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Situation of Engineering Ethics Education of Postgraduates in China: A Preliminary Investigation*

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This research aimed to investigate the current situation of engineering ethics education in China via the viewpoints of engineering students. Integrating social attributes of engineering, the pedagogy applied in engineering ethics education was illustrated. On this basis, a survey covering students' ethical awareness, theoretical knowledge, and problem-solving ability was designed and conducted in a representative engineering university of China. In total, 608 questionnaires from engineering postgraduates were collected to quantitively present students' awareness and theoretical knowledge on engineering ethics, while 196 responses to five designed engineering scenarios were received to review students' abilities to solve ethical problems. By comprehensive statistical analysis, the research results showed that the engineering ethics education contributed to a positive impact on students. Specifically, after systematic course education, participants perceived positive awareness, acquired sufficient knowledge, and enhanced problem-solving abilities to make appropriate ethical decisions in practice. Notably, there was a substantial difference in the engineering ethical awareness between students with and without work experience, indicating that the exposure to practical work environment influenced the establishment of ethical attitudes. Further, evaluations on the engineering ethics course highlighted the necessity of unique and creative teaching strategies and a preference for learning ethics principles in practice. The research finding can be referred as the theoretical basis for the design and implementation of engineering ethics education in China.

Keywords: engineering ethics education; engineering postgraduate; pedagogy; education situation of China

1. Introduction

Ethics plays a vital role in guiding professional behaviors and decisions of engineers [1]. In professional engineering societies (e.g., American Society of Civil Engineers, American Society of Mechanical Engineers, and National Society of Professional Engineers), codes were developed and updated to guide the ethical practice in the profession. Recently, the importance of engineering ethics education has been strongly emphasized. To strengthen the ethical level of engineers, engineering ethics has been set as the mandatory curriculum in more and more universities worldwide [2]. That is, engineering schools are obliged to teach professional ethics, not merely the technical knowledge to future engineers. Many developed countries, such as the United States, Germany, Japan, and Australia, have already constructed distinctive engineering ethics education systems on the basis of their own cultural backgrounds and engineering development levels [3].

With the rapid advancement of Chinese engineering and social construction, various social problems (e.g., environmental pollution, quality, and safety during construction) emerged at the same time. In this context, engineering ethics education has attracted wide attention. As the Ministry of Education of China stated in the "Standards for Education and Training Programs for Excellent Engineers" in 2013, society is calling for more ethical and excellent engineers. Additionally, China became a member of the Washington Accord in 2016, requiring that engineering graduates should achieve comprehension of the role of engineering in society, take the professional responsibility of an engineer to public safety, and consider the impacts of engineering activity (e.g., areas in economic, social, cultural, environmental, and sustainability) [4]. Considering the outdated content of the former guidance on the master of engineering training programing, the academic committee of the state council made the engineering ethics course compulsory for postgraduate engineering students in 2018. Aiming at students at technical universities and engineering schools, engineering ethics education strives to strengthen ethical sensibilities, engineering ideals, ethical judgments, and ethical willpowers when carrying out professional engineering obligations [2]. However, effective teaching strategies of engineering ethics education need further explanation [5].

Engineering ethics education can be regarded as a complex process, in which practice and decision-

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making are conducted by diverse views and values of different stakeholders (e.g., students, teachers, policymakers, and the public) [6]. Students are receivers of engineering ethics education programs and future decision-makers on engineering ethical problems. Therefore, it is important to understand the educational outcomes of engineering ethics education and determine whether Chinese education practices meet the society requirements on excellent engineers. However, limited attempts have been made to investigate the teaching effects of engineering ethics on Chinese engineering students. More specifically, do they realize the importance of learning engineering ethics? Can they recognize the correct theories of engineering ethics? Are they able to adopt the right solution to ethical dilemmas?

Addressing above research gap, considering social attributes of engineering, the pedagogy applied in Chinese engineering ethics education was first illustrated in this paper. Then, a preliminary survey integrating questionnaires and examinations was conducted in Huazhong University of Science and Technology (HUST) of China. By comprehensive statistical analysis, the research outcomes value in following ways: (1) it examined Chinese engineering students' perceptions about engineering ethics, and provided a better evaluation perspective of the differences of engineering ethics education between China and international environments; (2) it supported to develop education strategies and policies responding to major challenges encountered by Chinese students and educators.

2. Background

2.1 Teaching Pedagogy and Assessment of Engineering Ethics Education

Currently, ethical risk has attracted global attention, and scholars highlighted the urgency of combining ethics education and engineering process [1]. Unfortunately, it was pointed that engineering students' consciousness on ethical issues and conflicts remained weak [8]. Given that an increasing number of engineers exist to affect the world, engineering ethics education is becoming notable and worth discussing [5]. Ethics education is deeply rooted in western philosophy. One of the most important learning objectives is to argue about what is right and good in engineering ethics. To outline the content of engineering ethics, many researchers adopted conceptual analysis approaches and proposed several normative issues [9–11]. For example, Harris et al. illustrated the responsibility of engineers to the public, the organization, and the environment [9]. Luegenbiehl and Clancy proposed engineering ethics as a role ethics and highlighted the most important characteristics of engineers [10]. Raja and Abirami found professional codes to be a vital component of enabling students to distinguish between ethical and unethical behaviors [11]. Furthermore, empirical experiments have been conducted to improve the curricula [11–13]. Through investigations in Japan and Malaysia, Balakrishnan discovered that students' attainments of ethics education objectives and their attitudes toward engineering ethics were dependent on the pedagogy [12]. Drake compared the impact of a full semester ethics course and an engineering course involving an ethics module on students, and unveiled that a separate and comprehensive ethics course had better teaching effects [14]. Stappenbelt also called for a more holistic and integrated approach to teaching ethics [15]. In terms of the pedagogy, Kirkman shifted from an emphasis on primary sources to encouraging moral judgment in his teaching [13]. Ooi and Tan found that an ethics workshop could help undergraduate students to strengthen ethical awareness and reduce unethical behaviors [16]. In addition, various teaching strategies (e.g., motivational talks [11], input from engineering professionals [16], project-based learning (PBL) [13], ethical role-modeling by academic engineering staff [15]) and the use of teaching activities (e.g., role-playing scenarios [17]) have been encouraged to the engineering ethics education.

