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Online Course Design of "Fluid Mechanics" Based on "Higher Order Thinking"

Jian Wang[1, a], Fang He[1, b] and Jie Fan[1, c]

[1]School of Urban Construction, Wuhan University of Science and Technology, Wuhan 430065, China

[a]okwj@wust.edu.cn, [b]hefang@wust.edu.cn, [c]fanjie@wust.edu.cn

Abstract

Higher order thinking is a teaching concept that has been implemented since primary school in Europe, America and other countries. This paper expounds the connotation of higher-order thinking from the perspective of cognitive dimension, and analyzes the current teaching situation of "fluid" course. Combined with the educational environment of domestic colleges and universities, the teaching objectives of the course are constructed, and the localization design and implementation of teaching activities and evaluation are carried out. Through targeted design, it has improved the cultivation of students' independent thinking ability, and improved students' comprehensive ability and innovative ability to solve practical problems.

Keywords

Higher-Order Thinking, Classification of Course Objectives, Localized Design, Teaching Practice.

1. Introduction

On November 24, 2018, the 11th "China University Teaching Forum" was held in Guangzhou. Wu Yan, Director of the Department of Higher Education of the Ministry of Education, delivered a keynote speech on "Building China's Golden Curriculum". Wu Yan said that the curriculum is the "last mile" focusing on students' development. Although the curriculum is a micro problem in education, it solves the most fundamental problem in education. The curriculum problem is also a common weakness, bottleneck and key problem in Chinese universities. Wu Yan believes that "gender once" is the standard of Golden Curriculum, namely "high-order", "innovative" and "challenging". "High order" refers to the organic integration of knowledge, ability and quality to cultivate students' comprehensive ability to solve complex problems and advanced thinking.

Since 2020, under the influence of the COVID-19, online courses have become the main form of teaching in colleges and universities across the country and most countries in the world. Although China has achieved a major victory in the fight against the COVID-19, the pressure to prevent overseas imports and the rebound of the epidemic is still increasing, and the construction of online courses is imminent. Therefore, it is particularly critical to change the traditional teaching mode and explore ways to cultivate students' high-order thinking through the design and construction of online courses.

Taking Fluid Mechanics (Hydraulics) as an example, this paper introduces the online course design and localization practice based on the concept of high-order thinking.

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2. High Order Thinking (HOT) and Course Introduction

2.1. Bloom's taxonomy and higher order thinking.

Higher order thinking was first put forward by Bloom in 1956 [1]. After half a century of development, Anderson and others absorbed the achievements of modern cognitive psychology and revised it in 2001. The revised theory divides the educational goal into two levels: knowledge dimension and cognitive process dimension [2]. The knowledge dimension is used to help teachers distinguish what to teach, specifically referring to the classification of knowledge, namely, practical, conceptual, procedural and metacognitive. The dimension of cognitive process assists teachers to clarify the stage process of promoting students to master and apply knowledge, which is mainly divided into six categories: memory, understanding, application, analysis, evaluation and creation. The memory ability is related to the memory of the teaching content, that is, the retention of learning, while the other five kinds of abilities are related to the use of knowledge, that is, the transfer of knowledge. The last three types of analysis, evaluation and creativity constitute high-order thinking [3].

2.2. Conditions and Objectives of the Course Design of Fluid Mechanics.

Fluid Mechanics is an engineering course that is constantly developing and improving with the theory and application. It is not only a core basic course in civil engineering, but also widely used in water conservancy, machinery, chemical engineering, metallurgy and other majors. Therefore, the course has been highly valued by various colleges and universities, and has supported the reform of teaching methods and practice for undergraduates and postgraduates.

Compared with famous universities in Europe and America, the teaching of fluid mechanics in many domestic universities has the following phenomena [4]:

(1) From the perspective of teacher-student relationship, the famous European and American schools have formed a "critical" and "free" thinking atmosphere, created an equal relationship between teachers and students, and focused on inspiring students' thinking. Influenced by traditional culture, domestic students are often used to being guided and regard teachers as the authoritative source of knowledge and information. In the teaching process, teachers mainly focus on knowledge transmission.

(2) From the perspective of student source, the students in famous European and American schools have a solid foundation and strong learning autonomy. Individual students in China have poor autonomy, and their professional foundations are mixed. Students are used to "passive" listening, and the degree of active participation is not high, which is not conducive to the development of high-order thinking teaching.

(3) From the perspective of assessment methods, the assessment methods of European and American famous schools are diversified and full process oriented, and they are committed to the investigation of students' ability to think and inspire. The traditional assessment method of domestic colleges and universities pays too much attention to the assessment of factual and conceptual knowledge, which leads to the phenomenon of "not studying at ordinary times, rushing before the examination, and forgetting after the examination", and "getting high scores in homework and examination, which cannot solve practical problems".

