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Three Integrations: Exploration and Practice on Chemical Engineering Ethics Education in Chinese Universities

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Abstract: The petroleum and chemical industry is one of the basic industries of China's national economy and an important part of the real economy. Nowadays, it is facing safety, environment, and health issues. The enhancement of chemical engineering ethics is one of keys to solving these problems. It strongly appeals to the education of chemical engineering ethics and thus cultivation of engineering talents with strong engineering ethics concepts and green chemical technology. This paper briefly analyzes the new requirements for engineering ethics education in the training of chemical engineers, discusses the current problems in engineering ethics education during chemical engineering internships, and proposes that effective ethical education in chemical engineering should adhere to the principle of "Three integrations". First, the integration of education and cultivation can be accomplished by combining ethics education with the cultivation of students, with the fundamental objective of engineering ethics education being the cultivation of students. Furthermore, the synthesis of principles and skills can be achieved through the amalgamation of ethics and professional education, with green chemical technology serving as a significant avenue for addressing engineering ethical concerns. Third, the integration of theory and practice can be achieved by the combination of engineering ethics theory and practical education, instilling in students a heightened awareness of adhering to engineering ethics.

Keywords: Chemical Engineering, Engineering Ethics, Green Chemical Technology, Integration of Theory and Practice, Green Engineering Education

1. Introduction

The petroleum and chemical industry is China's national economy's fundamental and pillar industry. Since 2011, China’s chemical industry (around $1.5 trillion of sales in 2017) has been the world’s largest by revenue, accounting for half of the world’s chemical market growth over the past 20 years. [1]. Currently, the chemical industry output value accounts for more than 40% of the global aggregate [2]. China's petroleum and chemical industries have developed over 40 sub-industries, producing over 60,000 products, with over 27,000 large-scale enterprises and 7 million employers [3]. In 2022, the entire petrochemical industry achieved an operating revenue of RMB 16.56 trillion, accounting for 12% of the total revenue of China's large-scale industries. The import and export value amount to 1.05 trillion US dollars, accounting for 16.6% of the country's total import and export value, with a year-on-year growth rate of 21.7%. The entire profit amounted to RMB 1.13 trillion, representing for 13.4% of the overall profit of China's large-scale industries, which has made significant contributions to stable the economic growth, foreign trade and overall economic development [4].

However, the chemical industry in China continues to confront significant challenges, including inherent inconsistencies in its structure, resource and energy constraints, environmental concerns, and a pressing demand for essential technologies. In particular, it has been widely criticized for environmental, health, and safety issues. Firstly, it has caused serious ecological environmental pollution. Statistically, the amount of wastewater, waste gas and solid waste gas discharged by chemical industry in China ranks first, fourth, and fifth in the national industry respectively [5]. Secondly, it has resulted in severe food safety issues. For example, the contamination of rice with excessive levels of plumbum and cadmium due to polluted irrigation water and the harmful effects of additive abuse on the human body. Thirdly, there are significant safety issues in chemical industry. According to the Ministry of Emergency Management, there were over 150 deaths in the 122 chemical accidents in China in 2021 [2].

The environmental, health and safety problems in chemical industry can be caused by technical and non-technical factors, among which engineering ethics is an essential factor. Human factors are important contributors to the chemical accidents [6]. In recent years, engineering ethics education has been gradually emphasized in China. "Engineering Ethics" has been set as a required course for national engineering master's programs since 2018. In 2022, General Office of the CPC Central Committee and General Office of the State Council issued the "Opinions on Strengthening the Governance of Science and Technology Ethics," proposing science and technology ethics as an important part of undergraduate and graduate education in relevant disciplines. Universities, like Tsinghua University, Dalian University of Technology, and Zhejiang University, had already introduced engineering ethics courses prior to 2015. Since 2014, East China University of Science and Technology (ECUST), where the authors are affiliated, has mandated a compulsory course called "The Fundamentals of Enterprise EHS Risk Management" for all undergraduate students. The course aims to improve students' comprehension of health, safety and environmental aspects and enhance their awareness of engineering ethics.