Nowadays, some specific assessment methods and procedures on engineering ethics education have been developed on the basis of anthropologic and psychological theories. Assessments of engineering ethics education were mainly conducted on the basis of teaching objectives, including sensitivity, knowledge, judgment, and commitment [18]. For example, the Defining Issues Test 2 (DIT2) was employed to assess students [14, 19–20]. Based on DIT, Borenstein proposed a new test (ESIT) of moral reasoning in ethical dilemmas, which was suitable for science and engineering disciplines [21]. Alexander et al. developed the model of domain learning (MDL) framework, showing that learners exhibited varying degrees of domain-specific knowledge, strategic processing abilities, and interest when they progressed through the experience-based stages [22]. Ivan et al. used the MDL framework to determine the level of students' ethics learning during the engineering curriculum, considering three key points: knowledge, strategic processing, and interest [23]. Bairaktarova and Woodcock proposed a model that correlated the ethical awareness and ethical behavior to explain the learning path of students [24]. Murrugarra and Wallace conducted an empirical study to assess the

relative impact of the ethics education, and determined if the demographic characteristics of students contributed to this impact as individuals and a group [25]. Nudelman and English also recommended that assessment tools should be adjusted according to special objectives [26]. In summary, assessment can be conducted mostly from the following perspectives: interest, knowledge, and problem-solving. Several researchers explored what students learn and think specifically. For example, Harding collected survey data from nearly 4,000 engineering undergraduates at 18 institutions across the USS, and presented students' varied levels of ethical knowledge and reasoning, as well as ethical behavior [19]. Stappenbelt surveyed 1136 students on their ethical beliefs and perceptions of the actions of their peers [15]. Miller and Brumbelow surveyed 192 students to understand their attitudes toward several ethical issues by questionnaires [27]. However, above empirical studies mostly focused on western students, which were region and culture-limited and not representative enough. Relevant research on Chinese students was insufficient.

2.2 Development of Engineering Ethics Education in China

In recent years, Chinese engineering ethics education is more important than ever. As the Ministry of Education of China clearly pointed out in the "Guidelines for Ideological and Political Construction of Higher Education", engineering majors should focus on strengthening engineering ethics education. It is important to cultivate students' craftsmanship spirit and inspire their senses of mission under science and technology. Engineers are required by the country and the industry to have philosophical thoughts and engineering ethics awareness. Besides, they need to learn how to analyze engineering activities and involved problems from the perspective of philosophy and ethics, and solve problems under engineering rationality, engineering knowledge and engineering ethics. By judging the legitimacy of engineering behaviors, engineers can then make right decisions when faced with value conflicts. Especially, China became the official member of the Washington Agreement in 2016, which means Chinese students should be educated in line with international standards. According to the statistics, China has more STEM (i.e. Science Technology Engineering Mathematics) majors than any other country in the world, and some of them go abroad for further education every year [28, 29]. Moreover, as "the Belt and Road Initiatives" expand globally, Chinese engineers are becoming globally influential. However, Chinese students were found to have inherent thoughts on ethical values [30, 31], which were evolved from traditional culture [32, 33]. In terms of psychological traits and constructs, Chinese students may have different thought styles, causal attributions, and self-concepts [34–36]. In this case, most investigations were conducted on western institutions, and Chinese participants have been used in a few studies of engineering ethics [5, 10, 37, 38]. The former two studies used undergraduate engineering students enrolled in foreign – Chinese joint venture educational institutions, comparing Chinese and United States students [5]. Yan Yi focused on students' perceptions of engineering within society and ethical engineering principles.

However, existing studies were insufficient in representing the current situation of Chinese engineering ethics education [38]. Addressing the research gap, this research aimed to reveal and evaluate the current situation of engineering ethics education in China. Particularly, an empirical investigation was proposed to reveal details on what Chinese students learn in engineering ethics education and how they conduct the decision-making when confronting with ethical problems. On this basis, challenges and reformation of engineering ethics education in China were identified and discussed. The research results can provide a window and a basic view for the development of engineering ethics education in China.

3. Method

3.1 The Pedagogy of Engineering Ethics Education

Engineering ethics education is a comprehensive subject oriented to engineering practice, which analyzes and expresses the relationship between engineering (including process and results) and the outside world. It guides engineers to make rational and ethical behaviors under the engineering norms. With the increasingly prominent social attributes of engineering, engineers need understand the relations between engineering and society, including the social structure and relation, the social conflict and coordination, and the social problem and responsibility, etc. [39]. For meeting the cultivation requirements of contemporary engineer, integrating the engineering process and the ethical awareness, the innovative pedagogy of engineering ethics education was applied (Fig. 1). For achieving expected teaching effects, three key points were included: (1) organizing a multidisciplinary teacher team; (2) innovating the training model and teaching strategies; and (3) improving the assessment and evaluation system.

