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Engineering Education for Sustainable Development: A Case Study from East China University of Science and Technology

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In 2015, the UN adopted the *Transforming Our World: The 2030 Agenda for Sustainable Development*, agreeing on the 2030 Sustainable Development Goals (SDGs), which set the direction for global sustainable development for the next 15 years. Education is both one of the important goals of sustainable development and an important means to achieve it. Education for sustainable development has been given high priority by the international community. In May 2021, the World Conference on Education for Sustainable Development under the theme "Learn for Our Planet and Act for Sustainability" was held online by UNESCO, the German Federal Ministry of Education and Research and the German National Commission for UNESCO, adopting the *Berlin Declaration on ESD 2030*.

Engineering plays a vital role in sustainable development. On World Engineering Day 2021, the Chinese Academy of Engineering, Tsinghua University, in cooperation with UNESCO and the International Centre for Engineering Education, published "*Engineering for Sustainable Development*" the UNESCO Global Engineering Report. In this report, a series of initiatives taken by engineering to achieve global sustainable development goals are discussed in detail. Therefore, it can be seen that sustainable development engineering education is one of the important directions of engineering education in the future.

China has made a serious commitment to sustainable development. For example, on September 22, 2020, at the 75th General debate of the UN General Assembly, President Xi Jinping solemnly announced to the world that China "strives to peak carbon dioxide emissions before 2030 and strives to achieve carbon neutrality before 2060". In the past two years, China has also proposed a series of policies to promote "peak carbon dioxide emissions and carbon neutrality" actions.

As a research university with a strong focus on chemical industry, East China University of Science and Technology (ECUST) has certain advantages in science and technology innovation and talent training related to carbon neutrality. It has started sustainable engineering education since many years ago. In the process of implementing the national sustainable development strategy and achieving the two goals of "carbon peaking and carbon neutrality", ECUST has actively established the School of Carbon Neutrality Future Technology, to accelerate the training of low-carbon industry professionals, continuously promote scientific and technological innovation in the field of energy and chemical industry, and provide talent guarantee, professional support and technical reserves for China's low-carbon transformation and development.

This paper mainly introduces the vision of engineering education for sustainable development of ECUST, as well as the specific actions taken, including integrating

green engineering concept into the curriculum, building green engineering courses, building green engineering case teaching library, innovating classroom teaching methods and practice teaching mode, which provides a case of engineering education for sustainable development for the engineering education community.

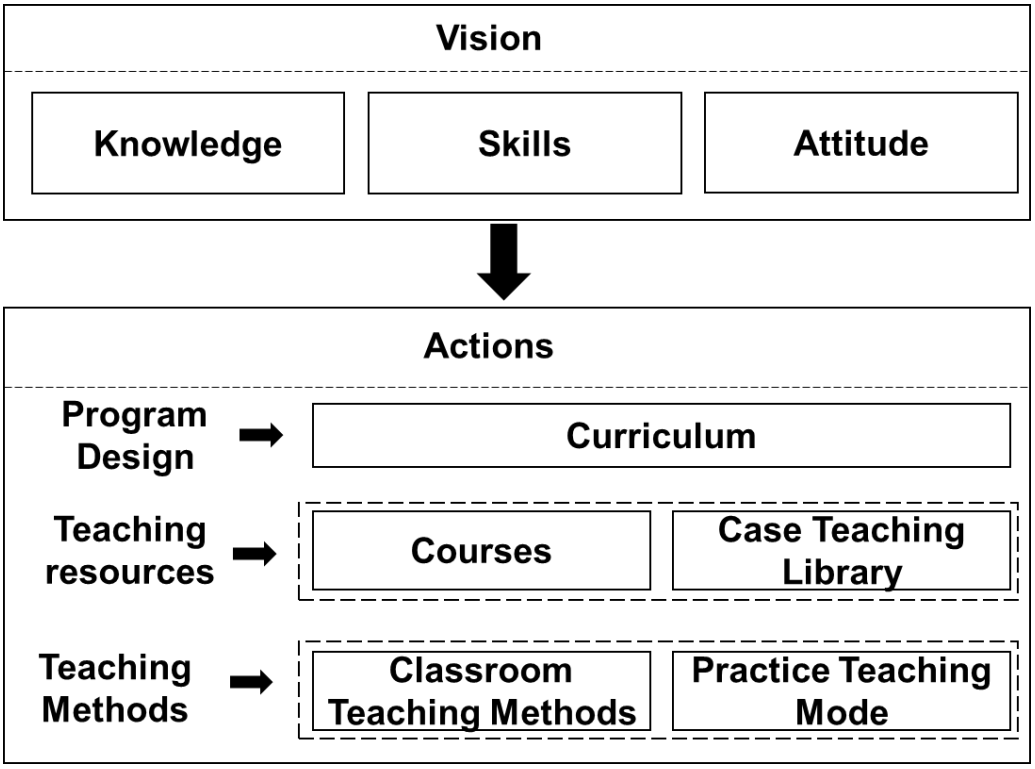

Figure 1 The vision and actions of engineering education for sustainable development of ECUST