However, there are still some problems, especially the barrier between character cultivation and theoretical education, hindering the development of engineering ethics education in China. Engineering ethics education has not fully played its role in cultivating well-rounded individuals.

In order to effectively strengthen the education of chemical engineering ethics, three integrations including the integrations of education and cultivation, principles and skills, and theory and practice have been proposed in this paper. By deeply integrating engineering ethics education into the entire cultivation process of engineering talents, it is possible to enhance students' engineering ethics and then further improve the quality of engineering talent.

2. The Integration of Education and Cultivation

Engineering ethics education not only imparts the relative knowledge to students but also serves as a crucial means of character development. It aims to cultivate students' comprehensive abilities, professional skill, and ethical values. It can help them establish a well-rounded knowledge and skill, develop basic professional ethics, and foster an awareness of the harmonious coexistence between humans and nature. Ultimately, it helps cultivate a group of engineers with engineering values, dedication, outstanding technological innovation capabilities, and adapting at solving complex engineering problems [7]. Nurturing individuals should be the primary goal in engineering ethics education. Imparting of engineering ethics knowledge should be integrated with character development, achieving "integration of education and cultivation, with nurturing individuals as the priority."

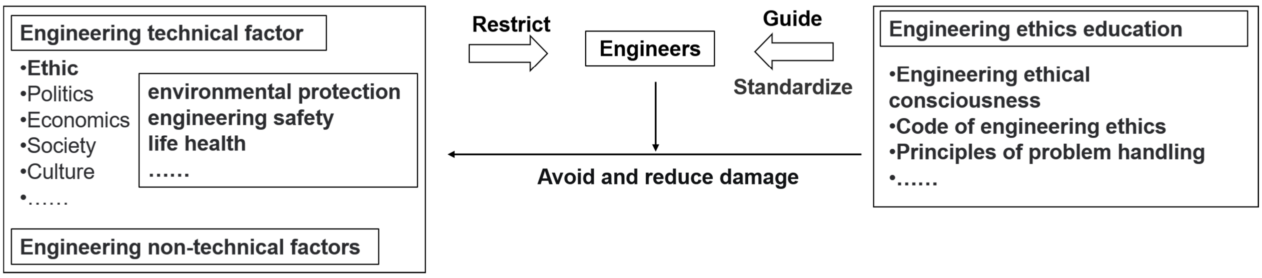

Figure 1. *The guiding and standardizing role of engineering ethics education on students' engineering ethics concepts.*

First and foremost, engineering ethics education is an essential element of developing comprehensive abilities in engineering talents. As a human activity that involves the creation of artificial objects, engineering practice is not only a technical endeavor to transform nature but also an ethical activity that involves considerations of humans, nature, and society. Engineering activities are influenced not only by technical factors but also by non-technical factors such as ethics, politics, economy, society, culture, and law. In the current era of rapid technological advancement, engineering technology can significantly improve production and living standards. It is even more important to consider the impacts brought about by non-technical factors in the process of engineering design, construction, and implementation. This is particularly true in the field of chemical engineering, where ethical factors such as the environment, safety and health have become primary considerations for industry development. As engineers are the practitioners of engineering activities, they must possess a high level of engineering ethics. By strengthening engineering ethics education, engineering students can develop an awareness of engineering ethics, understand ethical norms in engineering, and grasp principles for handling engineering ethics issues. This enables students with the ability of considering both technical and ethical factors in engineering activities and enhances their capacity of handling complex engineering problems holistically.

