Technology in Society 65 (2021) 101585

Contents lists available at ScienceDirect

Technology in Society

journal homepage: http://www.elsevier.com/locate/techsoc

Instructor perceptions of engineering ethics education at Chinese engineering universities: A cross-cultural approach

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ARTICLE INFO

Keywords:
Instructor perceptions
Engineering ethics education
The Chinese context
Global engineering education
Cross-cultural ethics education

ABSTRACT

During the past decade, governmental agencies, universities and programs, policymakers, and educators in China have been striving for reforming and "globalizing" the engineering ethics curriculum. Chinese scholars have proposed strategies for improving the teaching effectiveness of engineering ethics that integrate "global forms" derived from the "American-style engineering ethics" into the Chinese context. Nevertheless, limited empirical research is available that examines the alignment of these strategies and the cultures of engineering education in China (e.g., instructor perceptions of engineering ethics education). We argue that understanding how Chinese instructors perceive engineering ethics instruction is critical for designing instructional strategies sensitive to the Chinese sociocultural context. In this study, we reviewed the literature on teaching engineering ethics (primarily after the 2000s) and teased out a set of most "contested" questions concerning American educators since the emergence of engineering ethics education as an academic discipline. By using these questions as a guideline, we conducted semi-structured interviews with 12 Chinese engineering ethics instructors trained in three different fields: STS and philosophy of science and technology, engineering, and Marxist studies and ethical theories. This paper also briefly discussed how the ways Chinese instructors perceived engineering ethics education are connected to and distinct from the views held by American educators discussed in the literature review section. This paper is expected to shed light on the cultures of engineering ethics education in China and provide insights into formulating effective policies and teaching strategies sensitive to the Chinese context.

1. Introduction

During the past decade, governmental agencies, universities and programs, policymakers, and educators in China have been striving for reforming and "globalizing" the engineering ethics curriculum [1–3]. The national call for transforming the curriculum and instruction for engineering ethics has become more imperative than ever due to China's recent campaigns for enhancing its global manufacturing competitiveness (e.g., the Made in China 2025 Initiative) [1]. Scholars have proposed various strategies for improving the teaching effectiveness of engineering ethics including by integrating "global forms" (e.g., case studies, ethical codes, various pedagogical approaches derived from the Western context but prevalent globally) into the Chinese context [4]. In particular, Chinese policymakers simply adopted ABET's accreditation framework as an actionable "startup template," although they have rarely challenged the fundamental assumptions and ideologies underlying ABET's accreditation criteria [5]. The China Engineering Education Accreditation Association (CEEAA) employed their accreditation criteria which were largely adapted from ABET's criteria to accredit engineering programs at all Chinese universities. Unfortunately, there is limited empirical evidence that demonstrates to what extent these *globalizing efforts to innovate engineering ethics* education are aligned with *the cultures of engineering ethics education in China* including how different stakeholders such as instructors perceive engineering ethics education.

Professional ethics was firstly introduced into the engineering curriculum as a formal theme in the 1970s in the United States [6]. In the late 1990s and the early 2000s, engineering ethics education started to "take off as a research discipline" [6]; p. 1). To a large extent, the so-called "American-style engineering ethics" has become a "global paradigm" and exerted significant influence on the development of engineering ethics programs in East Asia especially China and Japan in the 2000s [7,8]. While they are trying to develop engineering ethics curricula responsive to their own cultures, educators in East Asia are

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https://doi.org/10.1016/j.techsoc.2021.101585
Received 6 August 2020; Received in revised form 22 December 2020; Accepted 2 April 2021
Available online 12 April 2021

challenged to deliberate: (1) how they should react to the dominant role of the American-style engineering ethics [7,8]; and (2) whether and how they can integrate the "global forms" of the American-style engineering ethics with locally situated ethics and politics in East Asia [5,9].

In China, the formal development of engineering ethics education and research started with the translation and introduction of classical American textbooks including typical American ethics pedagogies and curriculum designs in the 2000s [8]. In the early and mid 2000s, some Chinese engineering universities started to develop their engineering ethics courses and programs by incorporating resources from the American context. These pioneering Chinese engineering universities include Tsinghua University, the University of the Chinese Academy of Sciences, Zhejiang University, Dalian University of Technology, Huazhong University of Science and Technology, and Southwest Jiaotong University. Before the 2000s, some very general ethical discussions on engineering practice in China could be found in the scholarship in the ethics of science and technology. Philosophers in the 1990s started to discuss ethical issues arising from the development of emerging technologies such as biotechnology and nanotechnology [10]. Given the increasingly powerful role of these emerging technologies in shaping the future society, some philosophers who taught in engineering schools began to reflect on what meant to be a *responsible* scientist or engineer in the context of emerging technologies. The concept of professional responsibility became a relatively popular term in the late 1990s and the early 2000s. It was not until 2002 when Li Bocong's book *Gongcheng zhexue yinlun* (An introduction to the philosophy of engineering) was published that the concept "engineering" became a philosophical concept distinct from science and technology [10]. Since then, some engineers have joined philosophers in the effort to formally introduce professional ethics of engineers into the engineering curriculum. Most of these early efforts to introduce engineering ethics were focused on either very practical engineering experience or the Marxist ideology [8,10].

In this paper, we adopt a multi-stakeholder approach to understanding the practices and policymaking in engineering ethics education. We consider engineering ethics education as a complex process in which practices and decisions are shaped by the diverse views and values of different stakeholders (Fig. 1 shows the main stakeholders whose views and values affect engineering education practices and policymaking). Understanding the diverse views and values of these stakeholders is critical for evaluating whether the Chinese cultures of engineering education support their recent efforts to globalize engineering ethics curriculum. In this paper, we particularly study how instructors at Chinese engineering schools perceive engineering ethics education and how their perceptions affect their pedagogies and curriculum design. We believe that this project is valuable in at least the three following ways:

- it is critical for better reflecting on the assumptions, biases, and limitations underlying the practices of engineering ethics education in China;
- it is valuable for evaluating the feasibilities for integrating global forms into Chinese engineering ethics curriculum;
- it is helpful for creating instructional strategies responding to the major sociotechnical challenges encountered by the public in the Chinese society.[1]

In this study, we employed a cross-cultural methodology to investigate how instructors at Chinese engineering schools perceive engineering ethics education. In doing so, we first conceptualized the major questions central to the debates around the development of the globalized, American-style engineering ethics (e.g., who should teach engineering ethics, what should be taught, whether ethical theories should be taught, and what ethics pedagogies should be used). We mainly examined the literature in the 2000s on teaching engineering ethics. We then invited Chinese instructors to reflect on their views by responding to these questions that historically concerned American educators. Finally, we briefly discussed how the ways Chinese instructors perceived engineering ethics education are connected to and distinct from the views held by the American educators discussed in the literature review section. This paper is expected to shed light on the cultures of engineering ethics education in China and provide insights into formulating effective policies and teaching strategies sensitive to the Chinese context. Fig. 2 demonstrates the methodological design of this study.

