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Ethically Informed Intellectuals or Responsible Professionals? A Comparative Study of Engineering Ethics Education in China and the United States

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Abstract

This paper compares the historical trajectories, objectives, and practices of engineering ethics education in China and the United States. A comparative study like this contributes in several ways to the education of ethical and culturally-sensitive engineers in both countries. First, as engineers increasingly work in international teams and deploy projects outside their home countries, knowledge about ethical values emphasized in other cultures will help educators prepare students to practice engineering in ways that respect local values and ethical standards. Second, as engineering programs—especially those in the US—attract a great number of students from abroad, understanding international students' ethics training in their home countries will help engineering educators anticipate and accommodate their learning needs. Third, a comparison of the theories, practices, and challenges of ethics teaching in two of the world's leading countries in engineering education will serve as a starting point for a cross-national conversation about the opportunities, strategies, and best practices for educating ethically committed global engineers.

We start our analysis by reviewing the history of engineering ethics education in the US and China. Following that, we examine major theoretical debates that illustrate the core questions, concepts, and approaches that attract American and Chinese engineering ethicists' attention. Next we compare some exemplar curricular and instructional strategies adopted by educators in each country to facilitate engineering students' ethics learning.

Findings of this comparative study suggest that engineering ethics education in China and the US reflect distinct characters that result from different political, intellectual, and professional influences on engineering education. In particular, engineering ethics education in China has demonstrated a stronger emphasis on theoretical knowledge, whereas ethics teaching in the US focuses more on ethical decision-making in engineering practice. We suggest that the differing emphases result partly from Chinese scholars' attempt to establish engineering ethics as an academic discipline, and, compared with its counterpart in the US, a weaker professional identity for engineers in China.

We conclude this paper by summarizing lessons engineering ethics educators in both countries might learn from each other. We also suggest a few questions for future research that will help elucidate the respective intellectual and professional impacts on engineers' ethics learning in China and the US.

Introduction

President Trump's recent executive order that banned immigrants from seven Muslim-majority countries from entering the United States illustrated two points relevant to the focus of this paper: First, the immigration ban made it all too clear that the ethical impact of local and domestic decisions often extends beyond national borders. Such is also the case with engineering, for engineers' choices of materials, supply chain, and ways of production often impact global economy, environment, and geopolitics. Second, the Silicon Valley's strong reactions to the immigration ban signified the important role international engineers play in the US tech industry. For engineering educators, the immigration ban was but a fierce wave in a torrent of incidents that demanded our attention to the international dimension of engineering ethics. In particular, how can we prepare students to act responsibly with regard to the global impact of engineering? How can ethics education connect with students who come to study engineering from outside the US? And more importantly, how can engineering educators in the US reflect on their own ethical commitments in light of the ethical values and principles embraced by different nations and cultures? We argue that productively responding to these questions requires a cross-national conversation about engineering ethics in different nations and regions. In this paper, we contribute to such a cross-national conversation by comparing engineering ethics research and education in the US and China, arguably two of the most important nations for engineering education in the world.

We begin this paper by reviewing the historical evolution of engineering ethics in the US and China. Following that, we examine some major theoretical debates that illustrate the core questions, concepts, and approaches that attract American and Chinese engineering ethicists' attention. Next we compare some exemplar curricular and instructional strategies adopted by educators in each country to facilitate engineering students' ethics learning. We conclude this paper by highlighting some major differences between engineering ethics education in the US and China. We also summarize some lessons engineering educators in both nations might learn from each other.

Historical Pathways for Engineering Ethics in the US and China

The evolution of the concept engineering ethics in the US reflects the concerns, ambitions, and worries of the engineering profession as the latter grows and adjusts itself to changing historical context in the past one and a half centuries. The earliest engineers in the U.S. were trained not in technical schools but in actual engineering projects. For example, the building of the Erie Canal in the early 1800s provided the "field school" for training the first batch of civil engineers in the US [1]. During the second half of the 19th century, the concept of professional ethics was still in its infancy in North America. In 1847, the American Medical Association (AMA) created the nation's first code of professional ethics [2]. Compared with the medical profession, engineering societies in the 19th century acted somewhat like clubs for reputable and accomplished engineers. When it was suggested that the American Society of Civil Engineers (ASCE) should follow AMA and create a code of ethics for engineers, most ASCE members considered an ethics code unnecessary, for they believed that the ASCE membership was in itself a proof of technical excellence and respectability [3].