Furthermore, according to the perspective of engineering education accreditation, engineering ethics has become an increasingly important criterion. The United States is one of the countries that carried out engineering ethics education earlier. In the 1970s, there were already over 1,000 types of engineering ethics courses offered in the United States [8]. By the 1990s, engineering ethics courses were widely implemented in engineering schools across the country, especially after the release of the EC2000 criteria by ABET in 1997. These criteria provided comprehensive and explicit specifications for the ethical knowledge and abilities of engineering students, taking engineering ethics as an essential element of engineering education, which became a widely accepted consensus [9]. The "Accreditation Criteria for Engineering Education Programs in China" also includes ethical requirements in dimensions such as the design & development of solutions, the engineer and society, environment and sustainability, and ethics, etc.

Moreover, engineering ethics education is an important element of developing the professional talent of engineers. Ultimately, engineering talents are meant to serve society and enterprises. Universities should cultivate engineering talents with certain professional qualities. Engineering ethics is an important aspect of the professional qualities of engineers, and industry codes of engineering ethics, which reflect the professional ethics of engineers, have become significant occupational norms. The National Society of Professional Engineers (NSPE) in the United States established the "Code of Ethics for Engineers" as early as 1946, and it has been continuously improved since then. According to this code, engineers are required to pledge to utilize their maximum abilities, engage only in honest enterprises, live and work according to human laws and the highest professional ethical standards, and prioritize service over personal gain, with professional honor and status outweighing personal interests, and public welfare taking precedence over everything else [10]. In 1961, the Conference of European and American Societies for Engineering Education first put forward a comprehensive definition of *professional engineer*, which included requirements and standards for personal responsibility, virtues, and integrity [11]. These were early global requirements and standards for the professional ethics of engineers. After several decades of development, most international or national professional societies have issued engineering codes of ethics in their respective fields, such as *the IEEE Code of Ethics for Engineers* (Institute of Electrical and Electronics Engineers), *the IISE Code of Ethics for Engineers* (Institute of Industrial and Systems Engineers), *the FIDIC Code of Ethics* (International Federation of Consulting Engineers), and *the Code of Ethics - Engineers Canada*. In 2021, The Chemical Industry and Engineering Society of China issued its first *CIESC Code of Ethics*, which stated that members of CIESC should not only possess qualified professional competence but also have noble professional ethics and engineering ethics literacy. It listed nine principles that provide principled standards for chemical engineering ethics, demonstrating the increasing importance attached to engineering ethics in China's chemical industry. Therefore, it is evident that the industry's requirements for engineers are not limited to professional competence alone; engineering ethics is increasingly becoming an essential requirement for engineers and has been internalized as professional norms through codes of engineering ethics.

Thirdly, engineering ethics education is an important element of ideological and political education for engineering talents. The 20th National Congress of the Communist Party of China stated, *The most basic aim of education is to foster virtue. We will fully implement the Party's educational policy, carry out the basic task of fostering virtue through education, and nurture a new generation of capable young people with sound moral grounding, intellectual ability, physical vigor, aesthetic sensibility, and work skills who will fully develop socialism and carry forward the socialist cause*. Ideological and political education is an important measure to implement the fundamental task of cultivating people by morality. We must cultivate souls and educate people, and strengthen excellent traditional Chinese culture, the constitution and the rule of law, career ideal and professional moral education [12, 13]. In 2020, The Ministry of Education of the People's Republic of China issued *the Guidelines for the Construction of Ideological and Political Education in Higher Education Curriculum (Jiao Gao [2020] No. 3)*, which emphasizes the strengthening of engineering ethics education for engineering-related courses. Engineering ethics education has a rich connotation that aligns with the content and objectives of ideological and political education, as it inherently possesses the attributes of ideological and political education. Firstly, from the perspective of handling engineering ethics issues, engineering ethics should make safety, health, and well-being of the public the first priority. Engineers need to fully consider the interests of the general public throughout the process of engineering design, manufacturing, and operation, placing them as a top priority and prioritizing the interests of the general public and collective interests when facing ethical conflicts. Secondly, engineering ethics imposes moral and ethical requirements on engineers from both personal and professional perspectives, including honesty, responsibility, faithful service, fairness and justice, compliance with laws, loyalty, and reporting. Thirdly, engineering ethics places significant emphasis on environmental ethics. Environmental ethics considers the promotion of the integrity, health, and harmony of natural ecosystems as the highest goal [14]. It requires conducting engineering activities in accordance with natural and ecological laws to achieve harmonious coexistence between humans and nature. Therefore, it is evident that engineering ethics education reflects consistency with ideological and political education in terms of goals and shares commonalities in terms of content. Strengthening engineering ethics education can be an important approach to ideological and political education for engineering students.