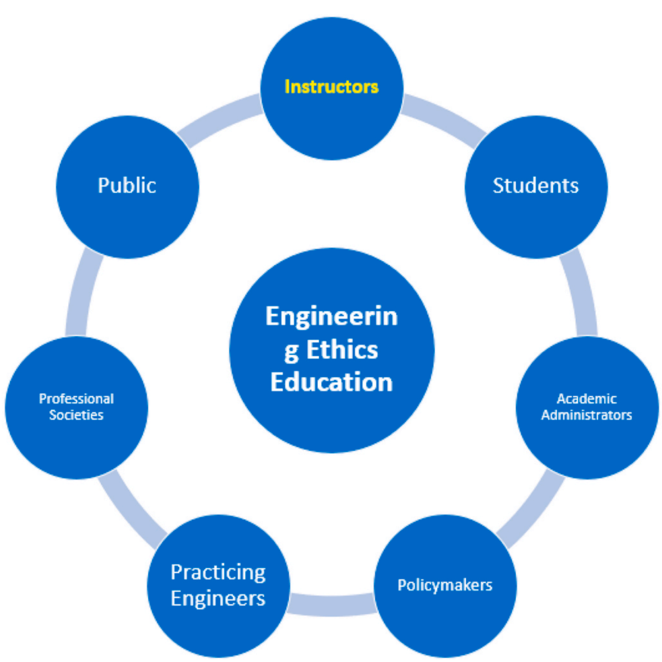

Fig. 1. Stakeholders in engineering ethics education.

2. Literature review

This section reviews the literature in engineering ethics education and summarizes the major questions that have been debated among engineering ethics instructors and researchers since 2000s when engineering ethics emerged as an academic discipline in the United States. The major questions conceptualized in this section will be fundamental for creating guiding questions in the interview protocol. We employed the Google Scholar to conduct the literature search by entering the key term "engineering ethics education." Particularly, we searched for literature published since the 2000s that focused on debates on teaching engineering ethics. All sources we found on Google Scholar were written in English. It is worth noting that our major goal here is not to conduct a systematic review of the whole body of the literature that represents all (or most) views of engineering ethics education. Rather, a major goal of our approach is to have a quick and rough sketch of the main issues that engineering ethics educators since the 2000s have been debating on.

[1] Also note that the Chinese society is not a monolithic or homogenous culture. People in different parts of China may experience different patterns of historical and cultural change and thus face different social, economic, and political challenges. One example might be that engineers in southeast China and northeast China may have different priorities in their everyday practice of engineering in the workplace. Engineers in southeast China such as Shanghai and Guangzhou may need to deal with ethical issues arising from globalized, cross-cultural interactions with engineers from other countries. In contrast, engineers in northeast China may need to address ethical concerns regarding how to revitalize the local economy given that the regional economy traditionally relying on heavy industries (e.g., coal, steel, petrochemical, machinery) has been declining.

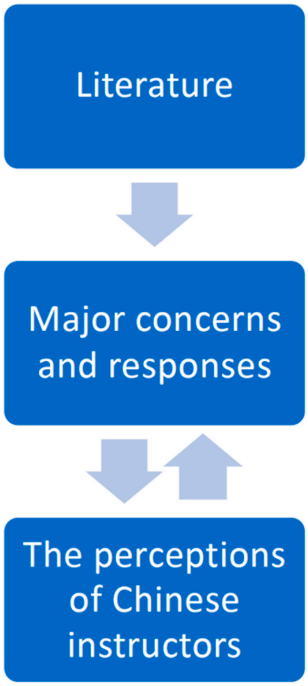

Fig. 2. Research methodological design.

Therefore, our brief review of selected papers and books do not represent the full picture of engineering ethics education in the United States. Likewise, our observations made in this section cannot simply be generalized to represent all American engineering ethics educators.

Among early discussions in the engineering ethics literature, one of the questions that attracted considerable attention from engineering educators was *who should teach engineering ethics*. Historically, the qualifications for someone to be able to teach professional ethics have been unclear [11]. It might seem to be "natural" to assume that qualified engineering ethics instructors would be better to receive an advanced degree (e.g., Ph.D.) in either engineering or philosophy. For instance, the Hastings Center studies in 1980s suggested that a qualified professional ethics instructor should have an advanced degree in her home profession (e.g., engineering) and solid background knowledge in ethics [11],[2].

However, according to Barry and Herkert [11]; the Hastings Center also noticed that most professional ethics instructors had little or no prior training in that specific subject area. In engineering, particularly, a major reason is that "current engineering faculty members are products of the admittedly ethics-deficient undergraduate engineering educational system of past years, but also of the completely ethics-devoid graduate engineering educational system" [12]; p. 349). Newberry [12] feels concerned that engineering faculty may not do outstanding jobs of integrating ethics into engineering education for two reasons: (1) engineering faculty may not have sufficient educational background to prepare them for ethics instruction; and (2) most universities do not have the reward systems that motivate engineering faculty to develop the background for ethics instruction. Similarly, McGinn feels concerned about having engineering-instructors cover ethical issues in their engineering courses, as these engineering faculty often lack formal training in ethics and thus their consideration of ethical issues is likely to be "intuitive and not grounded in ethics fundamentals" [13]; p. 9).

Nevertheless, Barry and Herkert [11] notice that a considerable number of engineering ethics instructors without formal training in either engineering or philosophy have been successfully teaching engineering ethics courses. In addition to engineers and moral philosophers, Barry and Herkert [11] suggest that instructors trained in history of science and technology, technical communications, and science and technology studies should also be considered as qualified for teaching engineering ethics, insofar as they are enthusiastic about discussing ethical issues in and the social implications of engineering. Despite that Barry and Herkert [11] do not explicitly suggest that faculty trained in these fields need to have some knowledge of engineering, the graduate programs in which they were trained may often require their students to have some general familiarity with engineering so that these students would be qualified for conducting interdisciplinary studies of engineering and technology.

A second classic theme that emerged in early discussions of engineering ethics was the *distinction between "micro ethics" and "macro ethics."* Herkert was the first major scholar who conceptualized and synthesized earlier discussions of such distinction in the history of engineering ethics education. According to Herkert, micro ethics refers to ethical issues that "consider individuals and internal relations of the engineering profession," whereas macro ethics are those issues that apply to "the collective social responsibility of the profession and to societal decisions about technology" [14]; p. 374). To a large extent, micro ethics exists in most teaching and research programs in engineering ethics. Micro ethics still serves as a dominant approach to teaching engineering ethics at least in the United States [15]. Bielefeldt, Polmear, Swan, Knight, and Canney's [16] empirical study showed that more than 50% of the engineering ethics topics in the engineering programs surveyed were about micro ethics issues or "professional practice issues."

Historically, the micro ethics of engineering has been widely criticized for its overly narrow scope. Eddie Conlon and Henk Zandvoort [17] call the micro ethics of engineering an "individualistic approach" that exclusively focuses on engineers as individual agents while overlooks the broader context in which engineers do their work. According to Conlon and Zandvoort, the individualistic approach exclusively focuses on the decision-making of the individual engineer who is expected to apply codes of ethics to solve professional ethical issues that only involve small scale human interactions (2011). Such approach neglects the broader social and organizational contexts in which engineers do their work and it does not address ethical problems of multi-actor situations.

