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Design and Construction of Chemistry Curriculum Based on Outcome-Based Education and XR Technology

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Abstract: *This paper studies the construction of chemistry courses based on the Outcome-Based Education concept (hereinafter referred to as the OBE concept) and XR technology. It aims to innovate the teaching mode of chemical experiments by integrating the OBE concept and XR technology. This study first defined the concepts of OBE concept, VR and XR technology, and virtual simulation technology, and analyzed the difficulties faced by traditional chemical experiment courses. Subsequently, the chemical experiment course objectives, teaching content, teaching methods and evaluation system based on the OBE concept were designed, and an XR chemical virtual simulation laboratory was constructed to achieve a flexible, safe and practical chemical experiment experience. It provides a new and feasible way to improve students' basic chemical knowledge and experimental ability, as well as the overall improvement of teaching quality.*

Keywords: *Outcome-Based Education; XR Technology; Chemistry Teaching*

1. Introduction

With the rapid development of information technology and virtual reality technology, the field of education is undergoing profound changes. Traditional chemical experiment courses have many limitations in teaching effectiveness, cultivating students' practical ability and safety. As a student-centered and goal-oriented educational concept, the OBE concept provides new ideas for curriculum reform. At the same time, the emergence of XR technology provides technical support for the innovation of chemical experiment teaching. By combining the OBE concept and XR technology, a new chemical experiment teaching model can be designed and constructed to solve the problems faced by traditional chemical experiment courses.

2. Definition of relevant concepts

2.1. Outcome-Based Education

Outcome-Based Education (OBE) is a student-centered and goal-oriented education concept. Its core idea is to ensure that students have the necessary knowledge, skills and literacy when they complete their studies by setting clear learning goals and evaluation standards. OBE focuses on "what students have learned" and "what they can do" after education, and emphasizes clear learning output standards. It meets social needs, is guided by student learning outcomes, and compares the core competency requirements of graduates. It reversely designs the curriculum system and teaching links, configures the teaching staff and resource conditions, and evaluates the training quality of students in various majors. [1] This concept is very consistent with the needs of undergraduate education and course teaching in engineering majors under the background of engineering education professional certification.

2.2. VR and XR Technology

Virtual reality (VR) technology is a technology that uses a computer-generated three-dimensional virtual environment to allow users to gain an immersive experience through multi-sensory interaction such as vision, hearing and touch. Today, virtual reality technology is in a stage of rapid development.

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Its technology has extended to new technical concepts such as augmented reality technology AR, mixed reality technology MR, and extended reality technology XR. Among them, extended reality (XR) technology is a general term that covers virtual reality (VR), augmented reality (AR) and mixed reality (MR). The diversity and flexibility of XR technology have made it show broad application prospects in various fields such as education, medical care, manufacturing, and retail. [2] In the field of education, XR technology can not only simulate complex experiments and operation processes to enhance students' learning interest and hands-on ability, but also break the time and space limitations of traditional teaching and provide students with a more personalized and interactive learning experience.

By combining XR technology and OBE concepts, educators can create a more flexible, safe and practical learning environment to comprehensively improve students' learning effects and practical abilities. This innovative teaching method not only promotes changes in educational methods, but also provides strong support for cultivating high-quality talents with practical ability and innovative spirit.

3. Dilemma faced by Chemical Experiment Courses

As an important part of chemical education, the core of chemical experiment course is to enable students to master experimental skills and scientific thinking through practical operations. However, in traditional chemical experiment teaching, there are a series of difficulties and challenges. These problems restrict the teaching effect and the comprehensive development of students.

3.1. Limited Experimental Equipment and Resources

Due to funding and resource constraints, many schools and educational institutions are unable to provide each student with sufficient experimental equipment and materials. This lack of equipment and resources has resulted in students having to work in groups when conducting experiments, and being unable to fully experience every step of the experimental process, which has affected the effectiveness and depth of their learning. In addition, chemical experiments usually require specialized laboratories and safety facilities, but due to limited site resources in schools, the number and frequency of use of laboratories are limited. [3] This makes it difficult to arrange experimental courses, and students are unable to conduct sufficient experimental practice at an appropriate time and frequency. The space limitations of laboratories also affect the flexibility and diversity of experimental courses, and are unable to meet the needs of different experiments.

