course Goal Achievement

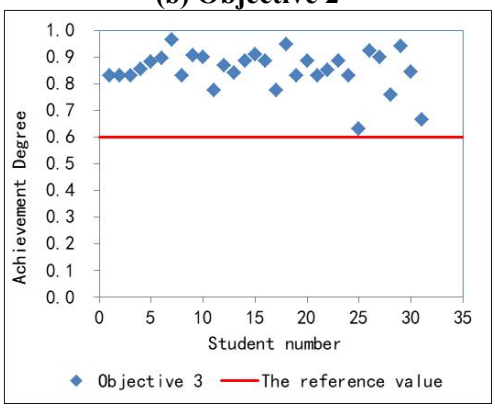
Course objective	Supporting link	Target value	Appraisal of value	Degree of achievement of curriculum objectives
Objective 1	final exam	13	12.1	0.922
	homework	5	4.5	
Objective 2	final exam	28	23.4	0.852
	homework	5	4.4	
	experiment	5	4.3	
Objective 3	final exam	8	6.4	0.815
	homework	5	4.5	
	experiment	5	4.2	
Objective 4	final exam	21	14.8	0.769
	homework	5	9	



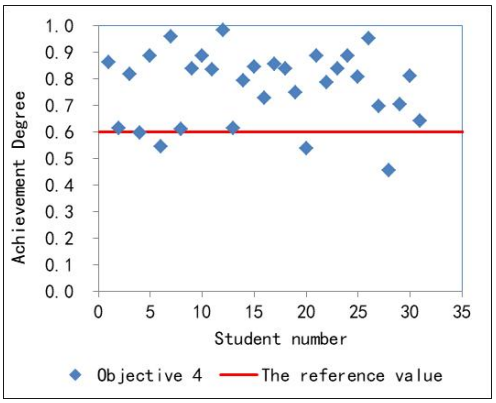
(a) Objective 1



(b) Objective 2



(c) Objective 3



(d) Objective 4

Figure 1. Distribution of Curriculum Goal Achievement

6. Continuous Improvement is Feasible and Feasible

6.1 Faults and Possible Causes

Based on the above achievement degree analysis, students still have shortcomings in mastering the following knowledge: decomposition of the total heat transfer process; The working process and characteristic analysis of thermal equipment. At the same time, there are shortcomings in the following ability training: the calculation ability of unsteady heat conduction is weak; The application of the characteristic number correlation of convective heat transfer is not skilled enough. The reasons for the above problems are as follows: (1) Students lack flexibility in the application of knowledge points and lack of extended understanding of knowledge points; (2) Students have poor learning effect of the advanced course, and the knowledge of the advanced course cannot

achieve the expected effect in the application of this course. For example, the basic knowledge of fluid mechanics that needs to be applied in the heat spreading is not firmly mastered, which makes it difficult to establish the theoretical model.

6.2 Continuous Improvement Initiatives

In response to the above problems, the following suggestions are put forward:

(1) In daily teaching, we continue to pay attention to the cultivation of students' engineering ability. Through classroom teaching and homework, we further improve students' thermal theory and calculation and analysis ability by combining the working principle of thermal equipment, the characteristics of thermal process and heat transfer process, and calculation methods of different heat transfer modes.

(2) In the assignment, emphasis is placed on the training of the analysis and calculation of the thermal process and the heat transfer process, and timely explanation and answer of the operation problems.

(3) Combined with the development needs of The Times, the traditional teaching model is reformed, and platforms such as "cloud class" and "rain class" are adopted to carry out "online and offline mixed" teaching, and multi-means and multi-resources assist teaching to improve students' learning interest.

7. Conclusion

Based on the requirements of engineering certification and the concept of OBE, the teaching links, course objectives and achievement evaluation methods of "thermal engineering Basics" are discussed. The following understandings are obtained:

(1) "Basic Thermal Engineering" course to support the mechanical design major graduation requirements of two indicators: "Master the basic theoretical knowledge of engineering" and "Identify and judge the key factors and links of complex engineering problems", the proposed course objectives from understanding basic concepts and laws to building models for solving, analyzing related phenomena, engineering problems, and influence laws, in-depth layer by layer, focusing on the integration of basic theoretical knowledge of thermal engineering and engineering practice;

(2) Test and daily work are used to assess the four teaching objectives respectively. Experiment is the main assessment objective 2 and 3, and the three assessment methods account for 20%, 60% and 10% of the total score respectively, comprehensively synthesizing students' daily homework completion, experimental skills, data sorting and analysis, basic theories and calculation methods. It highlights the requirement for students to use basic theories to explain thermodynamic and heat transfer phenomena and to analyze and calculate them.

(3) The achievement calculation method of weighted addition of each assessment score according to each course goal is proposed to obtain each student's achievement of each goal point, so as to accurately understand the weak links of students' learning, and put forward targeted continuous improvement measures in teaching methods, teaching content, after-school guidance, "help" and "heart-to-heart" for some students.

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