3. The Integration of Principles and Skills

The integration of principles and skills requires that the teaching of engineering ethics not only covers the general knowledge and principles of engineering ethics (briefly referred to as "principles"), but also combines the teaching of engineering disciplines with ethical problems in engineering (briefly referred to as "skills"). Engineering ethics education be effectively implemented by incorporating engineering ethics into professional education and embodying engineering ethics within the field. In the field of chemical engineering, green chemical engineering technology serves as a path to solve ethical problems. It encompasses not only the specialized techniques for addressing issues such as environmental concerns, safety, and pollution in chemical engineering but also incorporates the ethical requirements of safety, environment, and health. It vividly demonstrates the integration of principles and skills.

So, what is green chemical engineering? We can understand it by examining the concept of green engineering. Green engineering involves designing, commercializing, and using processes and products in a way that reduces pollution, promotes sustainability, and minimizes risks to human health and the environment, all without sacrificing economic feasibility and efficiency. It emphasizes the use of technologies that protect human health and the environment in the early stages of process or product design and development, aiming to achieve optimal economic, social, and environmental benefits [15]. Green engineering differs significantly from traditional pollution prevention and control, which mainly focuses on end-of-pipe treatment or remediation of environmental pollution. Instead, green engineering requires the adoption of green technologies in the design and development stages of engineering processes or products to minimize waste generation and environmental pollution, representing a proactive approach [16]. As a typical engineering discipline, green chemical engineering should integrate the principles and requirements of green engineering, incorporating concepts of environment, health, and safety in the design and development of chemical processes or products, and utilize green chemical engineering technologies to achieve environmentally friendly production.

Therefore, education in chemical engineering ethics should not only involve the teaching of knowledge and concepts of engineering ethics but also integrate ethics education into professional education. It is essential to enable students to grasp green chemical engineering technologies and incorporate green engineering ethics and techniques into their learning stages, such as design, experiments, internships, and practical applications, thereby enhancing their awareness and proficiency in green chemical engineering.

Firstly, it is necessary to strengthen the education of green chemistry and engineering principles. In 1998, Anastas and Warner proposed *The Green Chemistry's 12 Principles* (Table 1) [17]. In 2003, Anastas and Zimmerman extended these principles to the field of chemical engineering with *The 12 Principles of Green Engineering* (Table 2) [18]. The core concepts of these two sets of principles include waste prevention, the use of non-toxic and renewable materials and energy sources, pursuing atom efficiency in chemical reactions, designing and producing products according to demand, considering degradation and recycling after the product's lifecycle et al. In 2020, Paul T. Anastas et al proposed 12 changes that must be made in the field of chemistry in the future in the review “Designing for a Green Chemistry Future”, which can also be called *The New Green Chemistry's 12 Principles* (Table 3) [19]. These principles have gained widespread attention and recognition from governments, industries, and academia globally. They have become guiding principles for research, design, and production in the field of engineering, especially chemical engineering. Green chemical engineering education should initially teach students these principles, helping them establish a fundamental comprehension of green chemical engineering through a combination of theoretical explanations and case studies. This will facilitate their comprehensive utilization of green chemical engineering principles in their subsequent studies and work.

