Exploring the relations between ethical reasoning and moral intuitions among Chinese engineering students in a course on global engineering ethics

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Abstract: Research in engineering ethics has assessed the ethical reasoning of students in mostly the US. However, it is not clear that ethical judgments are primarily the result of ethical reasoning, or that conclusions based on US samples would be true of global populations. China now graduates and employs more STEM (science technology engineering and mathematics) majors than any other country in the world, but the moral cognition and ethics education of Chinese engineers remains understudied. To address this gap, a study was conducted examining the relations between ethical reasoning, moral intuitions, and ethics education among engineering students in China. Engineering students at a university in Shanghai, China completed measures of ethical reasoning and moral intuitions before and after a course on global engineering ethics. Among engineering students in China, (1) ethical reasoning is positively related to an emphasis on care and fairness and (2) global ethics education results in significantly higher levels of ethical reasoning, as well as a greater concern with fairness and loyalty. Whereas the relation between ethical reasoning and moral intuitions among engineering students in China is similar to that of students in the US, ethics education affects engineering students in China differently from their US counterparts. (200 words)

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1 Introduction

Engineering ethics has largely developed as a normative discipline, concerned with questions of right and wrong – what should and should not be done, and why – within engineering and regarding technology. These questions have typically had an educational objective, training engineers and those working with technology in ethics (Harris, Davis, Pritchard, & Rabins, 1996; Harris, Pritchard, Rabins, James, & Englehardt, 2018; Hess & Fore, 2018; Van de Poel & Royakkers, 2011; Zhu, Martin, & Schinzinger, 2022). Given these objectives, recent work has explored engineering ethics empirically, for example, what engineering students and faculty think about ethics (Burt et al., 2013; Falcone, Glynn, Graham, & Doorley, 2013; Holsapple, Harding, Carpenter, Sutkus, & Finelli, 2013; McGinn, 2003), and dishonest behaviors among students and practitioners (Carpenter, Harding, Finelli, & Passow, 2007; Harding, Mayhew, Finelli, & Carpenter, 2007). Most of this work has been carried out in the US and with US participants[1],

[1] There are a number of notable exceptions, and work has begun to grow in recent years, including research on engineering ethics education in Australia (Staehr & Byrne, 2003), Argentina (Monzon, Ariasgago, & Monzon-Wyngaard, 2010), Switzerland (Picard, Hardebolle, Tormey, & Schiffmann,

exploring the effects of educational interventions on ethical knowledge and reasoning (Borenstein, Drake, Kirkman, & Swann, 2010; Drake, Griffin, Kirkman, & Swann, 2005; Hess, Beever, Zoltowski, Kisselburgh, & Brightman, 2019; Loui, 2005). In engineering education research, ethical reasoning has tended to be conceived along "neo-Kohlbergian lines."

On this view, ethical reasoning consists in the application of normative principles to resolve ethical issues, questions about right and wrong, regarding what should or should not be done. These principles belong to three different "schemas," ways of thinking about matters of right and wrong, which can be more or less advanced and are responsible for distinctive styles of ethical reasoning/normative judgments. These consist in (1) the preconventional schema, reasoning on the basis of self-interest alone, (2) the conventional schema, reasoning on the basis of law and other social conventions, and (3) the post conventional schema, reasoning on the basis of universal principles (Kohlberg, 1984; Rest, Narvaez, Bebeau, & Thoma, 1999a; Rest, Narvaez, Thoma, & Bebeau, 2000). On this view, ethics is about one thing (moral monism) rather than many (moral pluralism), where the universal principles on which a distinctively ethical type of reasoning are based consist in a concern with justice or care alone (Graham et al., 2018; Haidt, 2012).

Although work is ongoing, initial conclusions indicate that standalone courses in engineering ethics are more effective than integrated modules, but more time spent on ethics does not necessarily result in better learning outcomes (Antes et al., 2009; Drake et al., 2005). However, as

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2021; Tormey, LeDuc, Isaac, Hardebolle, & Vonèche Cardia, 2015), Chile (Murrugarra & Wallace, 2015), Malaysia and Japan (Balakrishnan, Tochinai, & Kanemitsu, 2018; Balakrishnan, Tochinai, Kanemitsu, & Altalbe, 2021), and China (Clancy, 2020b; Clancy, Ge, & An, 2022).

with other psychological and sociological findings, it is not clear that these results would be true outside the US or with non-US populations.

US participants belong to WEIRD (Western educated industrialized rich and democratic) cultures, which are outliers on various psycho-social constructs, including self-concepts, thought styles, and ethical reasoning (Henrich, 2020; Henrich, Heine, & Norenzayan, 2010). Non-WEIRD populations tend to conceive of ethics in terms broader than justice or care alone (Haidt, 2012; Shweder, Much, Mahapatra, & Park, 1997). Conclusions based on these samples are, therefore, unlikely to be representative of groups from different cultures. For engineering, this is problematic, since engineering and technology are more cross cultural and international than ever before (Clancy & Zhu, 2022; Luegenbiehl & Clancy, 2017).

