Teaching Design for Cultivating Innovative Thinking in College C++Courses Based on STEM Education Concept

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Abstract. The purpose of STEM education philosophy is to cultivate innovative technology talents with comprehensive qualities, and it advocates focusing on cultivating students' scientific, engineering, technical, and mathematical literacy in teaching. There is relatively little integration of computer science courses into STEM research in China. Computer science and technology is one of the typical majors included in STEM projects, and object-oriented programming is the core course of this major. Its teaching objectives and content are very consistent with the STEM education philosophy. This article takes the teaching of the most important knowledge point of class and object as an example to design teaching based on the STEM concept. Carry out STEM oriented teaching in both classroom teaching and experimental teaching, integrating the advantages of STEM concepts. Through course practice and effectiveness evaluation analysis, teaching design guided by personalized STEM education philosophy can better cultivate and explore students' innovative thinking, and more effectively enhance their innovative thinking and ability.

Keywords: STEM, Innovative Thinking, Object-oriented Programming, Classes and Objects, Teaching design.

1 Introduction

The STEM education philosophy is to cultivate high-quality talents with practical, innovative, and problem-solving abilities based on interdisciplinary knowledge education in science, technology, engineering, and mathematics. STEM education advocates the use of interdisciplinary knowledge to solve practical problems, improve problem-solving abilities, and adapt to the needs of future technological development [1]. The focus of STEM education is to strengthen the education of students in four aspects: scientific literacy, technical literacy, engineering literacy, and mathematical literacy, in order to achieve the goal of cultivating comprehensive and innovative talents [2]. The core goal of STEM education is to cultivate a new generation with interdisciplinary literacy, international perspective, and innovative and creative abilities [3].

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The STEM education philosophy has been extensively studied in primary and secondary school curricula as well as other university courses. Fu Junfeng et al. [4] and Yang Diyong et al. [5] integrated STEM education concepts into high school chemistry teaching to cultivate students' innovative thinking abilities; In university teaching research, Cui Xiangping et al. [6] constructed a teaching model for university robotics courses by combining STEAM education with robotics education, aiming to promote students' hands-on and innovative abilities; Li Dingxiang et al. [7] integrated STEM education into graduate education teaching, including innovating training programs and reforming training objectives; Improve the curriculum system; Applying new information technology; Building an evaluation system; Cultivate STEM education faculty, etc. At present, there are relatively few programs that integrate STEM into computer science courses in universities, and computer science and technology is one of the typical majors included in STEM projects. According to the STEM concept, introducing STEM education concepts into computer related disciplines in universities can better meet the goals of talent cultivation and cultivate applied innovative talents suitable for national development in the future. Poonj et al. [8] designed computer vision, augmented reality, and tactile systems to detect and enhance student engagement in STEM education, and achieved good teaching outcomes.

This article takes the teaching of the "object-oriented programming course" in the field of computer science and technology as an example, combining STEM education concepts with course teaching, making effective attempts and bold reforms to cultivate and improve students' personalized thinking and innovative abilities, and cultivate software engineers who can meet future needs. Computer science and technology is a STEM major, and object-oriented programming is one of the most important core courses. Its teaching objectives and content are very consistent with the STEM education philosophy, making it suitable for curriculum construction and teaching reform as a STEM course.

2 Introduction to the "Object Oriented Programming" Course

2.1 Course Introduction

The object-oriented programming method absorbs useful concepts and effective methods from the field of software engineering, adopts a thinking approach that is very similar to human analysis and problem-solving, and effectively expresses, organizes, and manages different types of data in the real world. It integrates four characteristics: abstraction, encapsulation, inheritance, and polymorphism, helping people develop efficient programs. The high degree of data abstraction reflects the advantages of information concealment, reusability, easy modification, and expansion [9].

Analyze and research the teaching objectives of object-oriented programming and STEM education philosophy, and the degree of fit between the four aspects is reflected as follows:

1. Scientific: Reflected in the object-oriented programming method, it models and describes the basic principles and laws of the objective world.

2. Technical: Reflected in the use of computer programming languages in the course, teaching students the techniques of programming.
3. Engineering: Reflected in the need for students to master the entire process from problem analysis to program design to computer implementation.
4. Mathematics: Reflected in the need for students to describe and express abstract classes and concrete objects in the real world through object-oriented programming methods, achieve programmability, computability, and effective compilation, and run calculation results.