This state of affairs started to change by the end of the 19th century, when professional engineering societies sought to affect engineering licensure laws by creating their own model laws [3] [4]. In 1912, American Institute of Electrical Engineers (AIEE) became the first major national engineering society to adopt a code of ethics (AIEE, 1912). As philosopher Mitcham observes, early engineering codes of ethics often emphasized engineers’ responsibility to their employers and clients [5]. “Loyalty” was considered a central value of engineering ethics during this period.

After World War II, educational reformers sought to broaden engineering ethics by teaching the social implications of technology. In the following two decades, ethical thinking in the engineering profession was inspired and enriched by social movements for environmental protection, civil rights, and ending the Vietnam War [6]. Such a reorientation of engineering ethics to public issues is reflected in the “Fundamental Canons” of engineering ethics, which started with the statement that engineers “shall hold paramount the safety, health, and welfare of the public” [7]. As a consequence of this “public turn,” engineering ethics became “a field of sustained scholarly publication” and a regular component of engineering curriculum in the 1980s and 1990s [5]. Ethical thinking in the 21st century has drawn engineers’ attention to emerging challenges facing humanity, such as sustainability, transportation, urbanization, and public health. To address humanity’s most urgent challenges, teaching of engineering ethics is incorporated into holistic reforms of engineering education, which seek to adapt the engineering profession to recent global economic and technological development [8].

Although some scholars recognize the influence of ancient Chinese philosophy on contemporary engineering thinking and practice in China, formal research of engineering ethics did not start in China until the 1990s [9] [10]. Dong’s article, “The Background and Status Quo of Engineering Ethics Education in the United States,” published in 1996, is the first academic publication in the Chinese literature on engineering ethics [11]. The publication of Xiao’s *Engineering Ethics* [*Gong Cheng Lun Li Xue*]—the first monograph on this topic—in 1999 marked the birth of engineering ethics as a field of academic research in China [12] [13]. In the decade that followed, however, discussions of engineering ethics remained largely an intellectual exercise, attracting primarily philosophers. During this period, Chinese scholars continued to introduce and translate works on engineering ethics from the US, Germany, and Japan. Meanwhile, Chinese ethicists and philosophers of technology localized foreign theories on engineering ethics. However, these intellectual accomplishments had little effect in altering the educational practice in engineering schools, most of which remained largely indifferent to ethics education.

In 2007, the first National Conference on Engineering Ethics took place in Zhejiang University. Participants of the conference discussed major theoretical issues for engineering ethics in China. The conference also provided an avenue for sharing practices of engineering ethics education. Presenters at the conference explained the urgency of incorporating ethics into engineering education in China [14]. Two more conferences on engineering ethics took place in 2009 and 2012. Presentations at these later conferences still focused on the intellectual and institutional barriers for teaching ethics to engineers, and few presenters reported actual experience of teaching engineering ethics. A quantitative study of published articles on engineering ethics in China also confirms the underdevelopment of educational practice [15]. In addition, a survey of 1000 engineering students at a technical university reports that 96.2% of survey respondents did not think, or did not know if their institute had a mandatory course on engineering ethics, and 93.6% of survey respondents did not think, or did not know if their institute offered an elective course on engineering ethics [16].

More recently, some major institutes of engineering education in China, such as Tsinghua University, Zhejiang University, and Beijing Institute of Technology, have played leading roles in exploring and disseminating pedagogical tools for integrating ethics into engineering education. In 2014, Tsinghua University hosted "Engineering Calls for Ethics: A Forum on Engineering Ethics Education." The forum featured engineering administrators, professional ethics instructors, and representatives from industry and the engineering profession. A milestone for engineering ethics education appeared in June 2016, when China became an official member of the Washington Accord. The Washington Accord requires its members to meet international standards for educating engineers, including educating students in ethics. Driven by this external requirement, the National Advisory Committee for Graduate Education for Engineering Professional Degrees has coordinated a series of programs, including publishing a new textbook and sponsoring the development of a MOOC on engineering ethics [17]. The National Advisory Committee is also organizing four advanced seminars on engineering ethics between 2016 and 2017. The goal of these seminars is to train engineering ethics instructors for over 400 colleges and universities that offer engineering degrees. As of this writing, over 200 engineering faculty members have attended the first two advanced seminars.

Major Debates

The purposes of engineering ethics education as well as effective methods of teaching are objects of ongoing debate in the US. American engineering ethics educators often embrace one of three major approaches: a deontological approach that emphasizes professional codes of ethics, a sociological approach that stresses the social context of engineering, and a critical approach that highlights the need to unpack and question dominant assumptions in engineering thinking and professional practice.