In engineering, one cannot assume a shared basis of cultural or national values or professional standards among students, faculty, or coworkers, raising the question of how to approach global engineering ethics, engaging all affected parties (Clancy, 2021; Luegenbiehl & Clancy, 2017; C. Murphy, Gardoni, Bashir, Harris, & Masad, 2015; Wong, 2021; Zhu & Jesiek, 2017). Disturbingly, research has found that international students make smaller gains in engineering ethics education, but it has not always been clear whether this is a result of language or culture – lower English-language proficiency or cultural differences (Borenstein et al., 2010; Canary, Herkert, Ellison, & Wetmore, 2012). Subsequent research has provided support for a cultural explanation: Culture rather than language is responsible for lower ethical reasoning scores among foreign students (Clancy, 2020a). However, even if education were successful in raising the ethical reasoning abilities of all national groups equally, it is not clear that reasoning or knowledge result in more

ethical judgments. As a result, assuming ethical judgments are a goal of engineering ethics education, it is not clear that ethical reasoning or knowledge should be a primary focus of engineering ethics education. A growing body of work has shown that behaviors can be affected by unconscious, environmental factors (Bazerman & Tenbrunsel, 2012; Doris, 2005), and that ethical judgments involve intuitions, closer in nature to emotions than reasoning (Greene, 2014; Haidt, 2012; Roeser, 2018).

Whereas ethical reasoning consists in the slow, reflective process of applying principles to resolve issues, intuitions consist in spontaneous, pre-reflective reactions to situations. In research on moral psychology, the relations between ethical reasoning and intuitions have not always been clear. Some have claimed that moral intuitions simply operate more in some situations and contexts than others (Greene, 2014) – especially situations involving direct harm to identifiable individuals – whereas others have claimed that ethical judgments are overwhelmingly the result of moral intuitions – reasoning only steps in to justify judgments once they have been made (Haidt, 2012). On this view, moral intuitions cover a wider range of contents than justice or harm alone. For instance, moral intuitions would also concern loyalty and adherence to authority (Haidt, 2012). Additionally, if ethical reasoning and knowledge alone resulted in more ethical behaviors, then professional ethicists – arguably the most knowledgeable and skilled in ethical reasoning – would behave the most ethically, but research has consistently failed to find evidence to support this assumption (Schönegger & Wagner, 2019; Schwitzgebel & Rust, 2014).

To date, research on engineering ethics education has: (1) focused on ethical reasoning; (2) among engineering students in US populations. However, it is unclear whether (1) the ability to reason

ethically alone results in more ethical judgments or behaviors, or (2) US populations are representative of global, non-WEIRD ones. As a result, the current study sought to explore the relation between and assess the effects of education on ethical reasoning and moral intuitions, and to do so among students in a non-WEIRD country. It did so by administering a survey comprised by the ESIT (Engineering and Science Issues Test), measuring ethical reasoning, and the MFQ (Moral Foundations Questionnaire), measuring moral intuitions, on the first and last day of a course in China on global engineering ethics. Better understanding the relation between moral intuitions and ethical reasoning among an understudied population allows for the possibility of crafting more effective, culturally responsive ethics education.

2 Materials and Methods

2.1 Research Contexts and Participants

Participants were undergraduate engineering students enrolled in the course "Global Engineering Ethics" (GEE) at the University of Michigan-Shanghai Jiao Tong University Joint Institute (UM-SJTU JI). The UM-SJTU JI is a US-Chinese educational institute founded in 2006 and located in Shanghai Jiao Tong University (SJTU). It offers BS, MS, and PhD degrees in engineering, and has programs in mechanical engineering and electrical and computer engineering. Engineering education at the UM-SJTU JI is modeled on that at the University of Michigan (UM), which explains its focus on ethics education for engineering students. To partially fulfill ABET student outcomes related to ethics, the UM-SJTU JI offers GEE. GEE is a required, two-credit-hour course that students typically take during their junior or senior years, and it is unique in several ways.

Most curricula in engineering ethics take a top-down, micro-ethical approach, beginning with professional codes and/or normative ethical theories that are then applied to ethical issues facing individual engineers, which arise in case studies focusing mainly on disasters that have taken place in the Western world (Herkert, 2001; Hess & Fore, 2018; Polmear, Bielefeldt, Knight, Canney, & Swan, 2019; Van de Poel & Royakkers, 2011). However, such approaches are problematic for several reasons.

First, professional codes and technical guidelines can vary by country (AlZahir & Kombo, 2014) and – as explained above – engineering is evermore global. Educators can no longer assume a shared cultural tradition – or country of origin or destination for work – between themselves and their students (Clancy & Zhu, 2022). Next, there is widespread disagreement regarding which (if any) normative ethical theories are correct: Even after thousands of years, professional ethicists continue to disagree about which normative ethical theories should be used for ethical analysis (Greene, 2014; Luegenbiehl, 2010). Third, normative ethical theories used in engineering ethics education tend to come from the Western cultural tradition, including consequentialism, deontology, and virtue ethics. In recent years, attempts have been made to diversify the number and nature of ethical theories and traditions used in engineering and technology ethics, including ones from Asia and Africa (Verharen et al., 2021; Wong & Wang, 2021). However, this simply raises the first two issues again, regarding the national and cultural background/destinations of students enrolled in engineering ethics courses, and which normative theories are correct/should be used in engineering ethics. Finally, there is a growing consensus that engineering ethics education should move beyond case studies involving engineering disasters with a focus on micro-ethical issues alone, those involving disasters that result from decisions by and the behaviors of

individual engineers. Instead, education should focus on "aspirational ethics," cases where engineers have done the right thing (Harris, 2008; Harris et al., 2018), as well macro-ethical issues, for example, public policies, government actions, and corporate social responsibility (Polmear et al., 2019; Van de Poel & Royakkers, 2011; Zhu et al., 2022). GEE was developed and implemented to address these issues.