Therefore, we can learn from the concept of "high-order thinking" of famous European and American schools to cultivate students' ability to integrate, connect and innovate knowledge, that is, the goal of curriculum design is to "improve students' innovation ability through heuristic teaching".

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3. Course Design of "Fluid Mechanics" Based on The Concept of "High-Order Thinking"

3.1. Localized improvement of teaching environment.

Due to the above-mentioned problems of passive listening in the existing curriculum teaching, we can not directly copy the teaching methods of famous European and American schools, and we need to carry out localization improvement of teaching. In this paper, harmonious teacher-student relationship, interactive teaching and diversified assessment are taken as the basis for the development of high-level thinking teaching design, as shown in Figure 1[4].

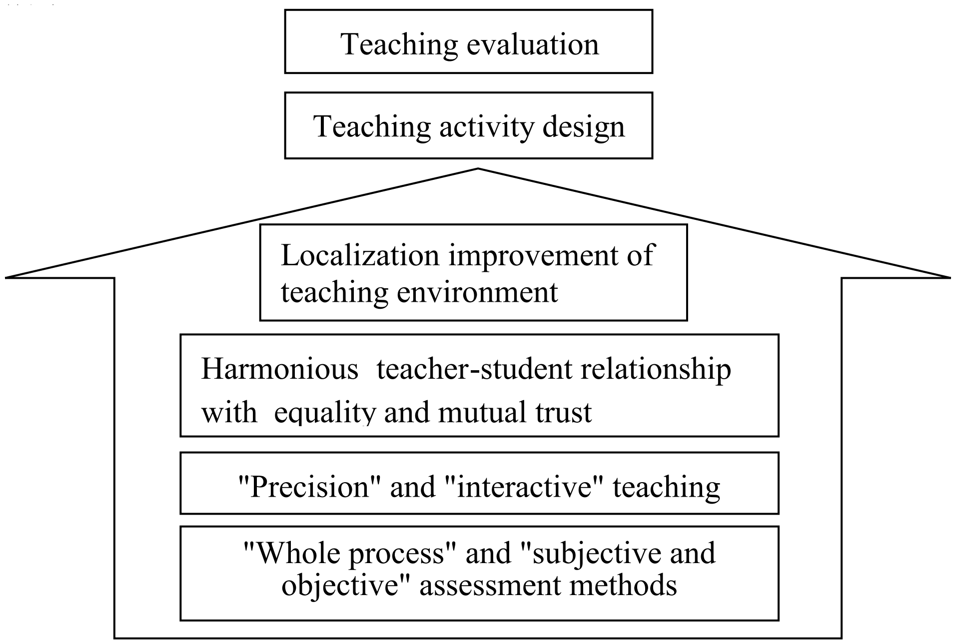

Figure 1. Block diagram of curriculum localization design

3.2. Two dimensional classification table distribution of teaching objectives.

For the teaching design of Fluid Mechanics, we can determine the teaching objectives, design the teaching process, arrange the teaching activities, and design the teaching evaluation according to the two-dimensional classification table composed of knowledge and cognitive process in the literature.

The teaching contents and corresponding classifications of Fluid Mechanics are as follows:

(1) The main physical properties of fluid and the forces acting on the fluid (knowledge points: continuum hypothesis, density, gravity, viscosity, compressibility, surface tension, vaporization pressure, volume force, surface force, etc.) are factual knowledge. Students need to remember and understand terms, understand and apply continuum hypothesis.

(2) Hydrostatics (knowledge points include Euler equilibrium differential equation, distribution law of hydrostatic pressure, total hydrostatic pressure acting on plane/surface), which is a conceptual knowledge, and needs students to understand and apply it to dam, gate design and other occasions.

(3) Two methods for describing fluid motion (Euler method and Lagrangian method) require students to master terms and differences. Continuity equation, energy equation and momentum equation belong to procedural knowledge. Students need to apply and solve the design and calculation problems of pressure pipelines and open channels.

(4) The similarity criterion is procedural knowledge, which requires students to be able to flexibly use to solve practical problems.

Combined with the students' self cognition goals, the above contents are formed into teaching goals as shown in Table 1.