Table 1. *The Green chemistry's 12 principles.*

Principle 1	Prevent waste: Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.
Principle 2	Maximize atom economy: Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.
Principle 3	Design less hazardous chemical syntheses: Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.
Principle 4	Design safer chemicals and products: Design chemical products that are fully effective yet have little or no toxicity.
Principle 5	Use safer solvents and reaction conditions: Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.
Principle 6	Increase energy efficiency: Run chemical reactions at room temperature and pressure whenever possible.
Principle 7	Use renewable feedstocks: Use starting materials (also known as feedstocks) that are renewable rather than depletable. The source of renewable feedstocks is often agricultural products or the wastes of other processes; the source of depletable feedstocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.
Principle 8	Avoid chemical derivatives: Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
Principle 9	Use catalysts, not stoichiometric reagents: Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.

Principle 10	Design chemicals and products to degrade after use: Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
Principle 11	Analyze in real time to prevent pollution: Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
Principle 12	Minimize the potential for accidents: Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

Table 2. *The 12 Principles of Green Engineering.*

Principle 1	Designers need to strive to ensure that all material and energy inputs and outputs are as inherently nonhazardous as possible.
Principle 2	It is better to prevent waste than to treat or clean up waste after it is formed.
Principle 3	Separation and purification operations should be designed to minimize energy consumption and materials use.
Principle 4	Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.
Principle 5	Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.
Principle 6	Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.
Principle 7	Targeted durability, not immortality, should be a design goal.
Principle 8	Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.
Principle 9	Material diversity in multicomponent products should be minimized to promote disassembly and value retention.
Principle 10	Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.
Principle 11	Products, processes, and systems should be designed for performance in a commercial "afterlife".
Principle 12	Material and energy inputs should be renewable rather than depleting.

Table 3. *The New Green chemistry's 12 principles.*

Todays' chemical sector	Tomorrow' chemical sector
1. Mostly linear processes	Circular processes
2. Fossil feedstocks	Renewable feedstocks
3. Reactive, persistent, or toxic chemical reagents and products	Benign chemical reagents and products
4. Catalysis using rare metals	Catalysis using abundant metals, enzymes, photons, or electrons
5. Covalent bonds	Weak noncovalent interactions
6. Conventional solvents	Low toxicity, recyclable, inert, abundant, easily separable green solvents or solventless
7. Material- and energy-consuming isolation and purification	Self-separating systems
8. Large "waste" volume	Atom-, step-, and solvent-economical processes
9. Waste" treatment	"Waste" utilization
10. Design exclusively for use phase with reliance on circumstantial control	Intentional molecule design for full life cycle
11. Performance = maximize function	Performance = maximize function + minimize hazards
12. Maximum chemical production for increased profit	Maximum performance with minimal benign material use for increased profit

Furthermore, it is important to vigorously develop green chemical engineering technologies and incorporate them as essential components in the training of chemical engineering talents. Green chemical engineering technology refers to the development of chemical engineering techniques that prevent environmental pollution from the source based on green chemistry principles. Ideally, these technologies should adopt atom economy reactions, generating no waste and avoiding the use of toxic materials, catalysts, and solvents, while producing environmentally friendly products [20]. In the context of the "dual carbon" goals, green chemical engineering technology plays a crucial role in achieving energy conservation and emission reduction, contributing to China's efforts in achieving peak carbon emissions and carbon neutrality. In 2021, the Ministry of Education issued the *Action Plan for Carbon Neutrality Technological Innovation in Higher Education Institutions* (Document No. 30, 2021), proposing the need to conduct fundamental research on carbon neutrality, accelerate key technological breakthroughs in carbon emission reduction, carbon-zero emissions, and carbon-negative emissions. This includes the development of low-carbon industrial raw materials, low-fluorine-containing materials, biomass energy, thermochemical technology, electrochemical technology, hydrogen energy, waste recycling technology, and biochar soil improvement technology, etc. [21] These technologies themselves are considered green chemical engineering or closely related to them. Research in chemical engineering and related disciplines in universities should shift from traditional chemical engineering techniques to green chemical engineering technologies, actively adjusting the knowledge and skills required, and cultivating chemical engineering talents with expertise in green chemical engineering technology.