I. Educational Vision

ECUST has proposed the core qualities of engineering education for sustainable development in three dimensions: knowledge, skills and attitude. A new concept of green engineering education has also been put forward. It integrates the 12 principles of green engineering into the talent training link of engineering education to cultivate systematic thinking of students of consciously following the principles of green engineering, cultivate the engineering culture of "environment, health and safety" of engineering students, and strengthen the sense of social responsibility for sustainable development of all students.

Table 1 Core Qualities of Sustainable Engineering Talents

Ability	Description
Knowledge	Enterprise EHS Risk Management Basics: EHS overview, risk and safety, environmental protection, product safety, occupational health, accident and emergency, process safety and public safety. Green China Series: Green chemistry, green chemical engineering, green materials, green pesticides, green food, green energy and environment, green law, green design, etc. Professional technical courses: new technologies, new processes, new

	products, new equipment, the social value and social evaluation of each production process and production technology, and the impact of the technology on the ecological environment, etc.
Skill	Systematic thinking, life cycle thinking, international perspective
Attitude	Engineering ethical quality, safety awareness, green awareness, social responsibility awareness

II. Specific Actions

1. Integrate Green Engineering Concept into the Curriculum

As a kind of "green development" concept gradually formed based on the idea of sustainable development and ecological civilization, the ultimate goal of the green engineering concept is to achieve common development of human social economy and ecological environmental protection[1]. ECUST launched the project of cultivating engineering ethics in 2016, focusing on strengthening the green development concept of graduate students[2]. In addition, School of Chemical Engineering of ECUST launched a new round of textbook update at the end of 2016. When revising the content, it focused on improving the content of courses involving high energy consumption and pollution, adding professional courses that popularize the content of clean production, as well as offering courses on the history of science and technology and the history of engineers. At present, 30 textbooks reflecting the concept of green engineering education have been revised and newly edited, covering various disciplines such as engineering, science, management and law.

2. Construction of Green Engineering Courses

ECUST has offered a series of courses related to green engineering. First, "*Fundamentals of Enterprise EHS Risk Management*" has been offered to all engineering undergraduates as a compulsory course. This course built by over forty corporate alumni and university faculty was listed as a national-level MOOC in 2017. Taken by about 2,300 people each year, it has been listed as a required or elective course by 106 universities nationwide. Second, eight "Green Engineering" elective courses have been offered in the "engineering technology courses" module of general education, accounting for 9% of the "engineering technology courses". Third, "Green China Course" has been offered, specifically including green chemistry, green chemical engineering, green materials, green pesticides, green food, green energy and environment.

Table 2 List of Green Engineering Module Courses

Course module	Course Name	Credit	Credit Hours
Green Engineering	Nuclear radiation safety and protection	2	32
	Environment and Health	2	32
	Introduction to Marine Science	2	32

	Green Chemical Processes	1	16
	Drinking Water Safety and Health	1	16
	Green Engineering and Emerging Technologies	2	32
	Green Pesticide	1	16
	Introduction to Sustainable Development	2	32

3. Construction of Green Engineering Case Teaching Library

(1) Course Case Base

The construction of the case base of green engineering education courses in ECUST is carried out mainly based on a certain course in the undergraduate teaching and training program or a new green engineering education special course. Among them, the content of the curriculum should reflect the content of engineering courses, laws and regulations, social responsibility and humanistic quality of green engineering education. Through case studies, students can form a deeper understanding of the concept of sustainable development and realize the importance of green engineering to human and social development.

Petrochemicals are China's pillar industry. To implement the concept of green development and sustainable development in the new era, Petroleum Refining Technology course of Oil& Gas Storage and Transportation Engineering in ECUST as a high-quality course in Shanghai, through case teaching and the "12 principles of green engineering", and with the "efficient utilization and cleanup of oil and gas resources" as the main line has designed seven cases that can reflect the principles of green engineering, and adopted the case teaching method to integrate the development concept of the new era into the course teaching to cultivate engineering and technical talents with sustainable development thinking[3]. Starting from three aspects of pollutants produced in the refining process, this course case focuses on the importance of cleaning the production process and reducing pollutant emissions while introducing the production of clean products from the perspective of process, to strengthen students' awareness of environmental protection, the concept of green development and social responsibility.