Critics of the micro, individualistic approach advocate that the integration of STS (Science and Technology Studies) research into the engineering classroom can be helpful for broadening the scope of engineering ethics education. STS scholars such as Kline suggest that teaching engineering ethics should include discussions of the role of the organizational culture in shaping ethical norms of engineering practice, detailed analysis of workplace routines, and the historical and social context of engineering work [18,19]. Herkert [14] suggests that more emphasis needs to be placed on the macro ethical issues of engineering such as the social and policy issues arising from the development and use of technology. Herkert [14] further argues that one way of bridging micro and macro ethics is to focus on the moral role of professional societies. However, Davis [20,21] criticizes that too much emphasis on the social and organizational context of engineering may free individual engineers and managers from taking responsibilities for the negative consequences of the decisions they make. In other words, can and should we blame cultures for engineering disasters? Do individual engineers have any moral agency to make changes in organizations?

A third theme that led to contested debates was about *whether and how ethical (moral) theories should be taught in engineering ethics courses.*[3]

[2] It is also worth noting that the Hastings Center does not say that an advanced degree in moral philosophy is necessary [11].

[3] For instance, the journal *Teaching Ethics* published two groups of papers on the "usefulness" of moral theory in practical ethics respectively in 2009 and 2011.

A major criticism of teaching moral theories in practical and professional ethics is that different moral theories employed to analyze the same ethical scenario may lead to different and incompatible conclusions. Such approach to teaching moral theories “leaves the problem unsolved [and] suggests that one conclusion is as good as another, thus paving the way to ethical skepticism” [22]; p. 51). Harris argues that such critique of teaching moral theories is “both frustrating and unhelpful” [22]; p. 51). According to Harris [22]; it is wrong to assume that each moral theory attaches equal importance to all considerations relevant to an ethical problem and all moral theories should always converge on the same conclusion. Even when different moral theories result in incompatible conclusions, they can still help us better understand the ethical controversies and encourage us to explore a more satisfactory resolution of these controversies by taking into account diverse considerations and techniques [22].

In contrast to Harris, Davis [23,24] challenges the idea of teaching moral theory in practical ethics. According to Davis [23,24] it is unrealistic to expect that two other major groups of practical ethics instructors, philosophers and religious ethicists who have only taken some moral theory courses and ordinary professors of professions (e.g., engineering), would do a decent job of teaching moral theories as qualified moral theorists. By drawing on his own experience teaching an undergraduate moral theory course, Davis [23,24] argues that it might be very challenging to teach students nuances about moral theories in practical ethics courses as very limited allocation of space is given to moral theories in engineering ethics textbooks. Furthermore, short presentation of moral theories in textbooks might “encourage” non-moral theorist instructors to teach more self-interpretations of moral theories which are not included in textbooks but in fact are flawed (or inaccurate) understandings of moral theories. When students become practicing professionals, it is very likely they will forget much of what they learned in practical ethics courses and thus will not make reliable use of moral theories (Davis [23,24].

A fourth theme in the engineering ethics literature that has drawn significant attention from instructors and researchers is *how engineering ethics should be taught* including the pedagogies of engineering ethics. Riley, Davis, Jackson, and Maciukenas [25] point out that there are three major approaches to ethics education in engineering and science: (1) standing-alone courses such as Ethics in Engineering; (2) ethics modules integrated into technical courses (e.g., an hour-long discussion of conflict of interest or a pedagogical movie with a focus on engineering or professional ethics); and (3) micro-insertions, small-scale insertions of ethics instruction into technical courses (e.g., a dozen “ethics mini--lessons” during a semester and each lesson may take only a few minutes, revised engineering problems or assignments that incorporate social and ethical dimensions). Compared to other approaches to ethics teaching, as argued by Davis [20,21]; the third approach micro-insertions has certain strengths (e.g., no substantial change in the engineering course, an approach that engineering students appreciate).

Similarly, McGinn [13] points out that there are at least three main approaches to teaching engineering ethics: (1) requiring a typical philosophy-department ethics class (e.g., a philosophy class on ethical theories); (2) integrating ethics study into technical engineering classes; and (3) teaching separate courses dedicated to ethical issues in engineering (e.g., a class offered in either philosophy or engineering on the ethics of engineering practice). McGinn [13] argues that the third approach is superior to other two approaches. Among the three approaches, McGinn [13] argues that the third approach teaching separate engineering ethics courses is the most fruitful one and the other two approaches do have serious limitations. The first approach that requires a typical philosophy-department ethics class often lacks sufficient coverage of engineering-related examples and cases. In contrast, the second approach that integrates ethics modules into the engineering course may create an impression that ethics is peripheral to the course and is detached from engineering practice, given the limited (often one or two lectures) ethics material covered in the course.

In terms of specific pedagogies for engineering ethics teaching, the use of case studies has been the most prevalent pedagogical strategy [26]. However, the cases used in most engineering ethics textbooks have been criticized by STS scholars. They argue that most of these cases are hypothetical dilemmas, whereas some cases adapted from real cases are oversimplified, “large scale” engineering accidents and disasters (e.g., the *Challenger* case) and students will rarely be involved in these cases in their future careers [18,27,28]. The reliance on the application of ethical theories and other decision-making tools may encourage students to ignore the messy reality of engineering practices [15,18]. According to the systematic review conducted by Li and Fu [26], other traditional pedagogical strategies employed in engineering ethics teaching include lectures, tutorials, written exams, team essays, presentations, group discussions, group projects, response papers on readings, and discussions on popular news articles.

Other scholars have experimented with more engaging approaches to teaching engineering ethics. Monk [29] describes his experience employing four plays to teach ethical issues in specific situations that connect to practical situations engineers encounter. Voss [30] discusses how young people’s lived experiences with personal technologies (e.g., cell phones, social networking sites, digital music and computer games) can be used to teach engineering ethics in a more engaging way. More recently, educators have become increasingly interested in using gaming as an ethics pedagogy in engineering. Lau, Tan, and Goh [31] report their experience using the BLOCKS game to cultivate engineering students’ awareness of ethical responsibilities. Briggle et al. [32] have explored how to use the gaming approach to teach students research and engineering ethics. More recently, an important report published by the National Academy of Engineering “Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs” collects a variety of “best practice” pedagogies for integrating ethics into the engineering curriculum such as conducting interviews with engineering faculty, creating personal engineering codes of ethics, case studies, role play, problem-based ethics learning, team ethics assignment, and humanitarian, community-based ethics learning [33].

3. Methods

We conducted in-depth semi-structured interviews with 12 faculty members who were teaching engineering ethics in Chinese engineering schools. We recruited participants through the Division of Science, Technology, and Engineering Ethics (STEE) of the Chinese Society for the Dialectics of Nature (CSDN) which is the largest professional society in China devoted to the philosophy of science and technology. Participants were not offered any compensation as no funding was secured for this project. All 12 participants came from different institutions. All of these institutions are research intensive engineering schools. All of them were teaching engineering ethics to either undergraduate or graduate engineering students as a stand-alone course. Research has shown that qualitative studies require a minimum sample size of at least 12 to reach data saturation [34]. We conducted a preliminary analysis of the 12 interviews and noticed that we already received data saturation and no new information or themes could be observed in the data.

Each interview took between 45 min and 1 h. The research protocol of this study was reviewed and approved by the ethics committee of the university that the first author was formerly affiliated with (at the time when the interviews were conducted), as all the interviews were conducted by the first author. All participants reviewed and signed informed consent forms and were informed that their identifying information will be removed in any publications of this study.