Rather than a top-down, micro-ethical approach using professional codes and/or normative ethical theories that are then applied to ethical issues that arise in case studies focusing mainly on disasters in the Western world, GEE takes a bottom-up, micro- and macro-ethical approach, beginning with case studies that focus on a broader range of global topics, reasoning to topic- and discipline-specific ethical principles and values on that basis. (A detailed description of this course, and factors shaping its development, can be found in (Clancy, 2021) and (Clancy, 2022).) This course is distinctive in its approach to engineering ethics education. It responsive to different technologies and cultural traditions, but it is not rooted in any one technology or tradition. This approach is the most appropriate for an educational institution such as the UM-SJTU JI, where students come from and go on to further study and work in countries and companies throughout the world. A thorough discussion of engineering ethics education in China would lead well beyond the current study and paper, but the interested reader is encouraged to consult the growing literature on the topic (Cao, 2015; Clancy, Zhu, & Tang, n.d.; Fan, Zhang, & Xie, 2015; M. J. Murphy, 2016; Tang, Zhang, & Yang, 2017; Wang & Yan, 2019; Zeng & Resnik, 2010; H. Zhang & Davis, 2018; Zhu, 2010).

Ultimately, 99 students were included as study participants (female = 29; mean age = 21.3), of whom none were US citizens. Data collection occurred in two waves, during the Fall and Summer

offerings of GEE. The number of participants who completed the survey, consented to have their responses used for research purposes, passed attention/earnestness checks embedded in the MFQ, and whose pre- and post-course surveys matched can be found in Table 1.

Table 1. Participant numbers

Semester	Beginning		End		Completed and matched
	Completed	Consented	Completed	Consented	
Fall	79	68 (86%)	88	84 (95%)	28
Summer	127	115 (90%)	132	126 (95%)	71
Total	206	183 (88%)	220	210 (95%)	99

The discrepancy between the number of participants who completed the survey at the beginning versus the end of the semester results from the fact that registration at the UM-SJTU JI is open the first two weeks of the semester, such that students dropped out and enrolled in the class after the first day of class and before the last day of class, when surveys were distributed and completed.

To ensure the sample quality, relatively stringent criteria were used to include responses: Only the response of participants who responded to all survey items and correctly – in other words, filling in only one response – were included. According to MFQ protocols, responses should be excluded for answering 3 or above on the "math" catch question, and 2 or below on the "good" catch question. Pre- and post-course responses were joined using a coded id, and only the responses of those participants who completed a pre- and post-course study survey were maintained.

2.1.1 Citizenship and language

None of the participants were US citizens. 1 came from Africa, and the rest identified their region of origin as China, Korea, or Japan. None of the participants were native-English speakers, but 68 participants had taken the TOEFL (Test of English as a Foreign Language), and the mean score of those participants was 103.4. Of undergraduate students who have taken the TOEFL, this score falls in approximately the 85th percentile (EST, 2018). These results are typical of students in the UM-SJTU JI. In 2017, the UM-SJTU JI conducted a survey of undergraduate students who took the TOEFL, finding the mean score was 102.45 (n = 186; SD = 6.19). As a result, all participants in this sample have high-level English-language proficiency. (For comparison, the average TOEFL score of test takers from China is 79 (EST, 2018).)

This results from the fact the official language of the UM-SJTU JI is English, and all study participants received immersive English-language instruction. Again, since students from the UM-SJTU JI go on to study and work in international engineering environments, where English is typically the language used, and since language can affect ethical decision-making (Chan, Gu, Ng, & Tse, 2016; Costa et al., 2019; Keysar, Hayakawa, & An, 2012), the assessment and educational instruction associated with this study took place in English.

2.2 Procedure and measures

Data collection occurred in two waves, first during the fall 2019 offering of GEE and second during the summer 2020 offering of GEE. During the first wave of data collection, participants completed a paper version of the survey, which was handed out at the beginning of the first day of class. During the second wave of data collection, participants completed a digital version of the survey,

which they accessed through a link or QR code also provided at the beginning of the first day of class. The same respective procedures were followed to collect post-course data, which occurred on the last day of class.

In all cases, participants were given 45 minutes to complete the survey. A brief description of the nature of and motivations for the research was given, and participants were required to consent to have their responses used for research purposes. Such work was exempt from securing IRB approval at the UM-SJTU JI, and only the results of participants who consented to have their responses used for research purposes were included in this study. The survey consisted in three parts: the 1. ESIT, 2. MFQ, and 3. demographic items.

2.2.1 ESIT

The ESIT is a neo-Kohlbergian instrument, an engineering-and-science-specific variant of the DIT (Defining Issues Test)/DIT2 (Rest et al., 2000; Rest, Narvaez, Thoma, & Bebeau, 1999), developed and validated by Jason Borenstein and colleagues (Borenstein et al., 2010). It presents participants with six ethical dilemmas related to engineering and/or science. Each scenario is followed by a choice of different ways to resolve the dilemma, as well as twelve considerations that could be relevant to that choice. Participants are asked to rate the relevance of each consideration and then pick the four they think are the most important. Each of these considerations corresponds to one of three different "schemas," ways of thinking about matters of right and wrong: 1. the preconventional schema consists in reasoning based on self-interest; 2. the conventional schema consists in reasoning based on authority and social norms; 3. the postconventional schema

consists in reasoning based on universal principles (Borenstein et al., 2010; Rest, Narvaez, Thoma, et al., 1999).

