Case-Based Teaching and Learning Design of Building Energy Saving Technology and Engineering for Postgraduate: Thermal Performance Testing of HPWFW

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Abstract: Building Energy-saving Technology and Engineering (BEsT&E) is a professional foundation course for postgraduate majored in Civil and Hydraulic, especially for the field of Artificial Environment Engineering. This program introduces basic theories regarding low-carbon development in building sector and building-related energy-efficient technologies. And the practice performance is highlighted to improve the abilities of problem solving and critical thinking of students. In traditional teaching process, the teaching is dominated by theoretical introduction and ignores students' practice, which has many shortcomings. A case based teaching and learning (CBTL) method is proposed. It is advantageous in several aspects, including the integration of engineering and academic case studies, and a research team consisted of university teachers and industry experts in various fields. The CBTL design is introduced based on an academic case "Thermal performance testing of heat pipe embedded water flow window (HPWFW)". The proposed 4 steps method, including preparation, operation, analysis, report and presentation, is applicable to other academic or engineering based case studies. With this novel CBTL method, abilities including but not limited to practical operation and problem solving, as well as critical thinking can be enhanced for students.

1. Introduction

1.1 Building Energy Saving Technology and Engineering

Carbon peak and carbon neutrality have become the critical target of China because of the worldwide energy crisis and environmental pollution [1]. Energy saving and carbon emission reduction in building sector is therefore necessary and emergent [2]. In Xihua University, the program of Building Energy-saving Technology and Engineering (BEsT&E) has been opened for postgraduate majored in Civil and Hydraulic. Dedicating to deliver the basic concept and enhance the critical thinking regarding high-quality environment built with less energy consumption.

Normally, in most of the universities, theoretical teaching is adopted for the program of BesT&E. This enables students to have a deep understanding of the related theories and technical systems, while the training in problems solving is not enough. In the teaching plan for professional degree postgraduate, a teaching section of "professional practice" is required to learn the technologies state-of-the-art. However, there is a lack of the related case studies in the common teaching practice. Therefore, the integration of theory with case-studies of building energy conservation is crucial for developing the abilities of problem solving and critical thinking.

1.2 Project-Based Learning

Comparing to the traditional theoretical dominated teaching mode, Project-based learning (PBL) is widely raised for its remarkable teaching effect. It enables students to apply their knowledge in real

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or simulated engineering environments [3,4]. And emphasizes the hands-on ability and practical skills. PBL takes a student-centered, project-driven approach to transform students from passive receivers of knowledge to active learners [5]. By participating in PBL, apart from gain professional knowledge, the students also learn to communicate, collaborate and make decisions effectively in a complex and changing environment. Liu [6] et al. applied this method to the PIE curriculum, the students were found achieved better results with improved experimental operation ability.

1.3 Case Based Teaching and Learning for BEsT&E

Considering the necessity of improving the practical problem solving and critical thinking abilities of students, a Case-based Teaching and Learing (CBTL) method is proposed for BesT&E by making use of the advantages of PBL. The ability training of traditional theoretical teaching and CBTL is compared in Fig. 1. With this novel approach, operational skills and ability of problem solving can be improved. Key skills such as theoretical analysis, solution development, teamwork and communication can be trained. In this learning process, students can demonstrate their understanding of engineering projects and novel technologies, especially the complex relationship between planning and design, energy consumption and environmental sustainability. Moreover, critical thinking ability can be enhanced through performance optimization.