The 12 interviewees were trained in three different fields which represent the major academic backgrounds of most engineering ethics instructors in China: (1) philosophy of science and technology and science, technology, and society (STS); (2) engineering; and (3) Marxist studies and ethical theories. Table 1 describes the backgrounds of the 12 participants in this study. The sampling of the participants in this study

Table 1
Interviewees and their backgrounds.

	Interviewee (pseudonym)	Academic Background	Gender
1	Xiaoqiang	Philosophy of Science and Technology and STS	Male
2	Fang	Philosophy of Science and Technology and STS	Female
3	Jianguo	Philosophy of Science and Technology and STS	Male
4	Donglai	Philosophy of Science and Technology and STS	Male
5	Xiaoli	Philosophy of Science and Technology and STS	Female
6	Jianjun	Philosophy of Science and Technology and STS	Male
7	Aiguo	Engineering	Male
8	Xiaojun	Engineering	Male
9	Keqin	Engineering	Male
10	Wei	Engineering	Male
11	Meizhen	Marxist Studies and Ethical Theories	Female
12	Aimei	Marxist Studies and Ethical Theories	Female

reflected the distribution of the academic background of engineering ethics instructors in China, as the majority of these instructors were trained in philosophy of science and technology and STS and very few of them were pure moral philosophers or what Davis calls “qualified moral theorists” [23,24]. All interviewees received their academic training at Chinese universities and none of them received degrees from Western universities. The “academic background” column in the following table lists the fields where participants received their doctoral degrees (in China today being a full time faculty member needs to have a PhD degree). All participants started to teach engineering ethics about the same time in early 2010s when engineering ethics was formally integrated into the engineering curriculum at the nation level.

All the guiding questions below were informed by the major issues summarized in the literature review section that were debated among Western (mostly American) scholars in 2000s when engineering ethics emerged as a scholarly discipline. The two authors of this paper discussed and agreed on all interview questions. These questions were translated to Chinese by the two authors and then verified by a third colleague who was not involved in this project. All the interviews were conducted in Chinese by the first author. Nevertheless, there are certain limitations with our approach to generating interview guiding questions based on our review of sources we chose from the Google Scholar database. For instance, it is worth noting that we did not conduct a systematic review of the complete engineering ethics education literature. Therefore, we need to conduct a more comprehensive, systematic review of the literature or add additional validity evidence (e.g., sharing our review findings with a group of domain experts who were not involved in this project) to ensure that our findings of the literature are reliable and valid.

Guiding questions for semi-structured interviews included:

1. Who are qualified for teaching engineering ethics? Or, who should be teaching engineering ethics?
2. What contents do you think should be taught or included in an engineering ethics course?
3. Do you think an engineering ethics should teach more on the individualistic professional responsibilities of engineers, the broader social and ethical implications of engineering and technology development, or anything else?
4. Should (Western) ethical theories (e.g., deontology, utilitarianism, virtue ethics) be taught?[4] Why and why not?
5. Based on your knowledge, what are some typical pedagogies for engineering ethics education in China? What pedagogies have you found effective? What pedagogies have you found less effective?

4. Findings

This section reports findings from the interviews we conducted with the 12 Chinese engineering ethics instructors. The findings include how Chinese instructors responded to some major questions concerning teaching engineering ethics in the United States that we summarized in the literature review section. The findings are organized in response to the five guiding questions in the interview protocol that were derived from a review of the engineering ethics education literature.

5. Who should teach engineering ethics?

Among all participants, all engineering faculty emphasized the *critical role of engineering expertise and experience* in teaching engineering ethics. Engineering faculty argued that instructors whose backgrounds were in the humanities had limitations in teaching engineering ethics. In particular, Aiguo summarized two major limitations of solely relying on humanities and social sciences professors in the teaching of engineering ethics at his institution:

> One issue is that the number of humanities and social sciences faculty cannot fulfill the teaching requirement …. Every year, our university recruits thousands of graduate students. As this course [engineering ethics] has become a required course for graduate students, even if one section can accommodate 200 students, we still need to have dozens of sections. In this sense, we are short of humanities and social sciences faculty who are able to fulfill this teaching requirement. The other limitation with having humanities and social sciences faculty teach engineering ethics is that they tend to overly theorize engineering ethics. Such overemphasis on theorizing engineering ethics might be okay to students with good humanities and social sciences background. However, for the majority of engineering students, their humanities and social sciences background is weak. These students will have challenges learning engineering ethics and keeping pace with the instructor. Finally, there will be some negative emotion towards engineering ethics among these students.

Engineering faculty also emphasized that effective engineering ethics instruction should be connected to engineering practice and be integrated into “*zhuanyeke* (specialized courses).” Xiaojun argued that the involvement of engineering faculty in engineering ethics education can “make the teaching more vivid” and “generate real impacts on

[4] Readers may wonder whether it is appropriate to include this question in the interview protocol. As one reviewer correctly pointed out that not all interviewees were trained in ethics, it is possible that those who were not trained in ethics may not know what exactly the three ethical theories are. The interview data showed that all of them demonstrated some understanding of the three ethical theories. One possible explanation is that all of the interviewees were all recommended by the government to use a common engineering ethics textbook edited by eminent Chinese scholars in engineering ethics which has a whole chapter devoted to the three ethical theories (like most engineering ethics textbooks in the United States). This is another example demonstrates some possible influence of American engineering ethics education in China.

engineering students."

Keqin suggested that governmental officials such as those who are responsible for investigating industrial work safety issues[5] should be involved in teaching engineering ethics. The reason is as follows,

> They [those governmental officials] possess more resources and information [about engineering accidents] than we [engineering faculty] do and they can provide good data. Most information we [engineering faculty] obtained was actually from the internet.

Compared to engineering faculty, most non-engineering faculty stressed the crucial role of either the *interdisciplinary collaboration between engineering faculty and humanities and social science faculty* or the *expertise from applied ethics, history of engineering, and STS* in engineering ethics education. They advocated that the perspectives of engineering ethics instructors need to be diverse. Xiaoqiang argued that engineering ethics instruction needs interdisciplinary collaboration and instructors need to include "ethicists, engineering faculty, and experts working in industry, especially the last group."

Furthermore, Xiaoli argued that the dialogue between ethicists and engineering faculty is more important and a critical method for facilitating such interdisciplinary dialogue is STS. Xiaoli discussed how the traditional role of ethicists and engineering faculty can be potentially transformed through the STS-informed dialogue:

> We as ethicists should conduct our theoretical work for engineering practice … An indispensable task for contemporary ethicists is to conceptualize the ethical issues in engineering practice … Earlier research in ethics studied human relationships. Ethicists today need to study a newer form of human relationship that is mediated by technologies and engineering practice … When I was communicating with engineering experts, they already realized some ethical issues in practice and they did know they needed to design for good and safety. However, they were not sure why they needed to do so [design for good and safety]. They lacked a kind of self-consciousness for ethical reflection.

Donglai felt worried that most engineering faculty were not well prepared for teaching engineering ethics and the most eligible instructors should be applied ethics faculty who know both ethics and professional practice. According to him,

> STEM faculty often do not have sufficient knowledge in ethics … Many of them do not know what the concept ethics is. When they teach engineering ethics later, their theoretical knowledge is significantly underprepared. They do not know anything about basic ethical rules, principles, or theoretical frameworks. They have never read any ethics works.