4. The Integration of Theory and Practice

Integration of theory and practice emphasizes the importance of experiential learning. Ethical education in chemical engineering should not only be limited to theoretical courses, but also incorporate hands-on practice courses. Engineering ethics should be integrated into various aspects of chemical engineering education, such as design, experiments, internships, and thesis work, allowing students to apply engineering ethics in practice and transforming theory into practice. ECUST, which is known for its excellence in chemical engineering, places special emphasis on engineering ethics education and has actively explored the integration of theory and practice through a green engineering education system, accumulating practical experience in recent years. The following are specific examples of the university's explorations in implementing green engineering education while integrating theory and practice.

Firstly, strengthening the theoretical teaching of engineering ethics to establish a solid foundation of theory. This includes integrating the 12 principles of green engineering into student outcomes and the curriculum system. By revising the training program, the university has incorporated the principles of green engineering into student development goals and graduate competency requirements. In the curriculum of chemical engineering, a supporting matrix was constructed between the professional courses and the 12 principles of green engineering, ensuring the continuous coverage of green engineering ethics education throughout the 4 years of undergraduate education. The university aims to have the professional curriculum reflecting the principles of green engineering, while the principles of green engineering covering the professional curriculum. Additionally, a dedicated course on green engineering education has been introduced. In the general education curriculum for undergraduate students, a module on green engineering education has been established, offering courses such as *Fundamentals of Enterprise EHS Risk Management* and *Green China* et al. Furthermore, starting from 2021, a compulsory course called *Industrial Ecology* has been introduced in the chemical engineering undergraduate program, covering sustainable development, resource management tools and practices, and green technologies. In the engineering master's degree program, a course on *Engineering Ethics* has been developed, including an online course and a teaching case library. Moreover, the university has created original textbooks and case studies on green engineering. Thirty textbooks that embody the principles of green engineering have been revised or newly developed, and a collection of sixty theoretical and practical case studies on green engineering has been created. These case studies cover a wide range of disciplines, including engineering, natural sciences, management, and law. By presenting specific examples, such as *Green Engineering Education in the Petroleum Refining Process Course* and *Environmental Law Case Study Base*, as well as practical cases like *Training in Urban Wastewater Treatment Plants* and *Continuous Flow Synthesis Technology,* students are exposed to the concepts and technologies of green engineering, enabling them to further grasp relevant knowledge and applications.

Next, we will deepen the practice of engineering ethics and enhance its implementation. Firstly, we will emphasize the concept of green engineering in laboratory experiments and practical training. The construction of all engineering laboratories in the school should fully implement the 12 principles of green engineering, and the content of 50 experimental teaching courses has been updated to highlight the concept of green engineering. By utilizing VR technology, we have developed eight large-scale VR training cases and 105 panoramic teaching videos in the fields of green chemistry, chemical engineering, energy, and the environment, which are leading nationally and even globally. Additionally, we have 60 virtual simulation experimental projects for laboratory experiments and practical training. Secondly, we are promoting green engineering innovation and entrepreneurship education. We have established a student cultivation model for green innovation and entrepreneurship called Green LCS (Green Lab + Green Club + Green Shop), guided by the EHS (Environment, Health, Safety). We have also built the "G Space," a multi-disciplinary shared innovation and entrepreneurship practice base with a focus on green engineering, covering an area of over 3,000 square meters. In recent years, 70% of the undergraduate innovation and entrepreneurship training programs have fully considered EHS and sustainable development. Thirdly, we have initiated the "SCIP+" Green Chemistry and Chemical Engineering Innovation and Entrepreneurship Contest. In 2019, ECUST, together with The China Petroleum and Chemical Industry Federation, the Chemical Industry and Engineering Society of China, and Shanghai Chemical Industry Park, co-founded the "SCIP+" contest, which focuses on themes such as carbon neutrality and green low-carbon. The competition seeks green innovative designs, products, services, and solutions in the fields of new materials, new energy, environmental protection, intelligent manufacturing, process control, and health and safety. Over the past four years, the competition has attracted 1,165 teams from higher education institutions, research institutes, startups, and teams from both domestic and international backgrounds, generating significant influence. It has provided opportunities for our students to compete with other students and startups, enhancing their capabilities in green engineering innovation and entrepreneurship.