Especially, except for the ethical knowledge, engineering students need to master the problem-solving abilities to make appropriate ethical deci-

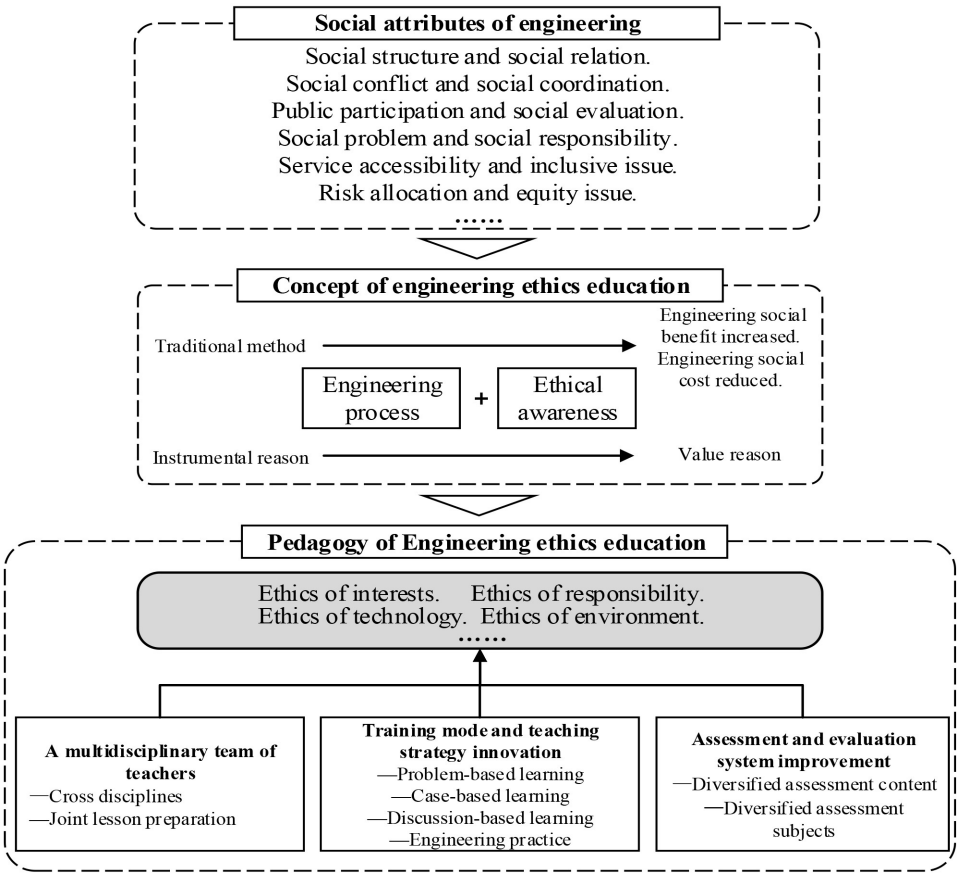

Fig. 1. Framework of the pedagogy of engineering ethics education.

sions in practice. Based on the ethical knowledge acquired in the class, the decision-making process on ethical problems in engineering practice was shown in Fig. 2. When faced with specific engineering ethical problems, engineers need to work out the basic reason of dilemmas. On this basis, integrating the ethics knowledge and their professional knowledge and experience, engineers can make appropriate decisions on ethical issues..

3.2 Evaluation of Situation of Engineering Ethics Education

Based on above pedagogy framework of engineering ethics education, a scientific survey in terms of Chinese students' perceptions on engineering ethics education was carried out. According to previous research, three key dimensions (i.e. ethical awareness, professional knowledge, and problem-solving ability) were selected in this research to assess the teaching outcomes of engineering ethics education in China. Correspondingly, measure variables and methods of above key dimensions were listed in Table 1. Based on Table 1, a survey was designed and revised by an experienced teacher team, including one professor from sociology, and six professors from civil engineering, mechanism engineering, and software engineering. The survey comprised four sets of questions (Table 2), which were explained as follows:

- *Demographics*: This part aimed to record demographic information. Participants were asked to fill in some personal information anonymously

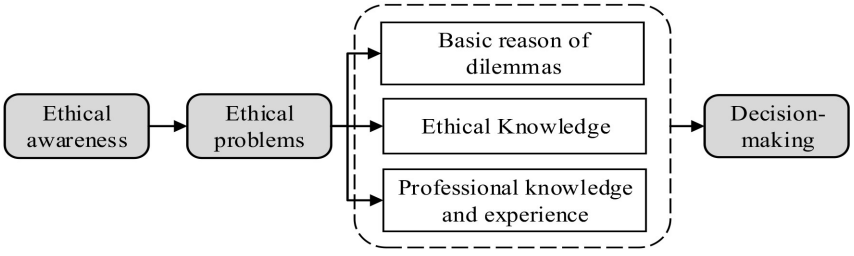

Fig. 2. Workflow of the decision-making of ethical problems in engineering practice.

Table 1. Assessment dimensions and suggested measures.