In contrast to Donglai, in terms of the eligibility of engineering faculty for teaching engineering ethics, Aimei placed more emphasis on assessing whether engineering faculty have "humanistic feelings" or moral sympathy. In her words, what she meant by "humanistic feelings" or moral sympathy was "a moral concern about the life and existence of humanity as a whole" or "a kind of benevolence or religious feeling." A good engineer should be able to "be empathetic to the harm and impacts on others" (Aimei). Aimei further explicated that most engineering faculty were educated in a culture of "realizing technological designs" and "overlooking any potential risks and harms associated with engineering practice." After becoming faculty, they will further "marginalize core values of the engineering profession such as public health and welfare … which have already been peripheral [in our society]" (Aimei).

[5] For instance, each level of the Chinese government has the Bureau or Department of Work Safety Supervision.

6. What should Be taught in an engineering ethics course?

A major approach to curriculum design in engineering ethics that emerged from most participants was the combination of "*zonglun* (general topics)" and "*fenlun* (subtopics)." *Zonglun* or "general topics" includes contents that are common to the engineering profession as a whole. In contrast, *fenlun* or "subtopics" discusses issues or cases unique to specific engineering fields (e.g., civil engineering, electrical engineering). Among the participants, most of their universities adopted a team-teaching model: general topics were often taught by humanities and social sciences faculty whereas subtopics were often taught by engineering faculty. Normally, new knowledge is mainly introduced in the teaching of general topics. When discussing subtopics, students are expected to apply the fundamental knowledge learned from general topics. When teaching subtopics, most engineering faculty either discussed specific cases in their own fields or shared their *own* practical experiences in their professional fields.

The following list summarizes the general topics that emerged from the interview data (to be included in the list, a particular topic had to be mentioned by at least three interviewees):

- Theoretical background
  - History of engineering
  - Philosophy of engineering (e.g., engineering epistemology, methodology)
  - Engineering as a social process (e.g., materializing social values, constrained by social norms)
  - Ethical theories and principle
- Decision-making methods and tools
  - Decision-making methods and tools from the Western textbooks (e.g., line-drawing)
  - Decision-making methods and tools from the Chinese/Confucian context (e.g., intuitive and emotional thinking, *zhengming*[6] or "rectifying names")
- Professional competency
  - "Typical" professional ethics issues such as conflict of interest, codes of ethics, etc.
  - Professional virtues, self-cultivation
- Social governance of engineering
  - "Engineering community": engineering is not defined as a profession practiced solely by engineers but a social enterprise that involves diverse stakeholders including engineers, workers, investors, managers, public, etc.
  - Collective governance: engineering ethics is a process in which responsibility is shared among all of these stakeholders in the "engineering community" and engineers only have limited responsibility.
  - The social role of professional societies
- Ethics of technology
  - Technological risk
  - Social impacts of technologies
  - The cultural context of technological design (mainly inspired by the national initiative "One Belt One Road")

[6] Zhengming (rectifying names) serves as a critical concept in classical concept. It mainly refers to the idea that all of the names or social roles (e.g., father, minister, son) we have are not simply describing who we are and what relationships we have with others but also providing normative assumptions and guidelines for living these social roles well [35]. Therefore, we need to reflect on a daily basis to what extent our words and actions are in accordance with the moral responsibilities prescribed by the names or social roles we occupy. For instance, an engineer needs to reflect on what means to be an engineer, what responsibilities are prescribed by the name "engineer," and whether her everyday words and actions accurately reflects her role as an engineer.

- Environmental ethics
- Engineering and social justice (e.g., justice in the distribution of interests)

7. Micro *vs.* macro Ethics in Engineering

In general, over half of the participants responded that engineering ethics should focus more on the micro ethics of engineering, or the responsibility of individual engineers than on the macro ethics of engineering. In comparison, only 5 out of 12 participants explicitly indicated that macro ethics should be more important or exclusively concentrating on micro ethics is unhelpful.

Among the advocates for micro ethics, their justifications for micro ethics were not all the same. The following reasons for supporting micro ethics emerged from the interview data:

- Engineers rather than the engineering projects they create possess moral agency (it is more "natural" to say engineer A rather than project B is responsible for outcome C) (Xiaojun)
- Macro ethics or the social and organizational ethics of engineering is "too vague" (Xiaoli). The social and organizational contexts of engineering are much more difficult than engineers to be changed. The discussion of social and organizational contexts may create a space in which *no actual person will be responsible.*
- The roles (e.g., employees, designers, etc.) engineers assume in the "engineering community" specify concrete *role responsibilities* for these engineers (Jianguo). However, Jianguo also warned that such role ethics approach has some limitations. For instance, not every individual engineer has well developed moral sensitivity and reasoning skills. They may justify that "yes, this is relevant to my role but I'm not willing to be fully responsible for it" (Jianguo). Eventually engineers will be proactively taking responsibility in their practice.
- Engineering ethics needs to be personalized. Students are all *different individuals. Personalized micro ethics* can motivate students to learn engineering ethics in class and make ethics relevant to their own life and career goals (Aimei).

Participants who preferred to teach macro ethics had the following justifications for macro ethics:

- Engineering ethics should focus on the *collective responsibility* of the "engineering community" rather than the individualistic responsibility of engineers (Aiguo). Engineers only have limited responsibility and responsibility needs to be distributed justly among all stakeholders. Aiguo argued that this approach is able to "defend the engineering profession" and assign appropriate responsibility to engineers that is proportional to their role in the society.
- Only teaching micro ethics creates an impression that "only engineers are responsible for engineering accidents and disasters" as well as a tension between engineering and humanities and social sciences (especially when humanities and social sciences faculty are teaching ethics to engineering students or they are discussing ethics with engineering faculty) (Meizhen). According to Jianjun, engineering ethics should not be limited to professional ethics and it needs to cover all stages of engineering that include diverse stakeholders. After they graduate, students may assume other roles in the "engineering community" than solely (design) engineers.
- The micro ethics that "simply tells what engineers need to do" overlooks the "larger context" of engineering practice (Donglai). In other words, the micro ethics approach that includes "decontextualized" ethical principles and regulations (most of them are "don'ts") for engineers. The micro ethics approach provides very limited (if any) guidance on what they need to do in a very complicated social context.
- The ethical principles emphasized in micro ethics "are nothing new." To a large extent, humans start to learn similar principles during early stages of moral development (Wei). For instance, we were all told to be honest when we were young. According to Wei, every engineering field has its own professional norms. Students may not know all of them but "they will and have to comply with these norms when they become practicing engineers." However, the technologies that engineers are dealing with every day "are more concrete" and "are closer to engineers' responsibility" (Wei). Engineering judgement arising from *reflective technological practice* is more important to engineers than codes of ethics.