2.2 Teaching Design Reform Based on STEM Education Concept

In the curriculum and teaching reform, the integration of STEM education philosophy aims to cultivate students' personalized thinking and improve their independent design ability, thereby enhancing their innovation ability. The specific reform ideas and measures include:

1. In classroom teaching, guide the personalization of examples and draw analogies.

In the case explanation of classroom teaching, different class designs and specific object designs, including different attribute designs and operation designs, are carried out through a case study. Transfer to other classes in the objective world, and so on, and explain examples by analogy, allowing students to construct data models and relationship diagrams of classes and objects in their minds.

2. Personalize the design of task-oriented tasks in after-school assignments, and provide choices based on the different levels of students, with hierarchical requirements.

In the homework section, different levels of homework requirements are formulated, and a basic requirement is given. The specific content is thought of by the students themselves. Each student's answer is different, including the selection of abstract classes, the design of data attributes and operation functions, as well as the operation of specific objects, which are all decided by the students themselves. For example, at least 2 attributes and at least 2 operation functions. Students have a lot of room for creativity, and different ratings are given based on different design results.

3. In experimental teaching, it is important to focus on the personalization of experimental content and the diversity of experimental results.

In line with classroom teaching and homework requirements, the experimental content for each student is not a uniform requirement, but only a framework requirement, allowing students to be designers and executors themselves. Run through software, analyze and debug program code, and achieve expected results.

Through personalized task orientation and measures, it is beneficial to cultivate and improve the four qualities. The two stages of classroom teaching and homework focus on cultivating the scientific literacy in STEM education philosophy, which is to use scientific knowledge to understand the natural world and participate in the processes that affect it, as well as the mathematical literacy, which is the ability to discover, express, explain, and solve mathematical problems in various contexts. In the experimental teaching stage, efforts are made to cultivate students' engineering literacy, namely their understanding and technical literacy of the technical engineering design and development process, as well as their ability to use, manage, understand and evaluate technology.

3 Innovative STEM Teaching Design for Class and Object

3.1 Teaching Analysis

1. Student Basic Analysis

The teaching target is sophomore students majoring in Computer Science and Technology in college. These students have studied the basic programming course "Advanced Language Programming (C Language)" in their freshman year, and have acquired basic programming knowledge and certain programming abilities. Before the previous content, students had already learned the basic knowledge of object-oriented programming, including the basic concepts and four basic features of object-oriented programming, and understood its differences from structured programming, laying a foundation for this course.

2. Knowledge point analysis

Classes and objects are the most fundamental and important teaching content in object-oriented programming. They are the third part of the course and reflect the two basic characteristics of object-oriented programming: abstraction and encapsulation. This section is based on the concept of personalized STEM education. In teaching, attention should be paid to connecting with the real world, with special examples of objective and real objects around as examples. The abstraction of concepts is transformed into intuitiveness, which is convenient for students to understand. Corresponding demonstrations are conducted in the experiment. At the same time, students are required to carry out personalized programming based on their personal experience and personalized thinking, allowing them to fully exert personalized thinking, which is in line with the STEM education concept.

3.2 Teaching Design Based on STEM Education Concept

Based on the above teaching analysis, personalized STEM teaching design was carried out. In teaching, first introduce the definition of classes according to the content of the textbook. Taking student classes as an example, this example is easy for students to understand. First, introduce the definition method of student classes, including the data properties of general student classes and operations on data. Then, define specific students as class objects to implement related operations. In the analysis and programming process, it should be related to the abstract and encapsulation characteristics of object-oriented programming. Pay attention to emphasizing the correlation between abstract classes and concrete objects, and demonstrate the general laws of people's understanding of the objective world in the real world, that is, from abstraction (generalization) to concreteness (individualization), from generality to individualization. Then, by extension, other classes in the real world can also be defined in this way, such as teacher class, classroom class, cat class, dog class, clothing class, table class, etc., and one example should be given to extend students from the general student class, such as teacher class, to illustrate their data properties and general operations. After the teacher demonstrates the analysis and programming of two examples, let the students fully utilize their personalized thinking. Each student is required to think about a familiar object as a programming experiment for classes and objects, and conduct on-site programming. The requirement is that they cannot be completely consistent with their classmates, including class names, attribute names, operation names, and object names. Then submit it as a classroom assignment, and the teacher will understand the students' mastery of the content based on their programming skills, and provide targeted summaries.