Ethic aspects	Definition or suggested measures or variables	Methods
Awareness	Identify ethical issues	Multiple choices
	Rate their agreement on ethics	Likert scale choice
Knowledge	Choose solutions on possible ethical dilemmas	Multiple choices
	Rate agreement on several ethics values	Likert scale choice
Problem-solving ability	Case discussion	Open-ended question

Table 2. The survey with four sets of questions

Survey dimensions		Questions or case description
Demographics		1. What is your gender?
		2. What is your age?
		3. What is your major?
		4. Do you have work experience before?
		5. Are you willing to work in an engineer-related industry after graduation?
		6. Do you have any previous education in engineering ethics?
Awareness		1. What do you think is an existing ethical issue during engineering ethics practice?
		2. Do you agree that engineers have an impact on the quality of the public?
		3. Do you agree that you will always practice engineering in accordance with the specifications of engineering ethics in your future work?
Knowledge	Responsibility to the public	1. What do you think is the most important idea of engineering ethics?
		2. Do you agree engineers should take vulnerable groups' interests into consideration in the project?
		3. Do you agree it is your responsibility as an engineer to inform the risks and impacts that the project may bring to the public?
	Responsibility to the environment	4. Do you agree the current ecological environment pollution is related to the professional ethics of engineers?
		5. Which do you think is the focus of engineering ethics? Please rank the following four options.
	Responsibility to the profession	6. In engineering practice, should engineers be responsible for normal accidents occurring within the allowable technical range?
		7. Should the engineer do good and ethical deeds in engineering practice?
		8. Should the engineers first report to the superior in the event of quality and safety problems in the project?
Problem-solving ability	Case 1	***Exploitation issue of hydropower resources in the Nu River*** The exploitation of Nu river aroused huge controversy in China in 2003. At that time, experts of ecology, water conservancy, electricity, as well as local governments and local public participated in this discussion. Interest of public, environment and local people were complex and needed to balanced.
	Case 2	***Ethical responsibility on the accident of Tianjin Port explosion*** Two massive explosions caused by flammable goods rocked an industrial area in the northeast Chinese port city of Tianjin late on August 13, 2015. Mismanagement and other ethical problem were being widely discussed on this occasion.
	Case 3	***Avoidance effects problem involved in Xiamen PX project*** Protest was raised against the paraxylene (PX) project planned for the Haicang Peninsula in Xiamen, Fujian Province in 2007. Finally, the government, enterprise and public made compromise and defended their interests.
	Case 4	***Ethical problems during the development of self-driving car*** The tensions between utilitarianism and moralism was discussed in this situation. It is asking what to choose when engineers are faced with that its consequences maximize public good and our individual intuitions about right and wrong.
	Case 5	***Identification of ethical issues happened in construction accident*** Qiongjiang Bridge in Fenghuang County collapsed on August 13, 2007, China. In this event, various parties were responsible and the main reason was to be hurry in schedule and some people neglecting duties. This is a very important lesson, telling us not to ignore quality to catch up with schedules

(e.g., gender, academic background, and working experience), which may be associated with survey results.

- *Awareness*: This part aimed to understand students' awareness on engineering ethics, including the sensitivity to ethical issues, students' awareness, and the importance of engineering ethics. Participants were asked to identify ethical issues

and rate the level of their agreement with the importance of each factor on a five-point Likert scale.

- *Knowledge*: This part aimed to measure students' knowledge of engineering ethics. Specifically, considering the engineer's responsibility on engineering practice (e.g., responsibility to the public, responsibility to the environment, responsibility to the profession), the situation of mastering ethical knowledge was investigated. Inspired by the DIT, this part provided a set of "cases" and "scenarios" where students must choose one kind of ethics codes or values and rate its degree. In this way, students' mastery of engineering ethics knowledge can be measured.
- *Problem-solving ability*: The last part was performed by the case discussion. Five engineering cases/scenarios in China were selected and applied in this survey. Students were asked to answer two of them.

The HUST is one of the comprehensive and key universities in China, well recognized for its engineering education and research. On the basis of the codes of higher engineering education, the HUST developed the engineering ethics in 2019 as a mandatory course [40]. Participants recruited in this research were the full-time postgraduates taking the engineering ethics course from 2020∼2022. Specifically, participants were mainly from eight engineering majors, including Civil Engineering, Engineering Mechanics, Telecommunication Engineering, and Materials Engineering, etc. Nearly 90% of participants did not have any formal and professional education experience in ethics. Only some students majoring in Civil Engineering have had a course about sustainability development during the undergraduate period.

As a section of coursework, questionnaires were assigned to participants thorough the Qualtrics online survey application. Students could finish the questionnaire anonymously in about 25 minutes. Furthermore, by clarifying in the class, the outcomes would be anonymously used for improving the teaching pedagogy. Students were instructed to fill the questionnaire honestly and independently. Finally, 735 questionnaires were collected. By the end of the survey, evaluation and advices about the curriculum were also collected. After discarding 57 incomplete copies as invalid, 608 copies were used for data analysis.

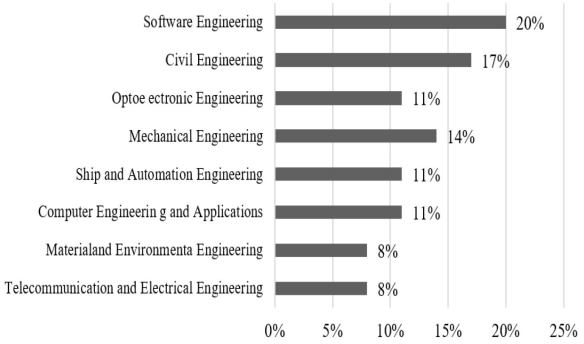

Fig. 3. Composition of disciplines.

4. Results

In this research, students from Software Engineering, Mechanics Engineering, Civil Engineering, and Optoelectronics Engineering accounted for the largest proportion of participates (Fig. 3). Most of participants (94.74%) are 18 to 24 years old. In terms of gender, 74.84% of participants are males, which reflects the remarkable proportional difference between the male and female in engineering majors. Particularly, 15.13% of participants ever have had work experience (Table 3).