8. Teaching ethical theories

Three out of four engineering faculty among the participants explicitly mentioned that ethical theories are necessary in engineering ethics education. Interestingly, they tended to employ an *engineering* perspective to justify the necessity and value of teaching ethical theories. To them, ethical theories are just comparable to scientific theories which serve as the foundation for modern engineering. Some engineering faculty (e.g., Keqin) emphasized the "guiding role" of these ethical theories in ethical analysis. Wei perceived ethical theories as something that ethical judgment can "depend on" to avoid subjective or personal views. Such role of "science" or "theories" in engineering is close to one of the four major dimensions of engineering proposed by de Figueiredo [36]: the dimension inspired by the basic sciences views engineering as the application of the natural sciences. Ethical principles are thus comparable to scientific or engineering principles. For instance, when being asked whether it is necessary to teach ethical theories, Aiguo replied,

> Yes, absolutely. We must teach [ethical theories]. This is because if you do not teach, when you are analyzing specific cases, we all know that we need theory and tools to analyze problems. Otherwise, how are you able to analyze and solve problems? Without [ethical] theories, your discussion can only be very general and superficial. Or, what you can only do is to approach a problem rather than analyze the problem, let alone solve the problem.

The idea of teaching ethical theories to students so that they can use these theories to analyze ethical scenarios in specific engineering fields or under so-called "subtopics" were echoed by other engineering faculty. For instance, As indicated by Xiaojun,

> Regardless of what program you are in, there are some common ethical theories which I think they are important … I think we must do some introduction [to these ethical theories]. Otherwise, if we do not have these theories as the foundation and start with teaching students subtopics [ethical cases in specific engineering fields], I feel that students will find no support or fundamental knowledge.

To some extent, most of these engineering faculty adopted an "applied ethics" approach to teaching engineering ethics, although they may not know the term in the ethics literature.

Meanwhile, Aiguo felt concerned about himself as an engineering faculty teaching ethical theories. Such a concern is well resonated with Davis's [23,24], critiques of the "usefulness" of moral theory in teaching practical ethics. As explicated by Aiguo,

> However, it is not easy at all to teach ethical theories well. I tried to seriously teach ethical theories but was not easy. Furthermore, different theories may lead to different conclusions sometimes they are in conflict with each other. How are we able to teach the conflicts between different theories? Given the conflicts between these theories, how are we able to guide students' thinking in their classroom learning?.. However, I feel obligated that we must teach students these conflicts between fundamental ethical theories.

In contrast to the engineering faculty, the humanities and social sciences faculty felt less optimistic about teaching ethical theories. For instance, Donglai felt concerned that ethical theories might be more interesting to graduate students in applied ethics programs than to engineering students. It is okay to mention the three ethical theories, but the theories should not become a focus in the curriculum. As further argued by Meizhen,

> if you want to teach students a comprehensive image of ethical theories, you may be very likely to turn the class into lectures. Students will not be then motivated to understand the meaning of these theories. These ethical theories may take too much of the class time as they are way too complicated.

Similarly, trained as an ethicist, Aimei remined that "all theories are not complete or perfect and deontology and utilitarianism have been fighting against each other for hundreds of years." Lecturing these theories might further confuse engineering students who have no formal training in philosophy.

Even if we want to teach the three classic Western ethical theories, some participants (e.g., Xiaoli) suggested that more emphasis should be placed on virtue ethics. In a similar way, Jianguo reminded us of the cultural context of the concept "virtue." According to him, unlike the Greek context in which technical competence could be considered as a kind of virtue, the Chinese context often separated technical competence from (moral) virtue. In the Confucian context, moral virtue is often superior to technical competence. It is fine that an engineer is morally competent but less technically competent. When evaluating an engineer, Jianguo suggested that we should start by looking at whether he or she has good (moral) virtues. If this engineer lacks well-developed virtues, no matter how technically competent such engineer is, he or she should not be called a real *good engineer*.

Others criticized that most classic ethical theories such as utilitarianism were derived from the Western context. Xiaoqiang felt worried that what puzzled him a lot when teaching Western ethical theories was "how to integrate these Western ethical theories with the Chinese context." For Chinese engineering practice, argued by Xiaoqing, "we need to find some Chinese thoughts and methods." Xiaoqiang further mentioned that Confucian (e.g., *zhengming* or rectifying names) and Daoist (e.g., *daofa ziran* or "the *Dao* takes its models from the nature") theories should be considered as potential resources for teaching engineering ethics.

9. Engineering ethics pedagogies in/for the Chinese context

Nearly all participants in this study mentioned that the most prevalent pedagogy for teaching engineering ethics is case studies. To a large extent, the prevalence of case studies in teaching engineering ethics in China was influenced by the classical American textbooks which often include a considerable number of cases. Nevertheless, some participants did notice that the case studies pedagogy does have some limitations that need to be overcome. Some participants challenged that the case studies pedagogy derived from the American context does not relate the cases to the specific learning needs, academic backgrounds, and professional goals of students. For instance, Xiaoqiang pointed out that "most cases are outdated now and we need to renovate the case studies ethics pedagogy." Aimei questioned that Chinese instructors using cases to teach engineering ethics often treat cases as the "experiment sites for theories." In other words, cases have become places where instructors expect students to simply apply the ethical theories and tools they learned in the classroom. One challenge with such approach is that students are often not motivated to fully engage in the discussion of these cases. Trained as an engineer, Wei argued that most cases used today are so far away from and thus irrelevant to students' interests and academic backgrounds. Therefore, both instructors and students lack sufficient technical knowledge and training for understanding the details of the cases. For instance, he questioned the use of cases such as the *Challenger* case. He suggested that some technical training is indispensable for making a good ethical judgment. In this sense, technical excellence and moral excellence cannot be separated.

Therefore, some participants advocated that effective ethics pedagogies for Chinese students should demonstrate some sense of *practical relevance* to students. Some typical practical approaches to engineering ethics education proposed by the participants are listed below.

- Xiaoqiang suggested that Chinese instructors consider teaching what he called "on the scene ethics." More specifically, he suggested that frontline engineers need to be invited to the classroom and share their everyday experience with students including the actual ethics cases they encountered in the workplace. And then students are invited to discuss these real cases within groups and with these frontline engineers. He argued that a strength of this approach was that both frontline engineers and students can both develop their interests and motivation when discussing real world engineering ethics issues: frontline engineers see the value of their experience for educating future responsible engineers and students find the relevance of these cases to the development of their professional identity and future career goals.
- In criticizing that most classical engineering ethics cases were outdated and happened many decades ago, Keqin suggested that engineering ethics education needs to incorporate social surveys into the classroom which were derived from Marxist movements in early 20th century [37]. More specifically, students are encouraged to go "into the field" and research current hot and yet controversial social topics related to engineering ethics, by conducting social surveys, interviews, and other empirical studies. Keqin argued that such practical approach to teaching engineering ethics can ignite students' passion for learning ethics. In addition, as argued by Keqin, students may share their reports with governmental regulatory agencies. Such approach further broadens students' understanding of the policy relevance of engineering ethics research.
- Similar to Keqin, Meizhen emphasized the practical relevance of engineering ethics for social and communal change. For instance, she asked her students to observe and reflect on the ethical significance of sociotechnical systems on campus and how to redesign these systems to cultivate moral values (e.g., frugality) that are upheld in the community.
- In his class, Wei focused on the practical dimension of engineering ethics education by incorporating what he might call "everyday engineering ethics." He often led students to discuss the ethical nuances of seemingly trivial everyday technologies such as cell phones and kitchen appliances. He argued that these micro cases were better than large scale disaster cases in bringing students' own personal experience and motivation into ethical reasoning.
- At her school, Xiaoli and her colleagues had been promoting a practical ethics education approach which she called "situational teaching" that invited engineering students to assume different roles in an engineering ethics case. Such approach is very much similar to the role play method that has been implemented in American engineering ethics education. The only difference might be that Xiaoli's situational teaching also emphasizes the involvement of an ethicist in the classroom who serves as a judge and provides feedback to students on ethical analysis and reasoning. Xiaoli further mentioned that emerging technologies such as virtual reality may be used to further improve the "situatedness" of learning engineering ethics cases.