The more postconventional considerations one picks in the top four, the higher one's P score, indicative of the prevalence of postconventional reasoning. This measure was designed, in part, to assess the prevalence of postconventional reasoning. The prevalence of preconventional and conventional reasoning is determined in this same manner. An additional measure of ethical reasoning used by the ESIT is the N2 score. The N2 score indicates the prevalence of postconventional *relative to* preconventional reasoning – not only that participants use postconventional reasoning but also that they do not use preconventional reasoning. On this view, reasoning based on universal principles related to justice would be the most developed/advanced and, therefore, the most ethical, while reasoning based on authority and social norms, and self-interest, would be less developed/advanced.

Higher levels of education, age, and more politically liberal views have been associated with higher P and N2 scores on the DIT and DIT2 (Dong, 2011; Rest, Narvaez, Thoma, et al., 1999). On average, US citizens/native-English speakers score higher on these measures (Borenstein et al., 2010; Canary et al., 2012), while East Asians tend to score higher on measures of preconventional and conventional reasoning (Hwang, 2012a).

2.2.3 MFQ

The MFQ is associated with MFT (Moral Foundations Theory) and presents participants with two sets of statements. For the first set of statements, participants decide how important each would be

when deciding whether something is right or wrong, the "relevance" subscale. For the second set of statements, participants indicate their levels of agreement, the "judgment" subscale (Graham et al., 2011). Each statement corresponds to one of five different "moral foundations," ways of conceiving matters of right and wrong, concerned with different kinds of behaviors and considerations. These are care-harm, fairness-cheating, loyalty-betrayal, authority-subversion, and sanctity-denigration, where caring for others is good and harming them is bad, acting fairly is good and cheating is bad, and so on (Graham et al., 2011). Care and fairness are called the "individualizing" foundations, since they are associated with virtues aimed at protecting individuals, whereas loyalty, authority, and sanctity are called the "binding" foundations, since they are associated with virtues aimed at binding individuals into groups (Graham et al., 2011). Higher mean scores on items corresponding to each of the foundations indicate the relative preference given to these foundations and their associated intuitions.

Those who identify as politically conservative and those from East-Asian cultures tend to care about all the foundations, whereas those who identify as politically liberal and those from Western cultures prioritize the individualizing foundations (Graham, Haidt, & Nosek, 2009; Graham, Meindl, Beall, Johnson, & Zhang, 2016; Graham et al., 2011; Kim, Kang, & Yun, 2012; Y. Zhang & Li, 2015). Such insights can contribute to developing more psychologically realist theories of ethics, concerned with how people actually think about matters of right and wrong rather than merely how they should (Ancell, Steenbergen, Flanagan, & Martin, 2014; Flanagan, 2017). For example, as a pluralist theory of ethical reasoning, MFT helps to explain how different, competing goods can conflict, resulting in the kinds of conflicts of interests that are central to engineering

ethics and other forms of professional ethics (Harris et al., 2018; Van de Poel & Royakkers, 2011; Zhu et al., 2022).

Although moral foundations have been likened to dispositions – collections of (relatively) invariant traits, similar in nature to personality types (Haidt, 2012) – little research has explored if or how moral foundations change over time (Graham et al., 2011; Hatemi, Smith, Alford, Martin, & Hibbing, 2015). Of the work that has been done, the methods used and conclusions drawn have been contested (Haidt, 2017). No research of which the authors are aware has explored the effects of education on moral foundations.

2.2.4 Relations between the ESIT and MFQ

As the foregoing makes clear, the ESIT and MFQ draw on two different conceptual models of ethical decision-making and moral judgments. While the ESIT is based on a model of ethical decision-making involving neo-Kohlbergian schemas, the MFQ is based on a model of moral judgments involving social intuitions. Although the ESIT and MFQ have not been used together, the DIT2 – the neo-Kohlbergian measure on which the ESIT is based – and MFQ have (Baril & Wright, 2012; Glover et al., 2014).

These studies found evidence of positive relations between ethical reasoning and the individualizing foundations, and negative relations between ethical reasoning and the binding foundations: P and N2 scores on the DIT2 were positively related to mean individualizing foundation scores on the MFQ, and they were negatively related to mean binding foundation scores. These relations are likely because the DIT2/neo-Kohlbergian model conceives of ethical reasoning

as applying universal principles related to justice and care, and the individualizing foundations concern intuitions about fairness and care. By contract, the binding foundations concern intuitions about loyalty, authority, and sanctity and, according to the DIT2/neo-Kohlbergian model, principles associated with loyalty, authority, and sanctity belong to conventional reasoning.

2.2.5 Hypotheses and planned analyses

In this study, MFQ and ESIT scores were treated as outcome variables, and education and demographic information were treated as input variables. Since relatively few studies have used the ESIT (Borenstein et al., 2010; Canary et al., 2012; Kerr, Brummel, & Daily, 2016) – and none have used the ESIT in conjunction with the MFQ – this study was largely exploratory in nature. Nevertheless, based on previous work, to conduct analyses and present results, the following hypotheses were posed:

1. It was hypothesized that students in this sample would receive lower N2 scores on the ESIT than those in (Borenstein et al., 2010), since the participants in this sample were non-US citizens, and non-US citizens have been found to receive lower N2 scores (Borenstein et al., 2010; Canary et al., 2012).

2. Since previous research found evidence for the effects of pre-course/-study ethics education on ESIT P and N2 scores (Borenstein et al., 2010), it was hypothesized that participants with pre-course/-study ethics education would receive higher P and N2 scores than those without and, by extension, that students would receive higher P and N2 scores after completing GEE.

3. It was hypothesized that higher mean scores on the individualizing foundations and lower mean scores on the binding foundations would be associated with higher P and N2 scores on the ESIT, based on prior work using the MFQ and the DIT2, a neo-Kohlbergian instrument like the ESIT (Baril & Wright, 2012; Glover et al., 2014).