In addition, Chemical Process Analysis and Development is a core course with comprehensive and applied characteristics for chemical engineering majors of ECUST. With case studies as the link and the methodology of scientific research as the main line, this course cultivates students' ability to analyze and solve practical problems by synthesizing what they have learned[4]. Students can learn about the frontier areas of the chemical industry and recognize the potential of the green chemical industry in current resource and environmental issues and future high-tech development[5].

(2) Practice Case Base

By sorting out the existing practice contents or adding new ones, the construction of green engineering education practice case base focuses on creating practice case

bases with characteristics of ECUST and reflecting the concept of green engineering education. Each case base should contain more than 5 cases. The construction content should reflect the experimental and practical training content of green engineering education and meet the green engineering education system, unit (component) or process design, etc. Each school of ECUST has added new practice contents based on sorting out existing practice cases to create a number of practice cases with school-based characteristics and reflecting the concept of green engineering education[6]. For example, focusing on green engineering education and sustainable development, the School of Biotechnology and the School of Resources and Environmental Engineer integrate relevant concepts into students' teaching experiment case bases and graduation internship sessions, which greatly strength students' ability to solve ecological and environmental problems in practice.

4. Innovate Classroom Teaching Methods

(1) Conducting Seminars Through the Flipped Classroom Teaching Model

In order to better implement the concept of green engineering education in the teaching process, help students learn more frontier knowledge and stimulate their desire to explore the high-end frontier technology of green chemical engineer, the teaching team of the Chemical Process Analysis and Development Course of the School of Chemical Engineering, ECUST has been actively exploring the teaching mode. On the basis of professional content teaching, several seminars with flipped classroom as the teaching mode are added. The teaching team has assigned two topics to the students: "Current Status and Application Prospect of Hydrogen Energy" and "Progress of Recycling Technology of Waste Plastics", focusing on "hydrogen energy" and "plastics" in the two frontier fields of chemical industry, namely new energy and safety and environmental protection. Students, as the main body of learning, form cooperative groups of 5 to 6. Each group reviews and organizes literature and data according to the seminar topics assigned in advance. In the seminar class, teachers will switch roles with the students, allowing them to be the true main body of the class. After each group reports in turn, teachers make short comments and suggestions for improvement based on the students' performance. The seminar session not only allows students to participate in the classroom teaching, but also improves their teamwork skills; It not only helps students learn the production technology of hydrogen energy and the recycling technology of waste plastics, but also cultivates students' awareness of energy saving and green chemical industry[7].

(2) Immersion Program is Used to Develop Students' Systematic Thinking

Green chemistry, life cycle and sustainable development are the focus in the production of chemical industry and material industry at present[8]. The thinking and application of green chemistry, life cycle and sustainable development in molecular material science will help to reduce the harmful impact of the use and production of chemical products or materials on the environment. System thinking is playing an increasingly important role in polymer material science, which also reflects the demand of modern material science for green chemistry, life cycle and sustainable development. The relationship between materials and human survival and development is very close. Therefore, in the course of of materials specialty, it is of

positive significance for students to master a systems thinking approach and to consider various factors such as moral, ethical and environmental factors and the relationship between materials and society in order to achieve sustainable development. The production, design, and development of materials will affect human development and needs from all angles, and a systems thinking approach will help students gain insight into how the materials discipline interacts with other disciplines and society[9]. In the past, the impact of the use of chemicals, resource consumption and waste generation in the process of material preparation on human beings and ecosystems has often been neglected in teaching. Therefore, the earth science and life science education for materials students has also received much attention in recent years[10].

The School of Materials Science and Engineering of ECUST conducts scene setting during the teaching process to simulate an immersive research and development project which requires students to carry out project research and development through system thinking mode, focusing on solving practical problems in the real world. It also combines carrying out project research and development with the course teaching content[11]. This method helps students improve their ability to make study serve the practical purpose while mastering the knowledge points, and can analyze the whole life cycle and all links of products from the perspective of system thinking, and build a full-cycle green engineering design framework that is not limited to the preparation and development of product materials. On this basis, a full life-cycle immersion teaching session is formed from the preparation design of polymer raw materials, to the injection molding of polymer products, to the promotion design of products, and finally to the recycling and reuse of products[12].