Thirdly, we aim to cultivate a green engineering culture and make the concept of sustainable development a conscious behavior among students. Firstly, we strengthen cooperation with enterprises to jointly create a campus green engineering culture. We have built the first "Waste Plastic Recycling and Environmental Protection Road" on campus, providing students with a unique example of green engineering education on how to deal with plastic waste and inspiring them to explore more unconventional solutions in the field of sustainable development. Secondly, we encourage student initiatives to innovate green campus activities and promote green concepts to society. We have established a "Garbage Bank" that acts as an account for the "Green City," allowing students to accumulate credits through recycling. The Youth Volunteer Association has launched the "Environmental Box" mini-program, providing one-stop precise garbage collection services such as appointment-based pickups and information feedback. The

"Garbage Bank" volunteer service project has been ongoing for over ten years, with over 1,800 volunteers organizing more than 50 garbage classification popularization lectures within and outside the university, covering over ten communities in Shanghai and benefiting more than 13,000 people. We have also published over 230 popular science articles online to promote environmental protection actions and foster students' green awareness. Thirdly, we create a green campus culture that subtly instills the concept of sustainability. We have appropriately allocated green spaces on campus and organized various green-related activities, such as campus waste classification, advocating green commuting, and implementing the clean plate campaign. In April 2021, the Ministry of Education held the National Education System Campaign to Stop Food Waste, promoting the construction of green canteens and the development of a green networked lifestyle to conserve resources. Through these efforts, we integrate the concept of sustainability into daily life and behavior.

5. Conclusion

Education is the foundation of national development in the long run, colleges should become the cradle for cultivating outstanding engineering talents in the future. Chemical engineering ethics education is an important part of cultivating outstanding chemical engineering talents. The three integrations can play an important role in promoting chemical engineering ethics education. The first is to adhere to the integration of education and cultivation. Chemical engineering ethics education not only imparts ethical knowledge, but also has the function of educating people. It is consistent and unified with the connotation and goal of students' comprehensive ability training, professional quality development, and ideological and political education. We must adhere to educating people first, taking education as the primary goal of chemical engineering ethics education to guide the teaching of chemical engineering ethics knowledge. The second is to adhere to the integration of principles and skills. Chemical engineering ethics education is not only to teach the principles of dealing with engineering ethical issues, but also to teach the paths and methods to solve chemical engineering ethical issues. Green chemical technology should be used as the skill to solve related ethical issues such as chemical environment, health, and safety. Universities is necessary to vigorously carry out relevant research and integrate it into the cultivation of chemical students. The third is to adhere to the integration of theory and practice. Chemical engineering ethics education requires not only theoretical teaching, but also practical teaching. On one hand, it is necessary to set up engineering ethics courses, develop engineering ethics textbooks and cases, and integrate engineering ethics into professional courses to lay the foundation of students' engineering ethics knowledge. On the other hand, chemical engineering ethics should be integrated into experiment, practical training, practice, graduation design, innovation and entrepreneurship training and competition, so that students can internalize chemical engineering ethics into behavioral consciousness in experiential teaching.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Hong, S., Jie, Y., Li, X., & Liu, N. (2019). China’s chemical industry: new strategies for a new era. McKinsey & Company.

[2] Wan, J., Qin, C., Wang, Q., Xiao, Y., Niu, R., Li, X., & Su, J. (2022). A brief overview of the 13th Five-Year plan for the protection of ecological environment. Environmental Strategy and Planning in China, 57-85.