Deontology is a branch of moral philosophy that emphasizes compliance to a set of ethical rules [18]. A rule-based approach often places professional codes of ethics at the center of ethical engineering and urges engineers to follow their codes. For example, Davis suggests that a code of ethics provides a bounding convention for all members of a profession [19]. Without such a convention, Davis argues, those who act in accordance to ethical principles will be uncertain whether ethical actions work to their disadvantage when they compete with other professionals [19].

The sociological approach is embraced by a number of scholars in the field of science and technology studies (STS). Following philosopher Ladd, Herkert distinguishes between microethics and macroethics in professional engineering: microethics concerns individual engineer's actions and her interaction with the profession, while macroethics evaluates the dynamics between an entire profession and society [20]. According to this definition, few engineering codes of ethics discuss macroethical questions, such as the social impact of engineering projects and how engineering work creates winners and losers. Therefore, the sociological approach to engineering ethics emphasizes the complex political, economic, cultural, and social contexts in which engineering work takes place. Ethics teaching inspired by the sociological approach attempts to help students examine the ways in which engineering choices are shaped by, and shape in turn, the broad contexts. The sociological approach not only questions the ethical and social implications of engineering but also seeks ethical intervention. The intervention approach has manifested itself in cases like the universal design movement [21].

A third, emerging approach to engineering ethics places the engineering profession under scrutiny. This critical approach to engineering ethics examines the fundamental values and assumptions upheld by the engineering profession as well as their ethical and political implications. For example, scholars of engineering studies argue that engineers' collective ethical commitment is but one facet of the profession's struggle for professional identity, status, and interests [3] [22] [23]. According to this analysis, unpacking the epistemological assumptions undergirding engineering thinking provides a pathway to evaluate the engineering profession's priorities, ambitions, and concerns. Following the critical approach, a series of studies investigate how engineers represent the technical and non-technical components in formalized engineering knowledge. This body of research identifies a "technical/social dualism" embodied in engineers' habitual ways of thinking [24] [25] [26]. Critical scholars of engineering argue that this dualist thinking not only marginalizes the non-technical aspects of engineering but also steers engineers' attention away from questions of discrimination, injustice, and other political and ethical repercussions of engineering work [27] [28] [29] [30].

From the very beginning, scholars in China have consciously sought to establish engineering ethics as an academic discipline. This enthusiasm stems in part from the fact that disciplinary status in the academic ecology of China in important ways shapes the institutional legitimacy of an academic field and the amount of resource it receives. As a result, the pursuit of disciplinary status provides the most important context for major debates among scholars of engineering ethics in China. That is, whether this emerging discipline should prioritize the development of systematic ethical principles for engineering (principle-orientation) or the analysis of particular ethical issues in engineering practice (issue-orientation). Advocates of the principle-orientation, inspired in part by the example of bioethics, argue that engineering ethics warrants a comprehensive system of principles and methods [31]. However, the majority of engineering ethics scholars prefer to analyze particular ethical issues and challenges generated in engineering practice. In particular, scholars have named four major issues for ethical analysis in engineering: risk, engineering decisions, loyalty, and the relation between engineering and the environment [14]. Meanwhile, a number of Chinese scholars have examined conflict of interest in engineering [13]. While studies of conflict of interest in the US tend to focus on engineers' competing loyalties (e.g., to employers, clients, and the public), scholars in China have redefined this concept to describe four types of broader conflict: the conflict between engineering and other professions; the conflict among different stakeholders; the conflict between engineering and society; and finally, the conflict between engineers' competing obligations [32] [33] [34] [35].

Another contribution made by Chinese engineering ethicists is the extension of ethical agency from engineers to a broader, collective "engineering community," which includes not only engineers but also "workers, managers, investors, and other stakeholders" [36]. Designating ethical agency to the broader engineering community, Li elaborates three levels of ethical issues: micro, meso, and macro. According to Li, micro engineering ethics examines the choices made by individual members of the engineering community; meso engineering ethics focuses on the ethics of organizations, such as business ethics and corporate ethics; and macro engineering ethics looks at national and global issues, such as climate change [36].[1]

Chinese scholars have also critically assessed the methodological limitations of engineering ethics research in China. Drawing from a quantitative analysis of publications on engineering ethics in Chinese language, Wang and Liu argue that Chinese engineering ethics researchers rely overwhelmingly on philosophical analysis [15]. They attribute this lack of methodological diversity to the "grand narrative" tradition that strongly affects humanities and social sciences in China. Others have called for more active utilization of empirical and quantitative methods in ethics research [37]. Arguing that the ethical dimension interacts with and penetrates other—e.g., the economic, technical, and environmental—dimensions of engineering, Li suggests a holistic and interdisciplinary approach to engineering ethics that incorporates the insights of the emerging field of engineering studies [38] [39].