In teaching, it is not only important to enable students to understand basic knowledge, but more importantly, to connect object-oriented programming with the real world, cultivate the core literacy of programming courses, utilize the innovation and flexibility of programming courses, cultivate personalized innovative thinking, and stimulate personalized thinking through students' own life experience and interests, thereby enhancing their innovation ability. Add some personalized questions to encourage students to actively participate, actively stimulate their learning initiative, and improve their enthusiasm; Capture inspiration from daily life and around students, connect abstract programming thinking with real life, make it concrete and implementable, and emphasize the importance of self-learning, improve students' ability to learn independently, and enhance the computational thinking ability required for programming. The specific core competency goals are shown in Table 1.

Table 1. "Class and Object" STEM Teaching Objectives and Core Literacy to be Cultivated

Target	Core Competencies
Science	Understand the relationship between object-oriented programming and the real world (macro cognition), computer programs can express objective world entities (computational literacy), programming and human cognitive processes are similar (cognitive literacy), and understand abstraction and concreteness (abstract thinking and visual thinking).
Technology	Express classes and objects through computer programs, and implement operations, input data, and output results to explore the basic principles and implementation process of object-oriented programming. (Computational Thinking)
Engineering	Using engineering thinking for program analysis and design, expressing different entities in the real world from abstract to concrete through computer programs, and testing them on the computer, correcting errors, and running them through (scientific modeling, trial and error correction, exploration and innovation)
Mathematics	Through limited computer program steps, achieve abstract definitions and entity operations of classes and objects, and establish class models (abstraction and logicality, specific applicability)

3.3 Classroom Teaching Practice

Firstly, through the teacher's demonstration and guidance, give three examples that are easy for students to understand, so that they can have a preliminary understanding of the concepts and definition methods of classes and objects. Then, encourage students to start from their own interests and familiar examples around them, and model and program abstract classes and concrete objects. Classroom examples are shown in the class diagram in Figure 1.

The three instances in the class diagram contain inherent principles and relationships in real life. For example, the personnel class is a higher-level abstraction, the student class and the teacher class are a generalization of the personnel class, Zhang San is a specific individual object of the student class, Liu Mei is a specific individual object of the teacher class, and there is also a generalization relationship between the student class and the teacher class.

Furthermore, it can be further explained that the essence of programming is the process of digital modeling of the real world. All entities can be digitally modeled using methods similar to object-oriented programming, thereby achieving computer simulation of the real world. Associate abstract classes with concrete reality, expand students' imagination space, enhance their learning interest, train and improve their computational thinking ability, and achieve the teaching goal of improving their personalized innovation ability. The core educational philosophy of STEM is how to effectively enhance students' scientific literacy, technical literacy, engineering literacy, and mathematical literacy in curriculum teaching, and cultivate innovative technology talents with comprehensive competitiveness.