3.2. Frequent Safety Issues

Chemical experiments involve many dangerous substances and operations, and safety issues are always an important consideration in experimental teaching. Students are prone to accidents due to improper operation during the experiment, causing injuries or accidents. In order to ensure safety, teachers often have to simplify the experimental steps or reduce the number of experimental projects. This has weakened the actual effect of experimental teaching and students' operational experience to a certain extent.

3.3. Difficulty in Evaluating Process and Results

Traditional experimental teaching evaluation mainly relies on teachers' observations and experimental reports. It focuses on the imparting of theoretical knowledge and neglects the cultivation of students' hands-on ability and innovative thinking. Traditional experiments are difficult to fully and objectively reflect students' actual operation ability and understanding level. Students often just follow the established steps in the experiment and lack the opportunity for independent design and exploration. Because the details of the experimental process are difficult to be fully recorded and evaluated, it is difficult for teachers to accurately judge students' performance and progress in the experiment. The limitations of this evaluation mechanism affect the quality of experimental teaching and students' learning motivation.

4. The Design of Chemical Experiment Course based on OBE Concept

The OBE concept is a mainstream educational concept and theoretical system widely used by colleges and universities in talent training such as "four new" construction, professional construction, teaching

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evaluation, and teaching reform. The chemical experiment course design based on the OBE concept not only focuses on students' mastery of chemical knowledge, but also emphasizes the cultivation of students' hands-on ability, scientific thinking, and innovation ability during the experiment. This study uses the People's Education Edition of the third grade of junior high school chemistry experiment course for teaching design.

4.1. Setting Course Objectives

As a basic natural science course, junior high school chemistry aims to cultivate students' scientific literacy, practical ability and positive learning attitude through diversified teaching activities. Chemistry, in particular, strengthens the experimental part. The course objectives are divided into "knowledge and skills", "process and methods", and "emotional attitudes and values". The descriptions are shown in Table 1.

Table 1: Objectives of Chemistry Experiment Course

Course Objectives	Contents
Knowledge and Skills	Students can understand and master the basic concepts and principles of the composition, structure, properties and laws of change of substances. Students can master the basic chemical experimental operation skills, and can personally verify chemical theories, deepen their understanding and memory of chemical knowledge. Students have the initial ability to design simple chemical experiments, can choose appropriate experimental methods and steps according to the purpose of the experiment, predict experimental phenomena, and can reasonably explain and discuss the experimental results, and cultivate the initial ability of scientific inquiry.
Process and Methods	Through experimental activities, students can understand the basic scientific inquiry process of chemical experiments and cultivate their cooperative learning and team communication abilities. By analyzing experimental data, students can be guided to learn to question and reflect, and cultivate their critical thinking abilities.
Emotional Attitudes and Values	Through the learning and experimental process of chemistry courses, students' interest and curiosity in chemistry are stimulated, and a scientific attitude of respecting science and seeking truth from facts is cultivated. Students are encouraged to be innovative in experiments, try different experimental methods and conditions, and cultivate innovative thinking and practical ability. Students are guided to realize the close connection between chemistry and society, cultivate the emotion of caring for nature and life, and establish a correct world view, outlook on life and values.

4.2. Design of Teaching Content

This study focuses on the core content of the chapter "Properties of Carbon and Its Oxides" in Unit 6 of the People's Education Press's Junior High School Chemistry Book for Grade 9. In view of the potential safety risks and high consumption of experimental materials in traditional experimental teaching, students often find it difficult to obtain sufficient hands-on opportunities, which limits the cultivation of their practical skills and deepening their understanding. At the same time, since this chapter is not only a key assessment point in the junior high school chemistry exam, but also the basic knowledge it covers is closely related to our daily life and has extremely high application value. In order to fill this teaching gap and stimulate students' interest in chemistry, this study innovatively introduced the "Colored Volcano Eruption" fun experiment. This experimental design cleverly combines theoretical knowledge

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with vivid life chemical phenomena, which can not only intuitively show the wonderful charm of chemical reactions, but also encourage students to connect the knowledge they have learned with real-life situations, thereby deepening their understanding and enhancing their learning motivation in an entertaining way.

4.3. Innovative Teaching Methods

The design of chemical experiment courses based on the OBE concept requires innovative teaching methods to ensure that teaching activities can support students in achieving their predetermined goals. Specifically, the following methods can be used:

4.3.1. Combination of Theory + Experiment

Theoretical teaching and experimental teaching are organically combined. The theoretical part adopts the method of "students explain and teachers evaluate". Through group discussions and student explanations, students' participation and understanding depth are improved. The experimental part adopts the method of "students do and teachers guide". Let students learn in practice and master experimental skills through independent operation and exploration.