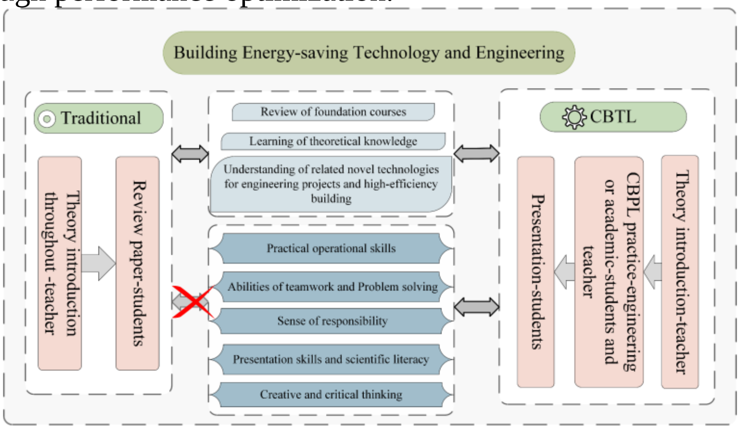

Fig 1. Ability training of traditional theoretical teaching and CBTL

2. Content and Design of BesT&E

BesT&E is generally scheduled at the second semester of the first year, with a sum of 40 teaching hours. It lasted for 10 weeks, with 4 teaching hours in each week. In order to improve the practice ability, CBTL is combined with the traditional theoretical-dominated teaching and learning. A comparison of the content is given in Table 1. Comparing to the traditional teaching process, more attention is paid to case-based practical teaching and learning. To improve the abilities of engineering operation and academic innovation of students, both academic-based and engineering-based cases will be used. Moreover, experts from industry are invited to carry out the teaching practice throughout the theory introduction and CBTL, as well as the final presentation processes.

Table 1. Comparison of the teaching plan of BesT&E with different methods

Traditional theoretical teaching		Week (4 hours/ week)	CBPL	
Lecturer	Method		Method/ Content	Lecturer
Teacher	Theoretical teaching	1-5	Theoretical teaching	Teacher & Experts (industry)
		6-7	CBTL: Academic-based case study	Teacher
		8-9	CBTL: Engineering-based case study	Experts (industry)
	Personal presentation	10	Personal presentation	Teacher & Expert

BesT&E focuses mainly on the building energy saving technology and the strategy to improve building energy efficiency. Considering the significant contribution to building energy saving with advanced façade, the novel Heat pipe embedded water flow window (HPWFW) has been proposed by the authors. And CBTL design will be introduced based on "Thermal performance testing of HPWFW" in this work. A whole set of experiment platform and equipment, as well as the research experience can fully support the case-based teaching and learning practice[7]. According to the data from the past two years, the number of students took this program is around 10. They will be equally divided into two groups in the CBTL. The teaching plan is given in Fig. 2. The basic theories regarding building energy saving and heat transfer in buildings will be introduced in the first place. Following this, CBTL including the preparation, operation and analysis process will be completed. Based on this, each group is required to finish a research report and give a presentation in the class.

2.1 Theory Introduction

The importance of building energy saving will be highlighted considering its contribution to energy and environment crisis. The heat and mass transfer process through building façade will also be introduced. Through Q&A, making students to explore the impact of building façade on energy consumption in depth. At the same time, students may have better understanding of the background of energy-efficient window development. Students are also encouraged to gain related knowledge through literature review.

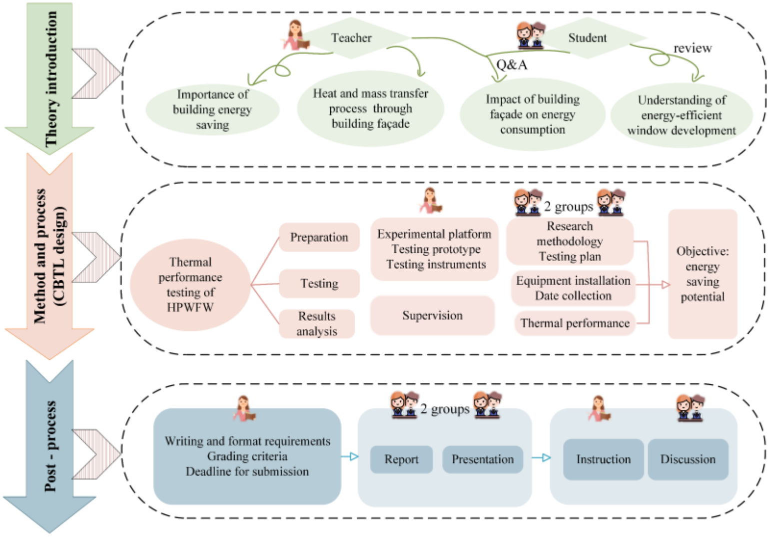

Fig 2. Teaching plan of CBTL on "Thermal performance testing of HPWFW"