Table 1. Teaching objectives of "Fluid Mechanics"

Knowledge dimension	Cognitive process dimension					
	1.Memory/recall	2.Comprehension	3.Application	4.Analysis	5.Evaluation	6.Creation
A. Factual knowledge	Main physical properties and forces of fluid	Continuum hypothesis				
B. Conceptual knowledge		Euler equilibrium equation	Hydrostatic pressure distribution law	Total hydrostatic pressure acting on flat/curved surface		
C. Procedural knowledge		Euler method, Lagrange method	Continuity equation, energy equation, momentum equation	Uniform flow in pressure pipeline and open channel	Similarity criterion	
D. Metacognitive knowledge		Understand the learning methods of professional basic courses		Analyze the strengths and weaknesses of self-learning		

3.3. Design of teaching activities and evaluation.

It can be seen from Table 4 that the curriculum objective has been upgraded from traditional memory teaching to a higher level of knowledge transfer teaching. The total hydrostatic pressure, pressurized pipeline, open channel uniform flow, similarity criteria, etc. acting on the flat/curved surface are at the level of "high-level thinking".

Research shows that students' memory retention rates vary greatly with different teaching methods. Students only have 5% memory retention rate when listening passively. Therefore, such methods should be used less in course teaching. Students' participation and learning initiative should be improved.

According to the set teaching objectives, the teaching activities and evaluation of the course can be arranged as follows:

(1) The main physical properties of fluids and the forces acting on them are factual knowledge.

The teaching activity design can be introduced from the knowledge points related to the definition of fluid, focusing on explaining the difference between fluid and solid, and conducting group discussion.

The teaching evaluation can adopt the repeated consolidation method of classroom test, homework after class and review test.

(2) Euler equilibrium differential equation is the basic principle of the course. Students should understand the profound principle behind the equation: the balance of fluid must be the balance of surface force and volume force. Teaching activities should be carefully designed to prevent students from being afraid of mathematical understanding and falling into formula memorization.

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The teaching activity can be divided into three steps. The first step is to introduce the fluid balance problem by means of cross metaphor. Step 2: Let the students read the literature after class and explain the Euler equilibrium differential equation in groups. Step 3, let students apply Euler equilibrium differential equation to solve the working principle problem of hydraulic machinery design such as hydraulic press and hydraulic crane. In terms of teaching evaluation, it is not limited to homework after class, but focuses on the performance of students in their explanations. The "Peer Evaluated Student Questionnaire" and "Teaching Content Record Card" can be used to test students' knowledge.

(3) Euler method, continuity equation, energy equation and momentum equation describing fluid motion belong to procedural knowledge of method class, and they are deeply related. The three equations of fluid mechanics can be derived from the differential equation of Euler motion to solve the problems related to velocity, pressure and force encountered in engineering.

The design of teaching activities can be divided into two steps. The first step is to describe the two methods of fluid motion for students to learn before class, and discuss the differences between the two methods in groups in class. Step 2, the application of the three equations is the key point of the course. Flipped classroom can be used to let students learn courseware and video before class, and teachers and students ask questions each other in class.

Teaching evaluation is not limited to homework after class, but should focus on students' performance in communication and discussion. "Group discussion evaluation scale" and "peer evaluation student questionnaire" can be used.

(4) Pressurized pipeline and open channel are procedural knowledge points with strong applicability, so we should pay attention to the combination of theory and application in teaching.

The design of teaching activities should focus on the energy equation, so that students can gradually transition from the group discussion of abstract concepts to the simulation, explanation and analysis of Fluent.

In teaching evaluation, students should pay attention to self explanation, and the "classroom demonstration evaluation scale" can be used.

(5) The similarity criterion is the summary and application of the course teaching content, and the design of teaching activities is particularly important, which is committed to cultivating students' innovation ability.

The design of teaching activities can be divided into four steps. The first step is to ask students to think about how to design hydraulic experiments? Starting from the design example of wind tunnel, let students observe, think and discuss the similar criteria that should be adopted in the design. The second step is to let students learn Renault's Criterion and Froude's Criterion by themselves, and discuss the core idea of the method in class. Step three, let students further think and try to meet the gravity similarity and inertia force similarity at the same time. Finally, from the perspective of complete similarity and partial similarity, cultivate their innovative thinking ability.

In teaching evaluation, students should pay attention to class discussion and knowledge sharing. The "Group Discussion Evaluation Scale", "Peer Evaluated Student Questionnaire", and "Class Presentation Evaluation Scale" can be used together.

In a word, fill the above contents into the corresponding positions of the classification table respectively to get the classification table of teaching activities and evaluation, as shown in Table 2.