10. Discussion

In this section, we systematically reflect on the empirical findings derived from this study with regard to how Chinese instructors perceived engineering ethics teaching. In doing so, we compare the findings derived from the interviews we conducted with 12 Chinese instructors with the insights from the American educators whose views were summarized in the literature review section. It is worth noting that we will not directly compare the views of Chinese instructors and those of the American educators whose works we chose to review. We want to use the views held by these American educators as a major "frame of reference" to make a clear contrast with the views held by Chinese instructors. We will try to avoid using the general term "American educators (or scholars)". Instead, we will compare the Chinese participants with *individual* American educators (rather than "American educators" as a group) included in the literature review section. A major reason for doing so is that the Chinese participants in this study and the American educators included in the literature review section are not groups that can be directly compared. The Chinese participants were chosen by the authors to do the interviews, whereas the American educators in this paper were not involved in any interviews. Instead, we learned their positions on the key questions with regard to teaching engineering ethics mainly from their published papers. The American educators we chose could hardly represent the whole group of "American educators" teaching engineering ethics.

In response to the question who are qualified for teaching engineering ethics, participants trained in engineering and those who were trained in non-engineering fields demonstrated different views on who should be teaching engineering ethics. Engineering faculty all emphasized the critical role of engineering expertise and experience in teaching engineering ethics. They also mentioned that it would be unrealistic and unsustainable to only rely on humanities and social sciences faculty to teach engineering ethics due to either: (1) there would be insufficient number of qualified humanities and social sciences faculty to teach engineering ethics given the large population of engineering students; or (2) humanities and social sciences faculty would focus too much on theories and thus disengage students.

In contrast, participants from non-engineering fields all embraced a more inclusive and broader view of teaching engineering ethics. While acknowledging the value of engineering expertise in teaching engineering ethics, most of them emphasized that such value could only be realized in interdisciplinary ways. In other words, effective engineering ethics teaching requires either (1) interdisciplinary collaboration between engineering faculty and humanities and social sciences faculty; or (2) expertise from fields that study engineering from interdisciplinary perspectives such as applied ethics, the history of engineering, and STS. The latter view calling for expertise from interdisciplinary studies of engineering is quite similar to Barry and Herkert's [11] view. Similar to Newberry's [12] and McGinn's [13] concerns, these non-engineering faculty expressed concerns that engineering faculty may not be prepared for teaching ethics to students due to the lack of training in ethics education among engineering faculty. Therefore, most institutions where the participants came from adopted the team-teaching model.

Furthermore, these non-engineering instructors emphasized the value of involving practitioners in engineering ethics education. These "practitioners" may include governmental officials who are responsible for investigating industrial work safety issues and practicing engineers. First, the perspectives of engineering ethics instructors need to be diversified. Engineering ethics issues are often multidimensional, complicated issues that involve more than just engineering and ethics perspectives. Teaching students practical ethical competencies in engineering calls for the inclusion of diverse perspectives including perspectives from not only engineering and philosophy but also legal studies, policy, management, and public administration. Second, the involvement of practicing engineers in engineering ethics education allows students to learn the tools, tactics, and practical wisdom that engineers often use to tackle with ethical problems or other ethical considerations (e.g., diversity and inclusion issues at work, cross-cultural ethical issues) which may not be included in most existing textbooks.

Regarding the curriculum of engineering ethics, most Chinese instructors mentioned that their schools adopted a model that combined "*zonglun* (general topics)" and "*fenlun* (subtopics)" while teaching engineering ethics. *Fenlun* includes those topics unique to specific engineering fields. It seems that these *fenlun* topics are similar to what McGinn [13] would call ethical studies integrated in technical courses. Nevertheless, the *fenlun* topics taught at most Chinese schools were in fact modules integrated in stand-alone engineering ethics courses (rather than technical courses) designed for students in particular engineering programs. Over half of the Chinese instructors agreed that more emphasis should be placed on the micro ethics of engineering or the responsibility of individual engineers. However, these Chinese instructors and the American educators mentioned in the literature review section employed seemingly distinct approaches to justify the value of micro ethics. To a large extent, American educators mentioned earlier in the paper tend to adopt a *professional* approach to defining engineering ethics or considering engineering ethics mainly as a professional ethic of engineers. For instance, Davis describes engineering ethics as mainly "special standards of conduct that apply to members of a group [such as engineering] just because of that membership" [38]; p. vii). Therefore, engineering ethics should mainly focus on the responsibilities of engineers as individual professionals. In contrast, the Chinese instructors employed more diverse approaches to define and justify micro ethics such as: (1) moral agency: only engineers as humans rather than technologies can be responsible; (2) role ethics: engineering ethics is mainly about the professional responsibilities prescribed by the specific role(s) (e.g., employee, designer, manager) that an engineer assumes in the engineering community; and (3) personalized ethics: engineering ethics education needs to serve the diverse learning needs and professional development goals of students who are distinct individuals.

In contrast to Herkert [14,39] who define macro ethics as ethical issues related to "the collective social responsibility of the profession and the societal decisions about technology" [14]; p. 374), Chinese instructors extensively expanded the concept of macro ethics in teaching engineering ethics. First, Chinese instructors replaced the term "engineering profession" with a much broader term "engineering community." The term engineering community includes other stakeholders (e.g., workers, investors, managers, the public) than just engineers. In this sense, Chinese instructors had a much broader understanding of engineering than Herkert [14,39]. In contrast to Davis [23,24] who attempts to prove that engineering is a universal concept that does not involve cultural variations, this study at least partly shows that Chinese faculty did hold a culturally sensitive understanding of engineering that focused on the cultural realities of engineering practice in China (e.g., the emphasis on large scale engineering projects and the engineering community). Furthermore, the Chinese instructors provided a culturally responsive justification for the inclusion of non-engineer stakeholders in the engineering community, that is, their students may assume other non-engineer roles in the engineering community after graduation. Thus it makes sense to have engineering students be aware of the collective social responsibilities of both engineer and non-engineer stakeholders. Therefore, macro ethics in this sense would be the collective social responsibility of all stakeholders in the engineering community that includes both engineer and non-engineer stakeholders. Second, Chinese instructors expanded the idea of macro ethics by including more diverse contexts of engineering practice. For instance, philosophical and historical backgrounds of engineering were integrated into Chinese textbooks. Also, the cultural (e.g., the Confucian tradition, intuitive and emotional thinking) and global (e.g., ethics for engineers working in cross-cultural contexts) contexts were also considered as central themes of engineering ethics education.

Compared to Harris [22] who emphasized the pedagogical value of ethical theories in teaching students moral reasoning, some Chinese engineering faculty adopted a more *instrumental* approach to justifying the value of teaching ethical theories. To these Chinese faculty, ethical theories are useful tools for analyzing and solving ethical problems, similar to scientific tools which are useful for solving engineering problems. However, other Chinese engineering faculty and most non-engineering faculty resonated with Davis's [23,24] concerns about teaching ethical theories, despite that it is unlikely they had read Davis's work. Like Davis, these Chinese faculty felt concerned that very few instructors would have sufficient training to teach engineering ethics, ethical theories are too complicated to teach, and ethical theories may take too much space of the curriculum.