2.2 Method and Process

CBTL regarding "thermal performance testing of HPWFW" is dedicated to explore the energy saving performance and potential in building energy conservation with optimized building façade. The experimental study includes three steps, namely preparation, testing and results analysis, which will be introduced in detail in section 3. In the preparation process, the experimental platform, testing prototype, and testing instruments will be introduced by teacher. At the same time, students are required to determine the research methodology and complete the testing plan. Following this, students will finish the experimental testing, including the equipment installation and data collection under the supervision of teachers. After that, the thermal performance of HPWFW in building application should be analyzed. This whole teaching and learning process will be completed within 8 class hours. During the testing process, supervision from teacher will be provided, and students are also encouraged to discuss with their classmates to solve the encountered problems and difficulties.

2.3 Post – process

After completing the testing, students are required to finish a research report. The research report should include at least the following 4 parts, namely the background, research methodology, results and discussion, as well as conclusions. The teacher will introduce the writing and format requirements, grading criteria, and deadline for submission in advance. Students are also required to give a 15min presentation based on the research report to illustrate the experimental design and process, testing results and analysis, and the lesson learned from this practical process. After that, they need to answer questions raised by the teachers and the classmates. And comments from teachers and students will also be given to each group.

3. CBTL Application-Thermal Performance Testing of HPWFW

"Thermal performance testing of HPWFW" is taken as the practical case study in this work. The CBTL is designed to be finished following the 4 steps given in Fig. 3. In the first place, the basic theory of thermal performance analysis, the research methodology used and the safety guidelines will be given. Following this, the schematic structure and working mechanism of HPWFW, the experimental platform and instruments used will be introduced to get ready for the experimental testing. During the testing process, students are instructed to complete the testing plan, finish the equipment installation and conduct the experimental testing in groups. And finally, the teacher will sort out the method of performance evaluation and data processing. Students are then required to finish the research reports and presentation in group.

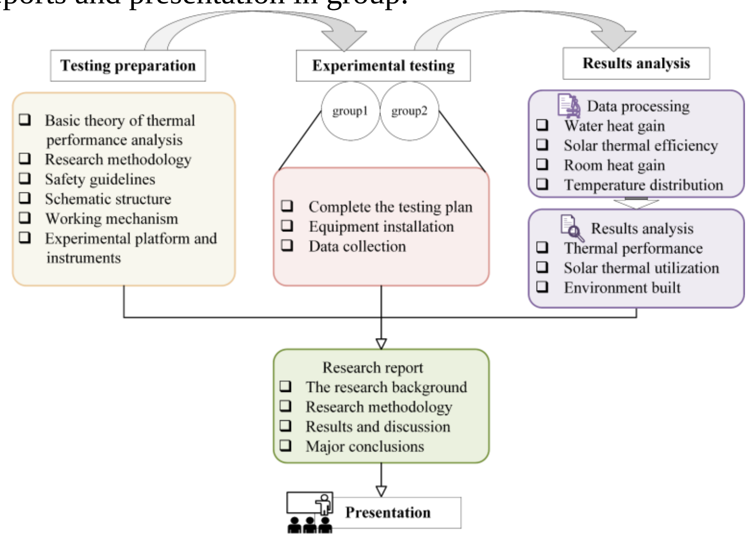

Fig 3. CBTL design of thermal performance testing of HPWFW

3.1 Testing preparation

In this part, the schematic structure and working principle of HPWFW as shown in Fig. 4 will be introduced. The HPWFW is mainly composed of three parts, including the double glazing with sealed water layer, the embedded heat pipe and the heat exchanger at the top of the window system[8]. The heat pipe can be divided into the evaporator and condenser sections. The evaporation section is submerged into the water cavity, the working liquid inside evaporates and flows upward to the condenser after absorbing thermal energy from the cavity water. In the condenser at the center of the heat exchanger, the high temperature vapor is cooled by the cold feed water and flows back to the evaporation section at liquid state. During this process, heat transfer inward to room space can be reduced. At the same time, solar thermal collection at the heat exchanger is realized. As a consequence, the energy consumptions for air-conditioning and hot water systems can be reduced.