Since previous research has not explored the effects of education on moral foundations, no hypotheses were made regarding its effects, although this was a point of interest as well, the results of which are reported below.

3 Results

3.1 Pre-course comparisons between waves of data collection

To ensure there were no significant differences between the pre-course scores of the two samples collected in this survey – during the fall semester by paper and summer semester by computer – a series of Welch independent sample t-tests were carried out on ESIT and MFQ study variables. The Welch independent t-test was chosen, since it does not assume equal population variances between groups. To check the assumption of normality regarding the distribution of data, Shapiro Wilk tests were carried out on ESIT and MFQ study variables. The results of these tests were statistically significant for preconventional, postconventional, fairness, loyalty, and binding scores, indicating the non-normal distribution of this data. As a result, effect sizes have also been used in comparing groups. No significant differences in ESIT or MFQ variables were found between the two different waves of data collection. (The results of these tests can be found in Tables 1 and 2 in the Supplementary materials.)

3.2 Pre- and post-course ESIT comparisons between study samples

To test hypotheses one, independent sample t-tests were carried out to compare the mean pre- and post-course P and N2 scores of US samples reported in the publication describing the validation of the ESIT (n = 319) (Borenstein et al., 2010) and the Chinese sample from the current study (n = 99). Pre- and post-course N2 scores of the two samples can be found in Table 1, as well as differences between them, tests of significance, and effects sizes.

Table 1 Comparison of postconventional and N2 scores between participants in the US and China

Before				Independent sample t-tests					After			Independent sample t-tests				
				95%		t	*p*	*d*				95%		t	*p*	*d*
	US (SD)	China (SD)	Difference	Lower	Upper				US (SD)	China (SD)	Difference	Lower	Upper			
P	0.51 (0.14)	0.48 (0.13)	0.03	-0.00	0.06	1.93	0.05*	0.22	0.53 (0.14)	0.54 (0.12)	0.01	-0.04	0.02	-0.65	0.51	0.07
N2	2.97 (1.50)	2.40 (1.56)	0.57	0.21	0.92	3.19	< 0.01**	0.37	3.41 (1.51)	3.37 (1.62)	0.40	-0.32	0.40	0.21	0.82	0.02

*significant at the ≤ 0.05 level, ** ≤ 0.01 level, *** ≤ 0.001 level[2]

These results indicate that hypothesis one was only partially supported. Although participants in the US received significantly higher N2 scores that those in China pre-course, no significant differences in N2 scores were observed between participants in China and the US post-course.

Although participants in the US scored higher in postconventional reasoning pre-course than those in China, this difference was only marginally significant and its effect – according to convention (Cohen, 1988) – was small (Table 1). However, the difference between pre-course N2 scores was highly significant and the country effect was large (Table 1). Since N2 scores are a measure of postconventional *relative* to preconventional reasoning, these results might indicate a difference

[2] In addition to reporting p-values in the tables, to facilitate comprehension, significance levels have also been noted.

in US and China samples between not only postconventional reasoning but also preconventional reasoning. In other words, relative to the US, ethics education affects ethical reasoning among participants from China more by decreasing preconventional than increasing postconventional reasoning. As a result of this finding, in addition to P and N2 scores, levels of preconventional and conventional reasoning for the China sample were also calculated (Table 2).

Table 2 Comparison of pre- and post-course ESIT variables among participants in China

	Before	After	Difference	Paired-sample t-tests				
	M (SD)	M (SD)		95%		t	*p*	*d*
				Lower	Upper			
Pre	0.14 (0.12)	0.09 (0.10)	-0.05	0.02	0.06	4.37	< 0.001***	0.41
Con	0.35 (0.10)	0.33 (0.11)	-0.02	-0.014	0.03	0.92	0.35	0.10
P	0.48 (0.13)	0.54 (0.12)	0.06	-0.09	-0.03	-4.40	< 0.001***	0.50
N2	2.40 (1.56)	3.37 (1.62)	0.97	-1.28	-0.66	-6.22	< 0.001***	0.60

*significant at the ≤ 0.05 level, ** ≤ 0.01 level, *** ≤ 0.001 level

Results in Table 2 provide partial support for hypothesis 2, since participants received significantly higher P and N2 scores after a course on engineering ethics. However, the results of independent t tests revealed no significant differences in either ESIT or MFQ study variables between students with and without previous ethics education, or between different kinds of ethics education (technical ethics courses, general ethics/philosophy courses, and ethics content in another courses). The full results of these test can be found Tables 3-15 in the Supplementary materials.

To test hypothesis three, correlations between mean, pre-, and post-course individualizing and binding foundations, and P and N2 scores were calculated (Table 3). The individualizing and binding foundation scores reported here are simply the means scores of the care and fairness foundations, and the loyalty, authority, and sanctity foundations, respectively. To correct for multiple comparisons, p-values were adjusted using the Holm-Bonferroni correction, to reduce the probability of making type I errors, mistakenly identifying an effect that does not exist.