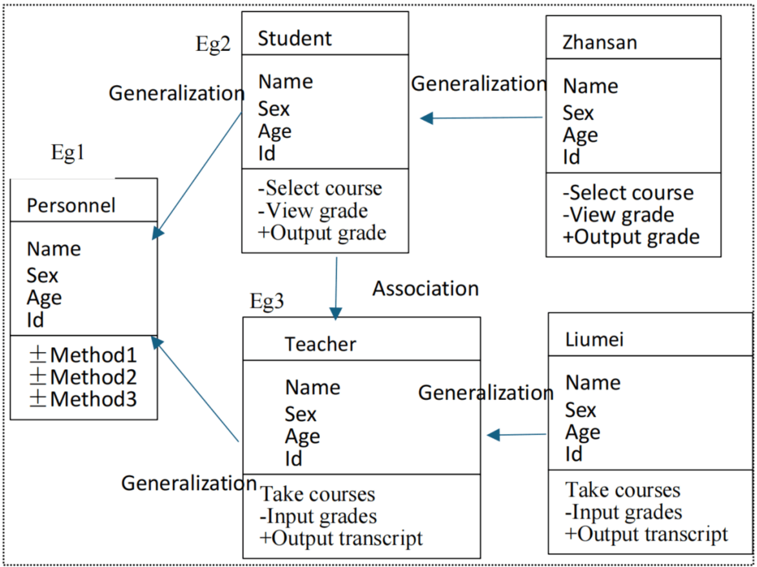

Fig. 1. Three Classroom Teaching Examples of Classes and Objects

3.4 Experimental Teaching Activities

Through classroom demonstrations, students have gained an understanding of the basic process of "classes and objects" from analyzing objective objects to programming implementation, including selecting a class from the real world for naming, determining the number and naming of its data attributes, and operating on the data for naming. This process involves defining abstract classes and encapsulating class attributes. After defining a class, consider defining a specific class object, assigning it actual data attribute values, and performing corresponding operations on the data as needed through operation functions. In the experimental teaching section, students design personalized programs based on their understanding of the knowledge points and the introduction of three examples. After understanding the definitions of classes and objects, they follow basic program syntax rules and conduct hands-on experiments,as shown in table 2.

Table 2. Experimental Activity Table and Cultivation and Improvement of Literacy

Activity Items	**Requirements**
Experimental Content	Customize any class with no less than 3 data attributes and no less than 2 operation functions. Referencing data through objects, calculating data through operation functions, and outputting: By integrating the four aspects of STEM education philosophy, enhance literacy and cultivate personalized innovative thinking ability
Experimental Requirements	Each student is required to select one abstract class based on their familiar real-world entities. Based on the characteristics of the abstract class, 2-3 feature data attributes are determined. Based on the characteristics of the feature data attributes, 2-3 function interfaces for manipulating data are defined. Each student's abstract class should be as different as possible and can be referenced to each other, reflecting their personal thinking process.
Experimental Preparation	After determining the abstract class, draw a class diagram to visually display the properties and operations of the class, and model the data; According to the format defined by classes and objects, first analyze the data properties of abstract classes and their operations on the data. Express classes and objects through computer programs, and implement operations, input data, and output results. Explore the basic principles and implementation process of object-oriented programming design, which is conducive to cultivating scientific and engineering literacy
Experimental Debugging	Require the establishment of an object-oriented model, programming, machine debugging, verification, and error correction: conducive to cultivating engineering and technical literacy
Experimental Result	Require multiple runs to produce multiple results, and validate and analyze the results. Computability, Practicability, From Theory to Practice: Beneficial for Cultivating Technical and Mathematical Literacy
Experimental Report	It is required to strictly provide the content, requirements, class diagram, and experimental results of the entire experiment according to the report template, which is conducive to cultivating scientific literacy, engineering literacy, and technical literacy.

3.5 Evaluation of Teaching Effectiveness

The following table presents the teaching reform and its effectiveness evaluation based on the personalized STEM concept, and compares it with the teaching design before the reform, as shown in table 3.

Table 3. Comparison of Two Different Teaching Models

Teaching Model	Classroom Teaching	Homework and Experimental Effects	Impact Assessment
The old teaching model	According to the examples in the textbook, copy and lecture without expanding	Fixed requirements, indicating what class is defined, and all student assignments are one answer	Easy to develop fixed thinking, mechanically apply, difficult to develop associations, and prone to copying
A New Teaching Model Based on STEM	Examples of textbooks+expanded examples	There are no fixed requirements, a minimum requirement is given, and flexible selection and expansion are possible. The answers of all students are different. In terms of data, after statistics, a total of 59 students in the class defined 59 classes that were not entirely identical. In terms of data attributes, operation functions, and object definitions, they all reflected students' personalized thinking. About 60% of students completed homework and experiments according to the minimum requirements, and about 40% of students were able to complete beyond the minimum requirements	Beneficial for cultivating personalized thinking, facilitating association and cultivating divergent thinking, and conducive to cultivating innovative spirit

4 Conclusion

This article conducts teaching reform on the object-oriented programming course of computer science and technology majors with STEM characteristics. Taking the teaching design of class and object as the core knowledge point as an example, teaching innovation and reform based on STEM education philosophy are carried out. In classroom teaching, expansion and association examples are used to help students understand the changes from abstract to concrete knowledge points of class and object, understand the main characteristics of object-oriented design methods, and adopt a new mode that is conducive to cultivating personalized innovative thinking in homework and experimental stages. Each student can design class and object according to their own interests and life experience, with different requirements and answers, and selectivity and flexibility. Teaching practice and test results show that, Teaching reform based on STEM education philosophy can effectively stimulate students' initiative, stimulate their personalized thinking, and promote their innovative thinking.

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