On top of the clearly understanding of the structure and working mechanism of HPWFW, the experimental platform used for testing will be introduced. As shown in Fig. 5, it is composed of two independent chambers and a water circulation system. The HPWFW under investigation can be installed on the south façade of the chambers to maximize its thermal collection and energy saving. In the experimental testing, cold feed water at the required temperature is generated by an air source heat pump. The water flow rate is controlled by a rotameter installed at the inlet of the heat exchanger. Moreover, the water pipe is well insulated to avoid overheating by the environment.

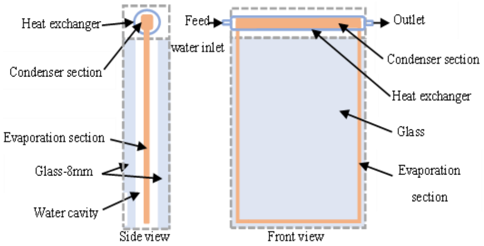

Fig 4. Schematic structure of HPWFW

Fig 5. Experimental platform

In order to evaluate the thermal performance of HPWFW, parameters including the solar radiation intensity, air velocity and temperature, lux level, water flow rate, water temperatures at the inlet and outlet of the heat exchanger, surface temperatures of heat pipe and window, as well as heat flux from the window need to be measured. A desktop computer connected to Agilent data logger is used for data collection and storage.

3.2 Experimental Testing

In the experimental testing, students are required to complete the testing plan, equipment installation, data collection and analysis in groups. To determine the testing plan, the influence of climatic and operational parameters should be taken into consideration. Therefore, the two groups are assigned to investigate the influence of feed water temperature and flow-rate to thermal performance, respectively. In this section, students should determine the testing plan based on systematic literature review, and start the testing after the correctness of the plan is confirmed by teacher. Based on this plan, they need to calibrate the instruments beforehand and conduct the testing under the supervision of teacher. The major steps are:

(1)Instrument calibration, to ensure the correctness of the testing results. Type-T thermocouple, pyranometer, heat flux sensor are connected to data logger for calibration. Those instruments with allowable measurement error are used in the following testing.

(2)Instrument installation according to the testing plan of each group.

(3)With the readiness of window and instrument installation. The air-source heat pump is turned on to generate cold water at the required temperature.

(4)The measured data is recorded at 1min interval upon the steady operation of the whole system. And in the following section, the hourly average value of the measured data will be used for results analysis.

3.3 Testing Results Analysis

In thermal performance analysis of HPWFW, water heat gain and solar thermal efficiency will be used to evaluate the solar thermal collection performance. They are calculated with the following equations.

$$Q=m\,c_w\,(T_{wout}-T_{win}) \tag{1}$$

In which, Q is water heat gain, W; T_{win} and T_{wout} are water temperatures at the inlet and outlet of the heat exchanger, ℃; m is the mass flow rate of cold feed water, kg/s; and c_w is the heat capacity of water, J/(kg·K).

$$\eta=Qc/(G\cdot A_{go}) \tag{2}$$

In which, η is solar thermal efficiency; A_{go} is the surface area of window, m^2; and G is the incident solar radiation on the window surface, W/m^2。

Apart from this, room heat gain from the window will also be calculated to evaluate its thermal performance. With the use of HPWFW, temperatures of window surface and room environment can also be lowered to enhance thermal comfort of occupants.

3.4 Report and Presentation

On basis of the previous three steps, students need to finish a research report in group. The research report should give a clear illustration of the following 4 sections:

(1)The research background, in which the significance and implication of the study should be clearly stated. And a systematic literature review is also necessary to show the connection of the current work with the previous studies. Besides, the objective of the study and the main contents of the research report should be included.

(2)Research methodology includes the introduction of the experimental platform and instruments, as well as the system operation mechanism. The testing plan illustrates the parameters setpoint and the data measurement scheme.