Table 3 Correlations between mean, pre-, and post-course individualizing and binding foundations, and P and N2 scores

	Mean (*p*)		Before (*p*)		After (*p*)	
	P	N2	P	N2	P	N2
Individualizing	0.37 (< 0.001***)	0.21 (0.10)	0.27 (0.02*)	0.17 (0.25)	0.40 (< 0.001***)	0.23 (0.05*)
Binding	0.11 (0.24)	-0.09 (0.48)	0.13 (0.33)	-0.03 (0.70)	0.06 (0.89)	-0.07 (0.89)

*significant at the ≤ 0.05 level, ** ≤ 0.01 level, *** ≤ 0.001 level

Hypothesis three was partially supported: Overall, higher mean scores on the individualizing foundations were strongly associated with higher mean P scores on the ESIT, but they were only marginally associated with higher mean N2 scores. This results from the fact that, while pre-and post-course individualizing scores were significantly related to P scores, they were only significantly relate to post-course N2 scores. Means scores on the binding foundations were not significantly related to either P or N2 scores.

To further explore and better understand this relation, correlations between mean, pre-, and post-course individualizing and binding foundations, and preconventional and conventional scores were calculated (Table 4).

Table 4 Correlations between mean, pre-, and post-course individualizing and binding foundations, and preconventional and conventional scores

	Mean (*p*)		Before (*p*)		After (*p*)	
	Pre	Con	Pre	Con	Pre	Con
Individualizing	-0.09 (0.51)	-0.27 (0.02*)	-0.02 (0.81)	-0.27 (0.02*)	-0.13 (0.52)	-0.28 (0.01**)
Binding	0.11 (0.51)	-0.22 (0.08)	0.11 (0.50)	-0.26 (0.02*)	0.09 (0.52)	-0.13 (0.52)

*significant at the ≤ 0.05 level, ** ≤ 0.01 level, *** ≤ 0.001 level

These results indicate that, on average, scores on the individualizing foundations were negatively related to conventional reasoning, and that pre-course scores on the binding foundations were negatively related to conventional reasoning. Neither the individualizing nor the binding foundations were significantly related to preconventional reasoning.

3.3 The effects of ethics education on MFQ variables

To explore the effects of ethics education on moral foundations, the mean scores of pre- and post-course MFQ study variables were calculated, as well as dependent-sample t-tests (Table 5).

Table 5 Comparison of pre- and post-course MFQ variables

	Before	After	Difference	Paired-sample t-tests

	M	SD	M	SD	M	95%		t	*p*	*d*
						Lower	Upper			
Fairness	3.32	0.74	3.57	0.68	0.25	-0.40	-0.10	-3.43	< 0.001***	0.36
Care	2.90	0.78	3.02	0.80	0.12	-0.25	0.01	-1.77	0.07	0.15
Loyalty	3.05	0.74	3.38	0.67	0.32	-0.45	-0.19	-4.95	< 0.001***	0.45
Authority	2.92	0.69	3.05	0.67	0.12	-0.25	-0.00	-2.00	0.04*	0.18
Sanctity	2.66	0.77	2.53	0.82	-0.13	0.00	0.26	2.02	0.04*	0.16
Individualizing	3.11	0.64	3.30	0.64	0.18	-0.30	-0.07	-3.25	< 0.001***	0.29
Binding	2.88	0.61	2.98	0.60	0.10	-0.20	-0.00	-2.10	0.03*	0.17

*significant at the ≤ 0.05 level, ** ≤ 0.01 level, *** ≤ 0.001 level

These results indicate that, on average, engineering ethics education had a positive effect on the development of moral foundations, with one exception and considerable variation.

Sanctity scores were lower post- than pre-course, indicating that students attached less importance to this foundation after a course in engineering ethics. The importance attached to care was the only foundation significantly unaffected pre- to post-course. Care scores began and ended relatively low. Most interesting here are the scores on loyalty and fairness. Fairness and loyalty changed the most, which is somewhat surprising, as these would appear to be opposed.

To better understand the nature of these relations, correlations between the individual foundations and preconventional, conventional, and postconventional scores were calculated (Table 6), using the same procedure as the calculations listed in Table 4.

Table 6 Correlations between mean, pre-, and post-course moral foundations, and preconventional, conventional, and postconventional reasoning scores

	Mean			Before			After		
	Pre	Con	Post	Pre	Con	Post	Pre	Con	Post
Fairness	-0.10 (1.00)	-0.20 (0.50)	0.29 (0.04*)	-0.06 (1.00)	-0.20 (0.41)	0.22 (0.27)	-0.13 (1.00)	-0.25 (0.14)	0.37 (0.01**)
Care	-0.06 (1.00)	-0.27 (0.09)	0.35 (0.01**)	0.02 (1.00)	-0.25 (0.14)	0.23 (0.22)	-0.09 (1.00)	-0.23 (0.25)	0.32 (0.02*)
Loyalty	0.07 (1.00)	-0.15 (1.00)	0.08 (1.00)	0.15 (1.00)	-0.20 (0.40)	0.03 (1.00)	-0.02 (1.00)	-0.04 (1.00)	0.08 (1.00)
Authority	0.03 (1.00)	-0.06 (1.00)	0.05 (1.00)	-0.02 (1.00)	-0.04 (1.00)	0.09 (1.00)	0.06 (1.00)	-0.10 (1.00)	0.04 (1.00)
Sanctity	0.16 (0.97)	-0.31 (0.02*)	0.14 (1.00)	0.15 (1.00)	-0.38 (0.001***)	0.21 (0.37)	0.17 (1.00)	-0.18 (0.83)	0.03 (1.00)

*significant at the ≤ 0.05 level, ** ≤ 0.01 level, *** ≤ 0.001 level

These results indicate that, in general, care and fairness are the most strongly related to postconventional reasoning, and that a concern with sanctity was negatively related to conventional reasoning. These results are driven by the fact that (1) a concern with sanctity was negatively related to conventional reasoning before ethics education and (2) concerns with care and fairness were most closely related to postconventional reasoning after ethics education.