Based on the received questionnaires, quantitative and qualitative approaches were adopted to analyze and reveal the current situation of engineering ethics education in China. Integrated with the content of the course and exams, students' answers were analyzed to provide a deep understanding of students' attitude. For the questionnaires, basic statistical analysis (e.g., descriptive and frequency analyses) was used to comprehensively analyze the educated situation of college students from aspects of awareness and knowledge. By identifying the percentage of each option, participants' ethical support and tendency in different questions were obtained. Notably, demographic factors were considered in the questionnaire results to recognize whether they would contribute to a significant difference in participants' choices. In terms of case discussions, answers were reviewed by experienced teachers to check whether applied ethical principles were correct and whether students had clear and logical thinking. Specific results reflected from students' responses were analyzed and described as follows.

4.1 Do the Engineering Students have Positive Engineering Ethics Awareness?

As shown in Fig. 4(a), when asked about the current situation of engineering practice, most participants could clearly point out involved problems. It was

Table 3. Demographics of participants

Sample features		Frequency	Percentage (%)
Gender	Male	455	74.84
	Female	153	25.16
Any work experience	Yes	92	15.13
	No	516	84.87

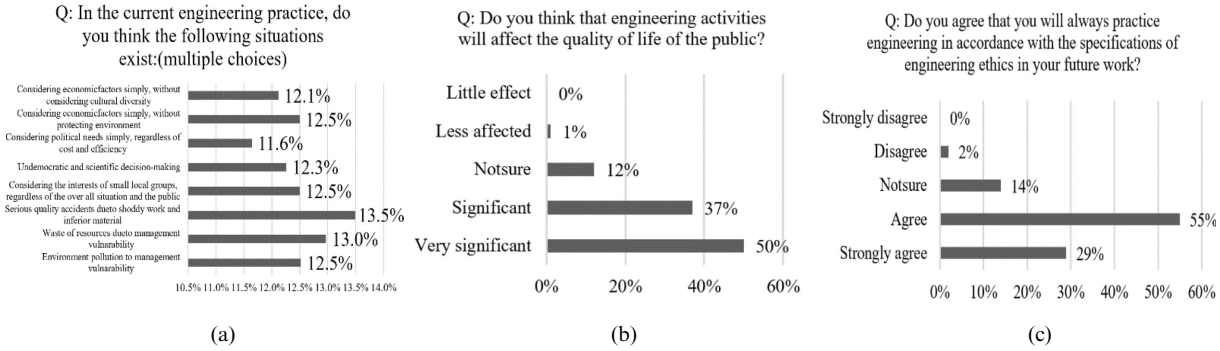

Fig. 4. Engineering ethics awareness of engineering students.

Table 4. Difference between students with and without work experience (by Likert scale).

Work experience	Strongly agree	Agree	Not sure	Disagree	Strongly disagree	Average	Variance	p-value
Yes	21	52	16	2	1	3.87	0.61	0.0017
No	156	285	67	7	1	4.14	0.49	<0.05

indicated that participants were familiar with the situation of engineering ethics practice and sensitive to existing ethical issues. Specifically, (1) in the process of project design, economic factors were simply taken into consideration, while protection of cultural factors and the ecological environment was not; prestige projects were constructed for political needs, regardless of cost and efficiency; (2) in the process of engineering decision-making, undemocratic and scientific decision were made solely on the will of the chief; some people took into account the interests of small groups, regardless of the overall situation and the public interest; (3) during the implementation of the project, serious quality accidents were caused by cutting corners, resources were wasted due to management vulnerability, and environmental was polluted due to management defects. However, no significant difference exists between males and females on the sensitivity to ethical issues.

In addition to being aware of the existing ethics dilemmas, students agreed that ethics has played an important role in engineering practice. When asked "Do you think that engineering activities will affect the quality of public life?", 87% participants believed that the effect should be very significant or significant Fig. 4(b). It can be inferred that students realized engineers' responsibilities and influence in their jobs. This could be the first step for an engineer to know that they were responsible for living surroundings. Students who are going to be engineers will have strong driving forces.

In terms of their attitude, most participants (84%) stated after the course that they would act with the ethics code in their future work (Fig. 4(c)). However, a significant difference exists between participants with and without work experience on this question. As shown in Table 4, participants with work experience rated lower average importance on this issue. From the result of the Student's t-Test, participants who had work experience were less likely to choose "agree to keep in accordance with ethics code" ($p < 0.05$). Therefore, it can be inferred that exposure to the working environment has a force on behavior choice in engineering ethics.

4.2 Do the Engineering Students grasp Sufficient Engineering Ethical Knowledge?

- Responsibility to the public

On the question of "what is the obligation of the engineer to the public", students have only a relatively vague understanding before the class. However, when asked "what is the highest value in engineering ethics" after the class, most participants (63%) chose the utmost right answer (protecting public safety and welfare), while 28% and 8% respectively chose duty and environment as the most important goal (Fig. 5(a)). It revealed that most participants have basically correct perceptions. Particularly, in terms of the responsibility to socially vulnerable groups, 91% of participants were inclined to protect their interests (Fig. 5(b)), which indicated that participants were educated to have humanitarian and social justice. To investigate what the participant would choose between the responsibility to inform the public risk of projects and protecting his own project, a Likert scale multiple choice was set. According to the result, most participants (85%) agreed or strongly agreed with passing information to the public, while only 10% and 5% chose "not sure" or "disagree" (Fig. 5(c)).