Furthermore, Chinese instructors (particularly those who were trained in humanities and social sciences) paid close attention to the cultural context of ethical theories. Some Chinese instructors suggested that more emphasis should be placed on virtue ethics given its close connection with Confucian ethics which is *the* most influential school of thought in the Chinese tradition. Other Chinese faculty were striving for integrating Chinese ethical thoughts and methods into engineering ethics education. However, in the interview data, nearly none of these interviewees provided a clear justification for the central role of the Chinese tradition in reforming engineering ethics education. For Chinese instructors who were supportive of incorporating Chinese thoughts and methods into engineering ethics practice and education, they may need to justify why it is necessary to incorporate resources with the Chinese characteristics despite that engineering ethics textbooks introduced from the West have already included a handful of resources for teaching ethical decision-making in engineering. To justify the value of incorporating additional resources from the Chinese tradition, it seems that Chinese instructors need to respond to at least the following questions:

- Is engineering itself a locally situated practice or a "global profession"?
- Even if engineering is a local practice, can Western ethical theories provide any useful implications for the Chinese context?
- Why does solving ethical issues in Chinese engineering practice call for *Chinese* (instead of Western) thoughts and methods?

With respect to the pedagogies for engineering ethics education, similar to what Li and Fu [26] point out, Chinese instructors agreed that case studies was still a dominant ethics pedagogy. Nevertheless, some Chinese instructors shared similar concerns about the effectiveness of case studies as an ethics pedagogy with American STS scholars such as Kline [18] and Sunderland [28]. These shared concerns include: (1) most engineering ethics cases are outdated; (2) some of these cases are hypothetical and overly simplified for the convenience of applying ethical theories; and (3) the contexts of these cases are often disconnected from students' own professional interests and career goals.

Therefore, similar to most recent efforts in the United States, Chinese educators strived to explore more engaging and practically relevant pedagogies to teach engineering ethics. Similar to Voss [30], Wei encouraged his students to examine the ethical implications of everyday technologies which were seemingly too normal and trivial. Doing so can cultivate students' moral sensitivity and imagination.

More recently, as indicated in the literature review section, some American educators started to explore more interactive ethics pedagogies such as the employment of drama, fictions, and games in etthics education. In comparison, Chinese instructors were also interested in developing ethics pedagogies that are more practically relevant. These ethics pedagogies often aim to help students cultivate practical ethical competencies beyond the classroom. These ethics pedagogies advocated by Chinese instructors can be practically relevant in both *technical* and *social* senses. In the technical context, frontline engineers were invited to facilitate student group discussions on the real cases they encountered in the workplace. A major goal of such "on the scene ethics" was to bring students to the "scene" of engineering practice and help students cultivate practical wisdom that prepared them for emergent ethical issues at work. These emergent ethical issues can be more complicated and yet more realistic than the textbook cases. In the social context, some Chinese instructors integrated social surveys into their classrooms. Students were then asked to go into the field (e.g., society, campus) and investigate ethical issues by conducting primary, empirical research. Instead of teaching students with textbook cases that include secondhand sources prepared by other scholars, the social survey approach to teaching engineering ethics allows students to construct their own cases by collecting firsthand data. To Chinese instructors, (both social and technical) evidence is critical for making informed ethical judgment.

11. Conclusion

This paper adopts a cross-cultural methodological approach to examining how Chinese instructors perceive ethics education in engineering. In doing so, this study first teased out a set of most contested questions related to teaching engineering ethics that were concerned by some American educators in the 2000s and the 2010s. It then created an interview protocol based on these questions and examined how Chinese instructors perceive engineering ethics teaching through their responses to these questions. This paper also compared how the ways Chinese instructors perceived engineering ethics education are connected to and distinct from the views held by American educators discussed in the literature review section. Our study showed that the American scholars included in our literature review section and Chinese instructors in this study shared some similar responses to these questions. One possible hypothesis subject to future empirical research might be due to the global nature of the American-style engineering ethics. In other words, Chinese scholars started to be familiar with engineering ethics as an academic discipline through the introduction of the American-style engineering ethics including those American textbooks. Therefore, it seems natural to assume that Chinese scholars shared some concerns as some of their American colleagues as these concerns may pertain to the American-style engineering ethics *itself*.

Nevertheless, our study did show that there might be some cultural differences in the perceptions of engineering ethics education between Chinese instructors and the American educators whose views were discussed in the literature review. For instance, compared to the American educators whose views were summarized in this paper, it seems that Chinese instructors held a much broader understanding of the engineering community that includes non-engineer stakeholders. Chinese instructors were more sensitive to the issues related to the cultural contexts of engineering ethics including the necessity of integrating traditional Chinese ethical resources and creating culturally responsive cases. Chinese instructors advocated for a more collaborative teaching environment of engineering ethics that involves practicing engineers and governmental officials. Finally, Chinese instructors focused more on the relevance of ethics pedagogies to the technical practice (e.g., learning practical wisdom for tackling ethical problems from frontline engineers) and social practice (e.g., learning ethics through going into the field and collecting firsthand data) of engineering.

However, it is worth issuing some methodological caveats here. Some readers may question that whether the views we summarized in the literature review section can represent the whole group of "American educators" teaching engineering ethics. As we acknowledged earlier, we fully agree that the American educators whose views we selected certainly cannot represent diverse views held by all American educators. Therefore, our observations of these selected American educators are not generalizable claims. Our major goal of selecting and reviewing some American educators in the literature review section is to provide a quick and rough (also less rigorous) sketch of the main issues that engineering ethics educators in the United States have been debating on since the 2000s. Our goal is not to have a direct comparison of the Chinese instructors and the American educators included in the literature review. Rather, we thought the views held by such select group of American educators can be useful in serving as a "frame of reference" for the reader to have a clear understanding of the perceptions of Chinese instructors.

In conclusion, we want to make some very general and preliminary recommendations for teaching engineering ethics in a cross-cultural context. First, Chinese instructors need to be critical of their own cultural contexts of engineering education and the underlying assumptions of the American-style engineering ethics, when they are trying to reform and globalize their engineering ethics curriculum. While they are importing the American-style engineering ethics into the Chinese context, they need to critically examine the cultural adaptability of Western resources and whether these Western resources are aligned with the goals of Chinese engineering education. Second, American educators need to expand their scope of engineering ethics education and develop a cultural sensitivity toward teaching engineering ethics. Some worthwhile reflective questions for them might include: (1) how to teach American students to be critical of the assumptions and ideologies underlying their own engineering ethics curriculum? (2) are there any ethical thoughts, cases, and pedagogies from other cultures that can help cultivate the moral creativity of American students? and (3) what does it mean to be a competent engineer in the global context? We sincerely hope that our paper can contribute to a much larger and more ambitious initiative on global engineering education that unifies (rather than divides) engineers from different cultures with a shared goal of promoting welfare for the whole humanity.

Credit author statement

Hengli Zhang: Conceptualization; Methodology; Resources. Qin Zhu: Formal analysis; Investigation; Writing – original draft; Writing – review & editing.

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