[3] Alexandra, K. (2021). Corporate social responsibility through the example of Wanhua-Borsodchem Zrt. Multidiszciplináris Tudományok, 11(5), 386-401.

[4] Shanghai Municipal People's Government. China's petrochemical industry sees increased revenue in 2022 https://www.shanghai.gov.cn/nw48081/20230221/48fb801d0a064255993034b1b1a40be3.html

[5] You, J., & Zhang, W. (2022). How heterogeneous technological progress promotes industrial structure upgrading and industrial carbon efficiency? Evidence from China's industries. Energy, 247, 123386.

[6] Fahlbruch, B., Dubiel, J., Neumann, L., & Raupach, O. (2007). OECD-CCA Workshop on Human Factor in Chemical Accidents and Incidents.

[7] Jinping, X. (2021). Deeply implement the strategy of strengthening the country with talents in the new era and accelerate the construction of an important talent center and innovation highland in the world. Qiu Shi (24), 4.

[8] Li, J., & Fu, S. (2012). A systematic approach to engineering ethics education. Science and engineering ethics, 18, 339-349.

[9] Clancy, R. F. (2020). The ethical education and perspectives of chinese engineering students: A preliminary investigation and recommendations. Science and engineering ethics, 26(4), 1935-1965.

[10] Rao Chitikela, S., & Ritter, W. F. (2021). Ethics, Ethics, and Ethics to All Professionals. In World Environmental and Water Resources Congress 2021 (pp. 719-733).

[11] Blum, M. (2022). Engineering Ethics. In An Inquiry-Based Introduction to Engineering (pp. 85-90). Cham: Springer International Publishing.

[12] Christensen, S. H., Didier, C., Jamison, A., Meganck, M., Mitcham, C., & Newberry, B. (2015). Engineering identities, epistemologies and values. Engineering Education and Practice in Context, 2.

[13] General Office of the CPC Central Committee, General Office of the State Council. Some Opinions on Deepening the Reform and Innovation of Ideological and Political Theory Courses in Schools in the New Era [EB/OL]. (2019-08-14) http://www.gov.cn/zhengce/2019-08/14/content_5421252.htm

[14] Ministry of Education of the People's Republic of China. "Notice of the Ministry of Education on Printing and Distributing the "Guidelines for the Ideological and Political Construction of College Curriculum" (2020-05-28) [2023-03-27]. (in Chinese) http://www.gov.cn/zhengce/zhengceku/2020-06/06/content_5517606.htm

[15] Zhengfeng Li, Hangqing Cong, Qian Wang et al. Engineering Ethics (2rd Edition) [M]. Beijing, Tsinghua University Press, 2019. (in Chinese)

[16] Shonnard, D. R., Allen, D. T., Nguyen, N., Austin, S. W., & Hesketh, R. (2003). Green engineering education through a US EPA/Academia collaboration. Environmental science & technology, 37(23), 5453-5462.

[17] Anastas, P. T., & Warner, J. C. (1998). Principles of green chemistry. Green chemistry: Theory and practice, 29, 14821-42.

[18] Anastas, P. T., & Zimmerman, J. B. (2003). Peer reviewed: design through the 12 principles of green engineering.

[19] Zimmerman, J. B., Anastas, P. T., Erythropel, H. C., & Leitner, W. (2020). Designing for a green chemistry future. Science, 367(6476), 397-400.

[20] Clark, J. H. (1999). Green chemistry: challenges and opportunities. Green Chemistry, 1(1), 1-8.

[21] Ministry of Education of the People's Republic of China. Notice of the Ministry of Education on Printing and Distributing the " Carbon Neutral Science and Technology Innovation Action Plan for Colleges and Universities " (2021-07-15) http://www.moe.gov.cn/srcsite/A16/moe_784/202107/t20210728_547451.html