- Responsibility to the environment

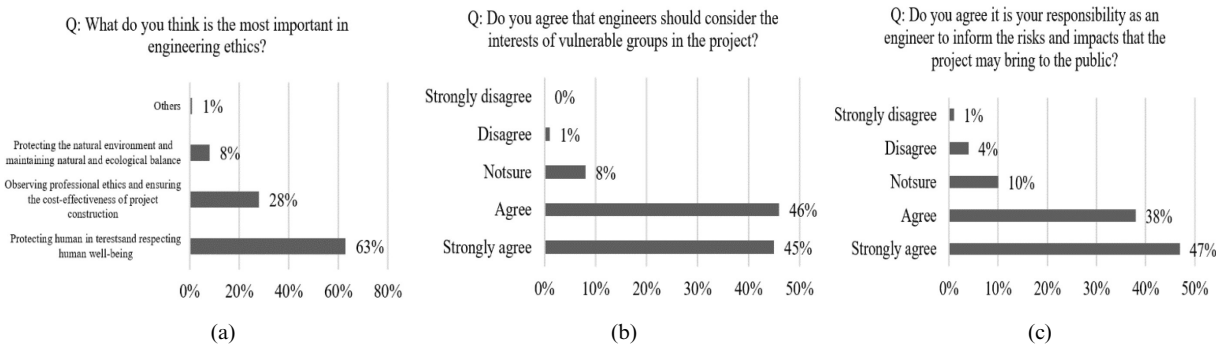

Fig. 5. Engineering ethical knowledge on the responsibility to the public.

With the development of industrialization and human being overexploiting nature, environmental ethics have gradually become an important ethical issue in the field of engineering ethics [27, 42, 43]. There are many reasons for environmental pollution. While, it cannot be denied that engineering practice made a great contribution to it. Paying attention to environmental issues is the first step to identify the teaching direction. In this research, it was found that environment health was regarded by most participants (67%) to have connections with what engineers do, as illustrated in Fig. 6(a). Technique ethics, interest ethics, responsibility ethics, and environmental ethics are common and basic dimensions of ethical problems. This research set above four options and asked participants to sort them to understand their bias toward ethics issues. Fig. 6(b) presents the results of this question. It remains unexpected that participants ranked the ethics of interests the highest and the ethics of responsibility the second highest, while the ethics of technology and the ethics of environment were ranked the third and the last. When exploring the reason behind, participants stated that the other three dimensions were considered as important motivations of engineers, because they were more common and comprehensive. While, environmental effects can be a result of above issues. For example, environmental ethics can be achieved by doing good in handling technical issues or interest issues. Therefore, the result was reasonable, and participants had an awareness of protecting the environment in engineering practice.

- Responsibility to the profession

To determine how students deal with ethical issues at work, they were asked to choose the answer they most agree with in the following scenarios.

Scenario 1: Should engineers be responsible for normal accidents occurring within the scope of technology?

In this regard, choices of participants were a bit diverse. As illustrated in Fig. 7(a), 64.64% of participants said they should be responsible; 19.41% said that it depended on the situation; only 15.95% thought they should not be responsible. Furthermore, participants from material engineering were found to have the highest percentage population who believed they should not be responsible. It can be inferred that most participants would behave ethically and responsibly even if they did not result in the accident on purpose.

Scenario 2: Should the engineer do good and ethical deeds in engineering practice?

Students should obtain appropriate moral rea-

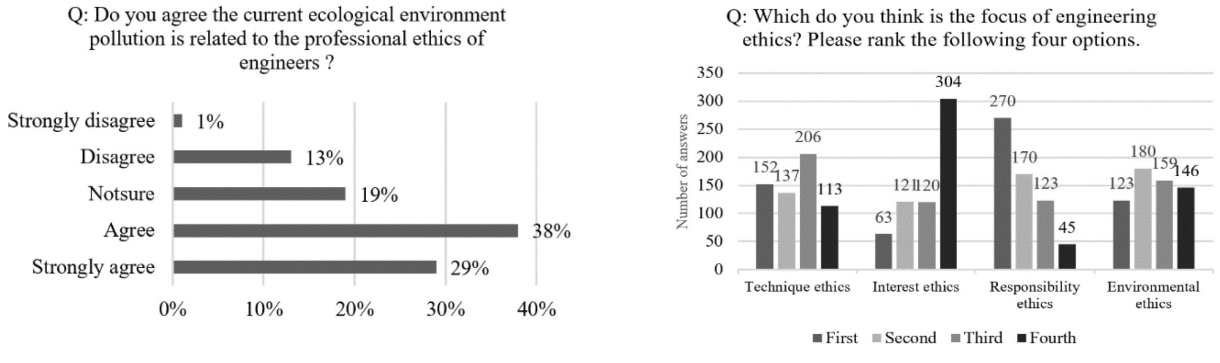

Fig. 6. Engineering ethical knowledge on the responsibility to the environment.

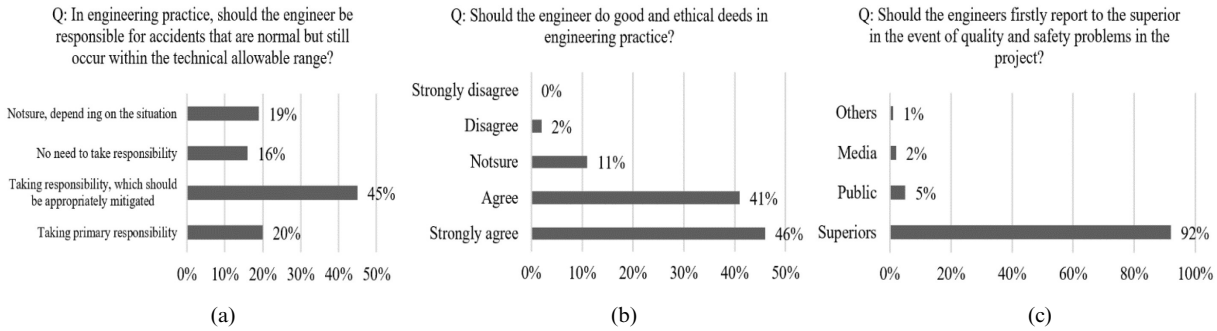

Fig. 7. Engineering ethical knowledge on the responsibility to the profession.

soning, moral awareness, moral communication, tolerance of diversity, integrity, and other abilities through engineering ethics education in colleges [44]. It is vital to acknowledge that a moral mind is important at all time. In this regard, when asked if good deeds should be conducted in the engineering practice, participants' attitudes were unanimously approved (Fig. 7(b)). It was a good symbol that students really combined ethics with their behavior.