Curricular and Instructional Strategies

In the US, much of the intellectual dialogue on engineering ethics is manifested in engineering education. Programs of engineering ethics education in the US often follow one of three popular curricular formats [40] [41]. The first is a semester long, stand-alone ethics course. Instructors of the engineering ethics course might come from engineering, philosophy, or other disciplines of humanities and social sciences, and sometimes the course is co-taught by instructors from technical and non-technical disciplines. A full course on engineering ethics allows students to explore relevant conceptual frameworks, such as ethical or social theories, and to apply the ethical frameworks to issues in engineering. In spite of its advantages, offering a stand-alone course in engineering ethics can be challenging. First, it is difficult to staff the course with faculty members who have expertise in both ethics and engineering, yet such expertise is required in order to teach ethical reasoning in ways relevant to the engineering profession. Second, many engineering programs find it difficult to require a full course in ethics, as engineering students already take more credits than many other majors. Third, research shows that effective ethics education requires students to experience ethical reasoning more than once [40]. Confronted by these challenges, many engineering programs choose a second approach: instead of offering a stand-alone ethics course, they distribute ethics education into a number of units (or "modules") and arrange these ethics modules in several technical courses. An ethics module is often designed to explore ethical issues relevant to the technical contents covered in the course. For example, a hydraulics course might examine the environmental and social ramifications of dam construction. Engineering design courses routinely include ethics modules, as engineers frequently interact with humans, institutions, and policies in design activities. In order to provide students with a consistent experience of ethical reasoning, some educators have embraced the "ethics across the curriculum" approach. Ethics across the curriculum usually involves training engineering faculty members in ethics instruction and supporting them to develop ethics

[1] Li derives the categories "micro," "meso," and "macro" from economic theory, and it is not clear whether he has been influenced by American scholars'—e.g., Ladd and Herkert's—discussion of micro-ethics and macro-ethics.

modules [42]. In this case, the ethics modules are carefully designed and coordinated to form an "ethics spine" throughout the engineering curriculum. This arrangement allows students to experience ethical reasoning in at least one course every academic year. The order of the modules facilitates incremental development of students' ethical literacy [43] [44].

Besides curricular development, ethicists and educators in the US have developed a number of pedagogical strategies for teaching ethics to engineering students. Ethics case study has been the most widely used pedagogical tool for teaching engineering ethics [41]. Research finds that case study allows students to grapple with complex factors that affect ethical choices in situations similar to the professional context [40]. While case study provides a clear and actionable structure for practicing ethical problem identification and solution, this method also encounters several limitations: first, the step-based method for analyzing ethics cases runs the risk of misrepresenting ethical reasoning as a linear process. Second, the relatively short timeframe for case analysis (usually no longer than one class session) makes it more congenial to exploring ethical problems with limited scope and complexity. As a result, ethics case study has appeared more effective for analyzing microethical questions.

As an alternative to case study, some educators prefer service learning as a means to help students engage more complex ethical challenges and critically examine the "engineering ideology" [45]. In service learning, students work on engineering and design projects that seek to serve underprivileged population in local or international contexts. Compared with ethics case study, service learning projects are usually broader in scope, spanning from several weeks to a whole semester. The project-based learning also allows students to work in teams and to tackle real world problems. To understand user needs, students often start their projects by observing or talking to their end users. The design solutions are sometimes presented to the users or deployed at the project sites, so that students could receive feedback from the users. It is suggested that direct interaction with the users encourages students to develop respect for different groups and to value different perspectives. Analyzing the needs of underprivileged population also provides opportunities for students to investigate the political, social, and economic factors related to engineering problems. These features make service learning a more appropriate medium for students to engage macroethical questions, such as sustainable community development and social justice [46].