4 Discussion

The following discusses the implications of these results, as well as shortcomings of the current study and directions for future work.

4.1 Implications

First, as with previous work on global engineering ethics education (Murrugarra & Wallace, 2015), this study found that engineering ethics education brought the perspectives of engineering students in different countries closer together. Even though engineering students in China began with lower

ethical reasoning scores that their counterparts in the US, after a one-semester, two-credit-hour course on global engineering ethics, no significant differences were detected between the ethical reasoning abilities of students in the US and China. Previous largescale, long-term research using neo-Kohlbergian instruments has found that time/age alone does not explain gains in ethical reasoning abilities: Control groups comprised by participants not exposed to education do not evidence similar gains in ethical reasoning (Borenstein et al., 2010; McCabe, Treviño, & Butterfield, 2001; Rest, Narvaez, Bebeau, & Thoma, 1999b).

This provides some support for the theoretical perspectives of Michael Davis and colleagues, that engineering comprises a professional culture distinct from and "stronger" than national cultures, on which global engineering ethics could be based (Davis, 2009, 2015, 2021; Davis & Zhang, 2017), which is sometimes referred to as "functionalism" in engineering ethics education (Clancy & Zhu, 2021, 2022; Luegenbiehl & Clancy, 2017; Zhu & Jesiek, 2017). Obviously, much more, further support would be needed to strengthen this claim, comparing in detail, for example, the kinds of education that bring the ethical perspectives of individuals from different cultures/countries closer together. A detailed description of the engineering ethics education used in the current study can be found in (Clancy, 2021) and (Clancy, 2022). This level of detail tends not to be a common feature of reports on the effects of engineering ethics education, but it is sorely needed.

An educational implication of the current study seems to be that teachers and institutions can better facilitate engineering ethics education among non-US students by using curricula in global engineering ethics. Traditional curricula in engineering and ethics used in previous studies have

not resulted in increased ethical reasoning abilities among non-US participants (Borenstein et al., 2010; Canary et al., 2012).

Next, the way that education affects this change across cultures/countries appears to be different. Whereas the educational interventions of (Borenstein et al., 2010) increased engineering and science ethical reasoning by lowering rates of preconventional reasoning – recall that, in their study, only N2 scores were significantly higher after than before interventions, not P scores – those of this study improved engineering and science ethical reasoning by not only decreasing rates of preconventional reasoning but also increasing those of postconventional reasoning. However, the specific nature of this difference is unclear, since (Borenstein et al., 2010) did not report rates of preconventional or conventional reasoning, or how these were affected by educational interventions.[3] Going forward, these dynamics need to be further explored.

Third, the current study revealed important relations between ethical reasoning and moral intuitions, and that the ESIT and MFQ can identify, differentiate, and track normative judgments in international/cross-cultural contexts. As was hypothesized, the care and fairness foundations were strongly related to postconventional reasoning. This provides evidence that there is nothing counterintuitive to Chinese engineering students about postconventional reasoning, that intuitions about care and fairness align with the use of postconventional principles in ethical reasoning. An additional teaching implication of this insight is that ethics could be explained in terms of the neo-

[3] The data for (Borenstein et al., 2010) is not publicly available. We contacted members of their team – requesting access to the anonymized data – but the study data was unavailable. While unfortunate, this problem is not unique to engineering education (Gabelica, Bojčić, & Puljak, 2022).

Kohlbergian taxonomy of preconventional, conventional, and postconventional reasoning, at least among Chinese engineering students. The extent to which this would be true among other national and cultural groups, however, would require additional exploration.

Similarly, among engineering students in China, scores on the binding foundations were negatively related to conventional reasoning, and none of the foundations were related to preconventional reasoning. This provides evidence that – versus participants from the US (Baril & Wright, 2012; Glover et al., 2014) – intuitions about loyalty, authority, and sanctity are different/distinct from the use of conventional and preconventional principles in ethical reasoning among the participants in China. Conventional reasoning and binding intuitions are two opposed ways that engineering students in China think about ethics, and preconventional reasoning is unrelated to moral intuitions in general. Although research on Chinese moral psychology is limited relative to China's global population, these findings support/are in line with earlier work showing that Chinese moral psychology is different from that of WEIRD populations (Buchtel et al., 2015; Dranseika, Berniūnas, & Silius, 2018; Hwang, 2012b; Nisbett, 2010).

4.2 Future research

The current study suffers from shortcomings that will be addressed in future research. First, this study took place at only one Chinese university, and SJTU is among the highest ranked universities in mainland China. Students admitted to SJTU typically come from households whose SES (socio-economic status) affords them access to educational opportunities unavailable to most Chinese citizens, limiting the generalizability of study results. Second, all assessment and educational

instruction associated with this study took place in English – a language foreign to the study participants – and foreign language has been shown to affect ethical judgements.

To address these concerns, efforts are underway to reproduce this study in simplified Mandarin at other Chinese universities, including provincial ones such as Shandong University. This will help to obtain more diverse and representative samples, and better understand the effects of language on ethical reasoning. (Initial results indicate that a Chinese-language version the ESIT is just as capable of discerning between preconventional, conventional, and postconventional styles of engineering and science ethical reasoning as the English-language original (Clancy et al., 2023)).