Scenario 3: Should engineers report to the superior first in the event of quality and safety problems in the project?

It is widespread knowledge that engineers have professional duties to their superiors. Undoubtedly, as illustrated in Fig. 7(c), Most participants (92%) tended to agree that ''they will first report to the superior in the event of quality and safety problems in the project''. This question seems to be a regular question. Nonetheless, a small number of participants thought that they should report to the public first. Actually, this issue can be argued in specific situations, considering what's the best for the public welfare.

4.3 Are the Engineering Students able to Solve Ethical Problems?

In this survey, to evaluate students' ability to solve ethical problems, they were given five scenarios and required to optionally accomplish two case/scenario discussions. By this, they had opportunities to express the process of logical thinking, clarify the understanding of ethics codes, and finally elucidate the preferred way to solve an ethical dilemma. By judging whether their answers were sufficient and convincing, we had a clue to know if they were able to solve a problem well. For this part, 196 responses from civil engineering and mechanics engineering were received in the course exam for analysis. Confronted with the ethical dilemmas posed in different cases, students solved them by identifying the basic reason for dilemmas and taking advantage of the ethics code and their experience. Finally, they proposed their solutions to ethical issues in a personal, but also professional way. In general, when faced with an ethical dilemma, they were educated to handle these issues from various aspects, such as technical ethics, interest ethics, environmental ethics, etc. For technical issues, they could consider the pros and cons of techniques dialectically. For interest issues, they tend to balance the interests of different groups. For environmental issues, sustainable development usually became the main principle of strategy.

5. Discussions

5.1 Current Situation of Engineering Ethics Education for Engineering Students

Ethical or moral consciousness is not born in nature, but cultivated by education. Engineering students must be aware of the contents of ethical problems and conflicts, as well as expecting to confront them [5, 41]. Positive engineering ethics awareness is the first objective of engineering ethics education. According to the research results, most participants were sensitive to ethical issues and had the consciousness of being beneficent. However, this is a preliminary measurement of students' ethical awareness. Good ethical awareness does not necessarily predict good ethical behavior [24].

Previous research revealed that in terms of harm prevention and honesty, parents are the major source of ethical values [10]. In the scope of engineering ethics, ethics code and principles make the most basic and important knowledge, which interpreted as multiple responsibilities [9]. IEEE code of ethics of 2020 also summarized 10 items of statements about the responsibility to the public, the environment, and the profession, requiring engineers to be honest, realistic, fair-minded, and to chase for progress and harmony in their work. Based on the survey, knowledge levels of participants in the responsibility to the public, responsibility to the environment, and responsibility to professions were analyzed in this research. Students thought that engineers should put the public welfare in a high position, even when the public welfare

conflict with other interests. That is what the ethical standards advocate. For the environmental protection, it can be regarded as a common perception existed among students. However, they may compromise when environmental issues conflict with other interests. However, based on the research results, it remains to be seen what students will do in future engineering practices. In terms of the ethical perception of professional duties, certain differences existed based on students' individual behavior and their training quality. Most students would behave ethically and responsibly for accidents occurring within the scope of technology. Students thought engineers should do good and ethical deeds in engineering practice. Besides, most students believed that engineers have professional duties to their superiors. The research findings reflected that students really combined ethics with their behavior.

Problem-solving in ethics is a vital skill for students, but quite difficult to be taught. Ethics education should train students problem-solving skills to recognize ethical issues, take into account the economy, environment, and humanitarian, and make the appropriate choice. However, there is no specific answer to the dilemma of engineering ethics. Engineers may rely on existing knowledge of ethical norms to carry out logical reasoning and propose solutions when making ethical decisions. In this research, students can analyze and make decisions on ethical problems based on principles of humanitarianism, social justice, and harmony between man and nature, which showed the good teaching effects on engineering practices.

5.2 Challenges and Innovations of Engineering Ethics Education in China

Students were asked to evaluate this course at the end of the questionnaire for triangulation purposes. In terms of advice, students wrote their opinions and concerns about teaching style, content, and so on. The feedback was in line with the survey data and showed the importance of engineering ethics education, and also revealed existed challenges.

5.2.1 The Engineering Ethics Education should be the First Lesson of Engineering Education

From student's perspective, the effect of this course is good on the whole. The majority of participants (93%) stated that "the course is beneficial to the compliance with the engineer code and ethical provisions in the future work". Besides, 92% of participants stated that engineering ethics awareness was strengthened through course learning. 88% thought it should be the first lesson of engineering education. This education has the potential of being effective, given that Chinese engineering students listed teachers as a source of ethical values [5]. However, despite the fact that engineering ethics becomes a compulsory course for engineering undergraduates in many universities in developed countries, this course is not open widely in China [2]. In this study, 80% of participants did not have access to engineering ethics education before this course, as expected. 76% of participants thought the engineering ethics course should be conducted during the undergraduate period. This situation revealed that the introduction of ethics education into the engineering curricula of China should be a priority.