In China, the government mandates learning of Two Courses [*Liang Ke*]—studies in Theory of Marxism and Political Ideology—for all college students. Consisting of four to six courses, the Two Courses curriculum takes a large proportion—sometimes almost the entirety—of students' general education credits in many universities and colleges. Therefore, the Two Courses requirement provides one of the most important contextual factors for engineering ethics education in China. Because the mandatory courses in political ideology also aim to assist students' moral and cultural development, many engineering departments find it convenient to incorporate some professional ethics in political ideology courses. As a result, instructors of political ideology courses, who belong to the faculty of humanities and social sciences, often take the lead in educating students about the ethical significance of engineering. In contrast, few engineering faculty members are involved in ethics education.

Scholars in China have explored and envisioned more systematic ways of teaching engineering ethics. For example, Cong suggests three objectives for engineering students' ethics education: 1) understanding the social and practical implications of engineering; 2) awareness of ethical norms that govern engineering; and 3) ethical sensitivity, moral judgment, and moral willpower [39]. These objectives indicate an attempt to integrate deontological and STS perspectives of engineering ethics. However, curriculum design for engineering ethics in China has remained largely a topic of intellectual exercise. In educational practice, the most common curricular format of engineering ethics education—apart from its coverage in the Two Courses curriculum—has been stand-alone ethics courses taught by humanities and social sciences instructors, and the primary instructional method has been lecturing [47] [48]. Although scholars have proposed internship as an alternative for engineering students' ethics learning, no such educational programs have been reported in literature [47] [49]. Some scholars believe that the lecture-based approach has the advantage of introducing a systematic body of ethical theory and knowledge to students, yet they recognize that this approach has limited efficacy in preparing students to identify and address ethical problems in engineering practice [47] [48].

Conclusion

In this paper, we suggest that engineering ethics in the US originated from professional engineering. In contrast, engineering ethics in China first appeared as a field of academic research, thanks to scholars who introduced engineering ethics research and education from abroad. Whereas engineering ethics in the US remains an important concern by professional engineers, it has developed primarily as the object of an academic discipline in China. The different origins of engineering ethics in the US and China have shaped the respective research focus of ethics scholars in both countries. Major theories of engineering ethics in the US respectively emphasize professional codes, the social context of engineering, and critical reflection on the "engineering ideology." In contrast, ethics scholars in China pay more attention to high-level questions that help define the field, such as the choice between principle-orientation and issue-orientation in engineering ethics research. Based on the social conditions in China, scholars have also expanded some concepts in engineering ethics. For example, Li suggests that the ethical agency lies not in engineers alone but in the broader engineering community, a concept that includes not only the engineers but also other stakeholders of engineering activities. Engineering ethics education in the US has attracted the participation of faculty from multiple disciplines (e.g., engineering, philosophy, social sciences, communication, etc.). Consequentially, a variety of curricular and instructional approaches have been pursued to help students engage the ethical implications of engineering practice and maintain the ethical standards of the engineering profession. Due to its current curriculum structure and the underrepresentation of engineering faculty members, engineering ethics education in China still relies on conventional curricular and instructional strategies. However, we might expect innovations as China officially joins the Washington Accord and takes initiatives to train engineering faculty in ethics education.

This comparative study reveals several lessons engineering ethics educators in the US and China might learn from each other. To begin with, the American engineering profession's active involvement in ethics education provides one of the most illuminating lessons for engineers and engineering educators in China. Emphasis on ethics by professional codes and the inclusion of ethics in accreditation standards and the "Fundamentals of Engineering" exam provide strong institutional incentives for engineering students to engage ethics learning. Professional engineers and engineering faculty members' participation in ethics education also helps maintain a close tie between ethical learning and the actual ethical challenges one might encounter in the professional context. Although China is a latecomer compared with the US, engineering ethics research in China has demonstrated some "second-mover advantages." For example, Chinese scholars are very well aware of the research and educational progresses made by engineering ethicists in the US and Europe; as a result, intellectual conversations about engineering ethics in China are much more internationally-oriented. Moreover, as the methodological debate indicates, the engineering ethics community in China is very actively engaged in critical reflection of its own limitations.

Moving forward from this preliminary comparison, we suggest a few questions for future research. First, a study that examines the disciplinary background of engineering ethics researchers and educators in China and the US might reveal how different disciplinary traditions affect approaches to engineering ethics in the two countries. Second, it is imperative to extend this bi-national comparison to other nations and regions. For example, we intend to pursue a study that compares the main contents of engineering ethics education in China, Europe, and the US. Such a comparison would shed light on different perceptions of ethical engineering from educators' standpoint in the respective nations and region. We also plan to study engineering ethics education in other countries.

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