5 Conclusion

Ethics is essential to engineering, but engineering is more cross-cultural and international than ever before, presenting challenges to effective engineering ethics education. It is unclear whether the results of engineering ethics studies based on WEIRD sample are representative of/transferable to non-WEIRD populations, and if ethical reasoning leads to more ethical judgments or behaviors. To address these issues, this study explored the relations between ethical reasoning, moral intuitions, and ethics education among engineering students in China. Results indicate that, while engineering students in China evidenced initially lower levels of ethical reasoning than those in the US, there were no significant differences in ethical reasoning abilities between the two groups after an educational intervention. While education affected ethical reasoning among US participants by lowering rates of preconventional reasoning, it did so among participants in China by not only lowering rates of preconventional but also raising rates of postconventional reasoning. Although postconventional reasoning, care, and fairness were related in the manner hypothesized

among participants in China, other types of reasoning and kinds of intuitions were not. Future research will reproduce this study (1) with a broader range of participants in China and (2) using Chinese-language assessment materials.

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Supplementary Materials

Table 1 Results of Shapiro-Wilk tests of normality

	W	p-value
ESIT		
Preconventional	0.87	0.001***
Conventional	0.98	0.17
Postconventional	0.95	0.003**
N2	0.99	0.67
MFQ		
Fairness	0.96	0.006**
Care	0.98	0.28

Loyalty	0.94	0.001***
Authority	0.98	0.55
Sanctity	0.98	0.17
Individualizing	0.99	0.71
Binding	0.96	0.01*

*significant at the ≤ 0.05 level, ** ≤ 0.01 level, *** ≤ 0.001 level

Table 2 Comparison of pre-course study variables between waves of data collection

	Fall mean	Summer mean	*t*	p-value
ESIT				
Preconventional	0.15	0.13	0.83	0.40
Conventional	0.35	0.34	0.15	0.87
Postconventional	0.47	0.50	-0.85	0.39
N2	2.27	2.71	-1.23	0.22
MFQ				
Fairness	3.26	3.45	-1.28	0.20
Care	2.89	2.92	-0.19	0.84
Loyalty	3.10	2.92	1.04	0.29
Authority	2.95	2.86	0.54	0.58
Sanctity	2.65	2.68	-0.17	0.86
Individualizing	3.08	3.19	-0.84	0.40
Binding	2.90	2.82	0.56	0.57

Table 3 Comparison of pre-course study variables by previous ethics education versus none

	Previous (n = 73)	None (n = 26)	*t*	p-value
ESIT				
Preconventional	0.14	0.15	-0.39	0.69
Conventional	0.34	0.35	-0.37	0.70
Postconventional	0.48	0.47	0.39	0.69
N2	2.52	2.04	1.51	0.13
MFQ				
Fairness	3.39	3.10	1.70	0.09
Care	2.98	2.69	1.52	0.13
Loyalty	3.10	2.91	1.06	0.29
Authority	2.99	2.75	1.56	0.12
Sanctity	2.69	2.57	0.70	0.48
Individualizing	3.19	2.89	1.82	0.07
Binding	2.93	2.75	1.35	0.18

Table 4 Comparison of pre-course study variables by type of previous ethics education

	Ethics content in other course (n = 49)	Ethics/philosophy course (n = 36)	Technical ethics course (n = 5)
ESIT			
Preconventional	0.14	0.14	0.16
Conventional	0.35	0.35	0.39
Postconventional	0.47	0.48	0.42

N2	2.52	2.61	2.24
MFQ			
Fairness	3.37	3.33	2.83
Care	2.93	3.04	2.86
Loyalty	3.04	3.03	3.03
Authority	3.01	2.92	3.13
Sanctity	2.73	2.61	2.76
Individualizing	3.15	3.18	2.85
Binding	2.93	2.85	2.97

Table 5 P scores of differences between pre-course **preconventional** reasoning by previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.75	_	_
Ethics content in other course	0.78	0.90	_
None	0.88	0.68	0.76

Table 6 P-values of differences between pre-course **conventional** scores by type of previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.33	_	_
Ethics content in other course	0.31	0.99	_
None	0.33	0.94	0.93

Table 7 P-values of differences between pre-course **postconventional** scores by type of previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.39	_	_
Ethics content in other course	0.47	0.73	_
None	0.475	0.71	0.98

Table 8 P-values of differences between pre-course **N2** scores by previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.63	_	_
Ethics content in other course	0.71	0.79	_
None	0.79	0.16	0.19

Table 9 P-values of differences between pre-course **fairness** scores by previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.49	_	_
Ethics content in other course	0.46	0.81	_
None	0.70	0.23	0.15

Table 10 P-values of differences between pre-course **care** scores by previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.74	_	_
Ethics content in other course	0.90	0.47	_
None	0.74	0.08	0.24

Table 11 P-values of differences between pre-course **loyalty** scores by previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.99	_	_
Ethics content in other course	0.96	0.94	_

None	0.74	0.52	0.50

Table 12 P-values of differences between pre-course **authority** scores by previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.62	_	_
Ethics content in other course	0.77	0.52	_
None	0.38	0.29	0.11

Table 13 P-values of differences between pre-course **sanctity** scores by previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.64	_	_
Ethics content in other course	0.91	0.50	_
None	0.57	0.82	0.40

Table 14 P-values of differences between pre-course **individualizing** scores by previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.58	_	_

Ethics content in other course	0.62	0.77	_
None	0.93	0.09	0.14

Table 15 P-values of differences between pre-course **binding** scores by previous ethics education

	Technical ethics course	Ethics/philosophy course	Ethics content in other course
Ethics/philosophy course	0.72	_	_
Ethics content in other course	0.89	0.57	_
None	0.51	0.43	0.47