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Table 2. Teaching activities and evaluation of "Fluid Mechanics"

Knowledge dimension	Cognitive process dimension					
	1.Memory/recall	2.Comprehension	3.Application	4.Analysis	5.Evaluation	6.Creation
A. Factual knowledge	Main physical properties and forces of fluid Group discussion: the difference between surface force and volume force. Quiz in class, homework after class, review test.	Continuous media is assumed to be explained in class. Quiz in class, homework after class, review test.				
B. Conceptual knowledge		Euler equilibrium equation Group discussion: principle of hydraulic press. Quiz in class, homework after class, review test.	Hydrostatic pressure distribution law Group discussion: principle of connector and water seal Quiz in class, homework after class, review test.	Total hydrostatic pressure acting on flat/curved surface ① Literature reading and group explanation: centroid and center of gravity. ② The drawing of pressure body. On-the-class test, homework after class, review test; Peer evaluation questionnaire and teaching content record card.		
C. Procedural knowledge		Euler method, Lagrange method Group discussion: the difference between Euler method and Lagrange method in describing fluid motion. Quiz in class, homework after class, review test.	Continuity equation, energy equation, momentum equation I) Group discussion: relationship between pressure and flow rate II) Actual operation: Fluent simulation On-the-class test, after-class homework, review test, self-explanation, classroom demonstration evaluation scale.	Uniform flow in pressure pipeline and open channel I) Literature reading and group discussion: the physical and geometric meaning of the energy equation; II) Flipped classroom: nature and application of energy equation. On-the-class test, homework after class, review test; Group discussion evaluation scale, peer evaluation questionnaire.		Similarity criterion I) Introduction: How to design hydraulic experiments II) Case observation and consideration: applicable conditions of similarity criteria. III) Self-study of calculation and group discussion: the core idea of Reynolds criterion and Froude criterion. IV) Flip class Don: Can we satisfy the similarity of gravity and inertia force at the same time. V) Method seeking: wind tunnel test design. On-the-class test, homework after class, review test; Group discussion evaluation scale, peer evaluation questionnaire, classroom presentation evaluation scale.
D. Metacognitive knowledge		Understand the learning methods of professional basic courses. Self-assessment form in the classroom.		Analyze the strengths and weaknesses of self-learning. Self-assessment form in the classroom.	Evaluate self-learning strategies. Self-assessment form in the classroom.	

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3.4. Implementation of teaching activities and evaluation.

In order to implement teaching activities and evaluation, it is necessary to prepare relevant standardized documents for students (name card, group discussion paper, assignment paper, literature reading report, peer evaluation form, classroom record form, classroom self-assessment form, listening experience and suggestion form, etc.) For teachers (such as teaching calendar, classroom tests, group discussion evaluation scale, classroom demonstration evaluation scale, usual performance template, final exam results, teaching summary, etc.), students and teachers share (written final exam/interview integrity countersign form, etc.). Then, we need to allocate time reasonably according to specific teaching hours. Finally, we need to summarize and analyze the advantages and disadvantages of the teaching process after class.

Taking the introduction of energy equation as an example, the implementation of one class hour (45 minutes) is as follows:

(1) Question: Which equation should be used to explain the "banana ball" principle, ship suction phenomenon and lift principle, so that students can think independently and write an equation (2 minutes/2 minutes in total);

(2) Ask individual students to tell their equations, and the teacher will bring out the topic: Application of energy equation (2 minutes/4 minutes in total);

(3) From the perspective of conservation of mechanical energy, guide students to think about the relationship between pressure and flow rate, and let students think about and discuss how to solve this problem in pairs (3 minutes/7 minutes in total);

(4) From qualitative to quantitative, the principle of Venturi flowmeter and Pitot tube is introduced (2 minutes/9 minutes in total);

(5) Ask the question: If the Venturi flowmeter or Pitot tube is placed at an angle, what is the difference in the calculation formula? Let students think independently (1 minute), then discuss in groups (2 minutes), and make group statements (3 minutes/15 minutes in total);

(6) The discussion results guide students to think about the following reasons: the potential energy difference is equal (2 minutes/17 minutes in total);

(7) Teach the calculation skills of piezometric tubes with different media (mercury, oil) (5 minutes/22 minutes in total);

(8) Use Fluent software to verify the energy equation and consider the cause of error. (5 minutes/27 minutes in total);

(9) Group discussion: phenomenon in demonstration (4 minutes), and group presentation (5 minutes/36 minutes in total);

(10) Summarize the students' discussion results, and give the change of the equation when there is energy input and output in the bifurcated pipeline (4 minutes/40 minutes in total);

(11) Students' mastery of the energy equation was tested in class: multiple choice questions (3 minutes/43 minutes in total);

(12) Summarize and arrange homework: practice the procedure of classroom demonstration and submit a report (1 minute/44 minutes in total);

(13) Preview The next section flipped the classroom and arranged self-study: use the energy equation to analyze the fluid phenomenon in life and write down the questions that need to be asked to the teacher (1 minute/45 minutes in total).

4. Conclusion

High level thinking mode is a teaching concept that has been implemented since primary school in Europe, America and other countries. Although there is a certain difference from the domestic higher engineering education environment, students' independent thinking ability

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can also be cultivated through the localized design and practice of this course, so as to improve their knowledge integration ability and innovative ability to solve practical problems.

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