The School of Biotechnology has conducted several experiments in biology teaching, such as the Biological Laboratory Safety Experiment, in which students will simulate different levels of biosafety protection and practice biological waste sorting operations to build awareness of biosafety and environmental protection; The protoplast fusion for polyploid preparation experiments uses plant cells, which avoids the use of blood products such as serum, compared with animal cells used in the previous teaching experiment; Fruits and vegetables pesticide detection experiments has abandoned chemical detection methods, using efficient and environmentally friendly enzyme products detection method. Compared with the traditional tea polyphenol extraction technology, the microwave method of tea polyphenol extraction avoids the use of organic solvents, which is more efficient and faster, saving time and energy; Microchip electrophoresis system is used to detect harmful microorganisms in food. High-throughput, digital, and visualized PCR electrophoresis system repalce traditional agarose gel electrophoresis, avoiding the use of toxic and harmful dyes such as ethidium bromide. These experiments have greatly improved students' ability to solve ecological environmental problems in practice[13].

Now, the immersive project teaching method has been implemented in the teaching of material mechanics for two-term students majoring in polymer. It plays a positive role in improving students' ability to deeply learn and flexibly use the knowledge they have learned. It has achieved good teaching results and promoted the

green chemistry teaching of polymer specialty. At the same time, this method can also be applied to the teaching of polymer specialty courses such as polymer chemistry, polymer preparation engineering, composite material structure design, etc., to allow students to evaluate the toxicity, life cycle, waste generation, product molding of a single material, or to evaluate the entire life cycle of a product from material preparation to final product sales and recovery. In addition, the immersive project teaching method can also be extended to the teaching of the whole material specialty, and even to the teaching of chemistry, chemical engineering and machinery specialty, so as to promote students to develop the habit of systematic thinking and comprehensively consider the impact of each link on the whole product cycle[14].

5. Innovate Green Engineering Education Practice Teaching Mode

In the process of practice carried out by most engineering universities in China, the traditional teaching method of "teacher-centered, textbook-centered and classroom-centered" and the limitation of laboratory equipment, space and quantity can hinder students from truly engaging in the ideal practice environment, which is not conducive for students to obtain a highly realistic experimental experience. Virtual Reality (VR) is a kind of simulation environment based on computer technology and relevant science and technology. It is highly similar to the real environment in terms of vision, hearing and touch. Users interact with objects in the digital environment with the necessary equipment to produce immersive feelings and experience[15]. Under the demand and guidance of actively integrating the concept of green development and sustainable development into the curriculum and practice of engineering students, VR technology can effectively solve many limitations in traditional experiments. Students can operate and experience various engineering practice cases "personally" in digital virtual space. It enhances the interest of learning and produces a more lasting memory effect, which is a appropriate practical teaching method of green engineering education[16].

The practical teaching of engineering education mainly consists of three parts: experimental teaching, practical training and social practice. In the new practical teaching mode of engineering education, the concept of green development is integrated into these three parts through VR technology, which realizes greening of experimental instruments, contents, processes and operations in experimental sessions with the help of VR technology; In the internship session, VR technology is used to build a virtual factory and carry out VR practice training of safety and environmental protection; In the social practice session, combining VR technology with professional knowledge and practicing the concept of green development in practical activities not only enriches students' practical experience, improves students' relevant skills, but also strengthens students' consciousness and initiative in practicing the concept of environmental protection and sustainable development, which contributes to the development of future engineers with green engineering literacy.

III. Conclusion

ECUST, committed to cultivating future engineers with sustainable development capability and homeland emotions, has implicitly engraved the “green” concept in the hearts of students in engineering education. By integrating the awareness and

concepts of green engineering and sustainable development engineering in the curriculum, students are trained to have the ability to consider the connection of their major with economy, environment and society while receiving professional knowledge, which can lay a solid foundation for their future participation in the practice and construction of sustainable development engineering. In the teaching method, ECUST adopts the flipped classroom mode and immersion teaching method different from the traditional classroom teaching mode, so that students can become the main body of learning, who can be more actively involved in the learning and thinking process. It further gives play to the subjective initiative of learners and creators, and deepens the understanding of green engineering practice and sustainable development practice. In addition, real practical teaching scenes are conducive to strengthening students' actual engineering experience, helping students better experience the specific process of engineering practice, and enhancing the ability of applying theory to practice.

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