5.2.2 The Teaching Style and Content of Engineering Ethics need Further Improvement

In terms of the teaching style and content of engineering ethics education, suggestions were summarized and can be used for making recommendations to educators in China about the education form. First, students stated that they would like the content of the course to be more specific and targeted to their disciplines so that it will be more practical. For example, students from software engineering stated that they had no access to any content related to their major in the class, so that they could not raise enough interest in the course. Secondly, some students reflected that the teaching style was boring and changeless. If the ethics education were primarily conducted as a theoretical course, the involved theories wouldn't impress students. Actually, compared to traditional teachers dictating theories in the classroom, many researchers suggested that lectures, seminars, mentoring, writing quizzes, teamwork, presentations, debates, and case teaching were more popular among students. Considering the teaching effect, it was suggested that teachers should adopt a more popular teaching pedagogy. Thirdly, students stated that teachers should introduce new cases and insights keeping pace with the times. Ethics case teaching is a combination of theory and practice. It can not only stimulate students' curiosity and enthusiasm, but also standardize students' behavior and teach them to protect themselves. In an increasingly complex environment, students should be trained by using contemporary ethical problems.

5.2.3 The Teacher Team must consider Professional Characteristics of Different Disciplines

Some theoretical and practical efforts have been made to show that integrating ethical principles or topics into a specific course (such as civil engineering courses) is necessary. In this survey, students who majored in different disciplines showed differ-

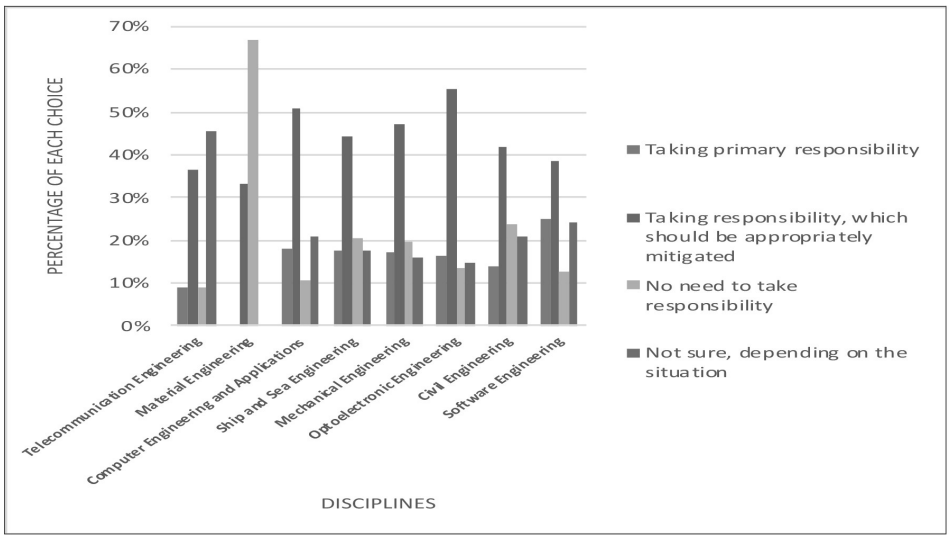

Fig. 8. Percentage of different choice among different disciplines.

ent cognitive attitudes toward certain engineering ethics norms (Fig. 8). Specifically, when asked "whether engineers should be responsible for normal accidents occurring within the scope of technology in engineering activities," most participants from Materials Engineering said they should not be responsible. In contrast, most participants from other majors (e.g., Computer Science, Ship, and Sea Engineering, Mechanics Engineering, Optoelectronics Engineering, and Civil Engineering) believed that they should undertake primary or partial responsibility. To some extent, it reflected that the subjects' focuses influenced students' perception on specific issues. It suggests that, as educators, making a good balance between the common ethical knowledge and engineering professional knowledge is important. Even it is not easy to find a way to combine them. Besides, teachers should have not only knowledge of ethics code but also experience in the engineering field. This is another challenge to educators.

5.3 Limitations and Future Work

Some limitations exist in this research. First, this research investigated the current situation of engineering ethics education for Chinese engineering students by questionnaire. Then, explanations about students' performance on engineering ethics were offered. However, as educators, we must seek a more appropriate and comprehensive method of ethics instruction and assessment in future work. Second, personal factors, such as students' personality and cultural background, may play a role in ethical decisions. That is, the diverse student group adds complexity to teaching ethics. In this research, different evolve paths influenced by those factors and how the factors interevent the development of moral awareness and reasoning process were not investigated. These factors must be considered in future work with the advancing of ethics education. Third, this survey was limited to a university in China, which can be extended to a wider research range including typical engineering schools in China and other countries in the future. In this way, the overall ethical education state of engineering universities in China and abroad can be better revealed.

6. Conclusions

This research aimed to understand the educational outcomes of engineering ethics education in China and to evaluate the education at the university level. First, the pedagogy applied in engineering ethics education was illustrated. Then, a detailed survey research aiming at engineering postgraduates in HUST was conducted. The scientific survey measured students' awareness, knowledge level, and problem-solving abilities. The results statistically showed that students had an upright and positive attitude toward engineering ethics and determination to conduct it in practice. They were also educated to understand the ethics codes and their responsibility in doing good to the society, the environment, and profession. Especially, students showed capabilities of solving ethical dilemmas with an appropriate way of thinking. Although the research found current education to be effective, there remains a long way to go for educators. Some challenges to Chinese ethics education were reflected. Consequently, innovations in ethics education are urgently needed. The research finding can further support the design and implementation of engineering ethics education in China.

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