4.3.2. Case + Inquiry Teaching

Select typical chemical experiment cases, combine them with actual application scenarios, and conduct case analysis and practical operations. Students are encouraged to independently design the experimental process in some experimental processes, through raising questions, formulating plans, implementing experiments, and analyzing results. This will cultivate students' comprehensive application ability, scientific inquiry spirit, and innovative thinking.

4.3.3. Project-based learning

Project-oriented, comprehensive experimental projects are designed. Students complete project tasks through teamwork, and develop teamwork and practical skills in the process.

4.4. Evaluation System Construction

The evaluation system based on the OBE concept should comprehensively and objectively reflect students’ learning outcomes and progress. The evaluation system can include the following aspects:

4.4.1. Process Evaluation

By observing students' operation performance, experimental records and experimental reports during the experiment, students' hands-on ability, experimental skills and scientific thinking can be evaluated. For example, the data tracking function of XR technology can be used to accurately record every step of students' operations in the virtual laboratory, such as reagent collection, instrument use, and experimental step execution. The accuracy, efficiency and standardization of these operation data can be analyzed through algorithms to provide instant feedback and scores. This can not only evaluate students' hands-on ability, but also help them correct mistakes in a timely manner and improve their experimental skills.

4.4.2. Final Evaluation

The students’ achievement of course objectives is evaluated through final lab exams and comprehensive lab project reports. XR technology is used to create simulations that are close to real working environments, allowing students to complete a series of chemistry-related tasks or challenges in a virtual environment. Through simulation exams, students’ adaptability and professionalism in complex situations are evaluated.

In summary, the chemical experiment course design based on the OBE concept can provide a strong guarantee for improving students' learning effects and comprehensive abilities by clarifying course objectives, innovating teaching methods, rationally designing teaching content, and building a comprehensive evaluation system. This student-centered and goal-oriented educational concept will promote the reform and innovation of chemical experiment teaching and cultivate high-quality talents with practical ability and innovative spirit.

5. Design of XR Chemistry Laboratory

According to the course objectives, the functional design of the XR Chemistry Laboratory is divided

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into four modules: "navigation, experimental guidance, experimental operation, and test questions".

5.1. Navigation Module

This module serves as the entrance and guide to the XR Chemistry Laboratory, providing a clear learning path and navigation function. Students can quickly locate the experimental content or knowledge points they want to learn through the navigation module. Through an intuitive interface and clear navigation path, it helps students quickly grasp the overall structure of the XR Chemistry Laboratory and the functions of each module, laying the foundation for subsequent in-depth learning.

5.2. Experimental Guidance Module

Before the formal experiment, the background knowledge, purpose, principle, required materials and safety precautions of the experiment are introduced in detail through pictures, texts, videos or virtual reality. Through the guided learning content, students can fully understand the basic knowledge of the experiment, stimulate their interest in learning, and make full theoretical knowledge preparation for the experimental operation.

5.3. Experimental Operation Module

Students conduct actual virtual experiments in this module. Using XR technology, students can simulate real experimental processes in a virtual environment, observe experimental phenomena, collect data, etc. Through practical operations, students can consolidate and deepen their understanding of theoretical knowledge, improve experimental skills and problem-solving abilities, and achieve the learning goals of knowledge and skills.

5.4. Test Question Module

After the experiment, a series of test questions related to the experimental content are used to test students' mastery of experimental knowledge and the depth of their understanding. The test questions not only test students' memory ability, but also focus on their ability to apply knowledge to solve practical problems, as well as their ability to improve learning effects through reflection and summary. It can also help students find problems in time and improve their learning methods, so as to achieve the purpose of optimizing the learning process.

6. Conclusion

Through in-depth research on OBE concepts and XR technology, this paper designed the chemical experiment course objectives, teaching content, teaching methods and evaluation system based on the OBE concept, and constructed an XR chemical virtual simulation laboratory. This design not only overcomes many limitations in traditional chemical experiment courses, but also provides students with a more flexible, safe and practical chemical experiment experience. It is expected that this teaching model can enhance students' interest in chemical learning and practical ability, and provide strong support for the cultivation of high-quality talents with innovative spirit and practical ability. In the future, we will continue to explore and optimize this teaching model to adapt to the ever-changing educational needs and technological development.

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