(3)Results and discussion should be finished based on systematic and logical analysis of the testing results. In this part, in depth analysis should be completed in combination with well-made figures and tables. Thermal performance can be evaluated based on the calculated water heat gain, solar thermal efficiency, as well as the temperature distribution on the window surface and in the room space.

(4)In the last part, major conclusions drawn from this study should be summarized.

After that, students are required to share this whole case study through presentation with a summary of the above four parts. And research questions need to be further investigated can also be proposed.

4. Assessment and Feedback

In this CBTL program, assessment and feedback from students, teacher and the society will be collected to guarantee the scientific and proper assessment of the effectiveness of this method. Self-assessment and peer assessment can fully reflect the learning situations and outcomes of students from their own perspective. Multi-dimensional self-assessment should be completed from the aspects of program learning, case practice and presentation et al. Peer assessment and feedback provides good opportunities of communication among students. Moreover, the outcome and feedback from students on this CBTL method will also be collected.

Scoring is the core aspect of teacher assessment. Aiming to evaluate the learning effectiveness comprehensively, the course grade is determined by the attendance (10%) and practice performance (90%) in CBTL (Fig. 6). For the practical part, the testing plan (20%) and testing process (20%), research report (40%) and presentation (20%) will be taken into consideration. As postgraduate, the ability of writing scientific paper is important, and thus the quality of research report is highlighted with a larger proportion. The completeness of its content, the depth of analysis, and the rationality of the conclusions will be evaluated. Special attention is also paid to the practice and operation abilities, with the testing plan and operation takes 20% equally. By comparing to the conventional grade distribution, the effectiveness of CBTL can be evaluated.

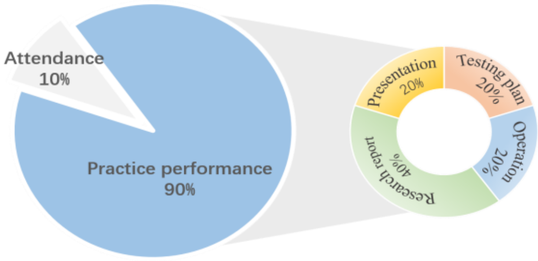

Fig 6. Grade distribution

Society assessment, as an effective approach to test the learning effectiveness of students and improve the teaching quality, cannot be ignored. Through in-depth communication within and between universities, professional comments from different fields can be obtained to continuously improve the teaching methods. Students are also encouraged to participate in diverse activities such as academic lectures and seminars, and engage in in-depth conversations with experts and scholars on campus [9]. Close cooperation with other universities and research institutions to carry out academic exchanges is also helpful for building an open, inclusive, and innovative academic environment.

5. Conclusions and Limitations

A CBTL method is proposed to enhance the practice ability training of students Iin the program of BEsT&E. And the CBTL design is introduced based on an academic case study-thermal performance testing of HPWFW. The major conclusions and limitations of this work are summarized below.

(1)The teaching and learning process are modified and both students and teachers can benefit a lot from CBTL. For students, abilities of problem solving and critical thinking, cooperation and communication, as well as the understanding of up-to-date technologies can be enhanced. For teachers, the continuous learning process is beneficial for teaching performance improvement.

(2)Practical and academic experiences of experts from industry and teachers are integrated throughout the teaching and learning process. This is helpful for promoting the integration of theory education and practice. Moreover, teachers in various research fields are included to guarantee the diversity of case studies to fit for the different research interests of students.

(3)In this work, CBTL process is introduced based on an academic case study. It provides a teaching and learning model, which is applicable to other academic-based and also engineering-based case studies. For each CBTL process, it should include 4 separate parts, namely the preparation, operation, analysis, report and presentation.

(4)Both academic-based and engineering-based case studies should be used in CBTL. The previous one can help students gain a deeper understanding of the latest academic perspectives, master the methods of scientific research. While the latter one is beneficial in helping students to have better understanding of the industry needs, and improve the ability of practical problem solving.

(5)The CBTL design is proposed based on an academic case study in this work. The effectiveness of the method application to both academic-based and engineering-based case studies in the program of BEsT&E should be further investigated in the future. This is expected to be finished in the up-coming 2-3 years.

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