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Assessing the Effects of a Short-Term Global Engineering Ethics Course on the Development of Engineering Students' Moral Reasoning and Dispositions [Traditional paper – research/evidence-based, DEI/research methods]

Dr. Rockwell Franklin Clancy III, Virginia Polytechnic Institute and State University

Rockwell Clancy conducts research at the intersection of technology ethics, moral psychology, and Chinese philosophy. He explores how culture and education affect moral judgments, the causes of unethical behaviors, and what can be done to ensure more ethical behaviors regarding technology. Central to his work are insights from and methodologies associated with the psychological sciences and digital humanities. Rockwell is a Research Scientist in the Department of Engineering Education at Virginia Tech. Before moving to Virginia, he was a Research Assistant Professor in the Department of Humanities, Arts, and Social Sciences at the Colorado School of Mines, Lecturer in the Department of Values, Technology, and Innovation, at Delft University of Technology, Associate Teaching Professor at the University of Michigan-Shanghai Jiao Tong University Joint Institute, and Research Fellow in the Institute of Social Cognition and Decision-making, Shanghai Jiao Tong University. Rockwell holds a PhD from Purdue University, MA from Katholieke Universiteit, Leuven, and BA from Fordham University.

Dr. Scott Streiner, University of Pittsburgh

Scott Streiner is an Assistant Professor in the Industrial Engineering Department, teaches in the First-Year Engineering Program and works in the Engineering Education Research Center (EERC) in the Swanson School of Engineering at the University of Pittsburgh. Scott has received funding through NSF to conduct research on the impact of game-based learning on the development of first-year students' ethical reasoning, as well as research on the development of culturally responsive ethics education in global contexts. He is an active member of the Kern Engineering Entrepreneurship Network (KEEN), the American Society for Engineering Education (ASEE), and serves on the First-Year Engineering Education (FYEE) Conference Steering Committee.

Dr. Qin Zhu, Virginia Polytechnic Institute and State University

Dr. Zhu is Associate Professor in the Department of Engineering Education and Affiliate Faculty in the Department of Science, Technology & Society and the Center for Human-Computer Interaction at Virginia Tech. Dr. Zhu is also an Affiliate Researcher at the Colorado School of Mines. Dr. Zhu is Editor for International Perspectives at the Online Ethics Center for Engineering and Science, Associate Editor for Engineering Studies, and Executive Committee Member of the International Society for Ethics Across the Curriculum. Dr. Zhu's research interests include global and international engineering education, engineering ethics, engineering cultures, and ethics and policy of computing technologies and robotics.

Xianghong WU
Dr. Ryan Thorpe

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1 Introduction

This paper describes a project to develop, deliver, and assess a short-term (one-week) course on global engineering ethics at Shandong University in the Summer of 2022. This project builds on previous work regarding the development and assessment of global engineering ethics education, shortening the time required to deliver and assess such a course. The goal was to explore whether a shorter version of the course "Global Engineering Ethics" resulted in gains like the longer version, and whether shorter versions of the instruments used to assess this course could track these gains.

1.1 Global engineering ethics education

Ethics is increasingly recognized as central to engineering, although disagreement exists concerning how it should be carried out and assessed [1]. These disagreements stem from the goals of engineering ethics education, concerning why and how it should be delivered [2]. These disagreements are compounded by the global nature of engineering, where technologies span multiple countries, and peoples from different cultures work together as never before [3]–[5]. Separation in time and space between those developing technologies and those affected by these technologies can increase difficulties associated with identifying and mitigating the negative effects of technology on human life [6]–[8]. Identifying the negative effects of technology on human life should be a basic goal of technology ethics and, by extension, engineering ethics, since engineering deals with technology. For engineering, many have argued ethics should include more than identifying the negative effects of technology on human life. It should also consist in mitigating these negative effects and ensuring technology makes the world a better place [9]–[14]. What this means and how it should be done is complicated by the global nature of engineering, because of different regional and national regulations, as well as culture.

Regulatory and cultural differences can lead to disagreement regarding how technologies should or should not be developed and used [3]–[5], [15], [16]. These differences stem from policies and laws, as well as values, which would affect how not only engineering does occur but also how different stakeholders think it should occur, as a result of different priorities related to norms and values. For these reasons, efforts have been made to develop global engineering ethics education.

These efforts have tended to follow one of two courses of action and theoretical orientations, universalizing approaches and particularizing approaches. Universalizing approaches consist in identifying or developing a common ground on which global engineering ethics education could be based. These have consisted in the development of global codes and justice-/human rights-based approaches to engineering ethics, as well as "functionalist" approaches, based on the idea that engineers together are members of a common culture, as a result of their training and work – engineering functions as a common culture to which engineers from different national and cultural backgrounds belong, regardless of countries or regions in which engineering occurs [15], [17]–[19]. By contrast, particularizing approaches consist in identifying or developing different

approaches to global engineering ethics education. These have consisted in the development of regional codes of ethics, as well as different regional and cultural approaches to engineering ethics, for example, African, Chinese, and Confucian approaches to engineering ethics education [20]–[24]. However, there are problems with both approaches [25]–[27]. Universalizing approaches can tend towards *homogenization*, overlooking relevant differences. Particularizing approaches can tend towards *fragmentation*, overlooking relevant similarities. As a result, members of this team have developed a course in global engineering ethics that attempts to avoid both pitfalls.

1.2 "Global Engineering Ethics"

This course attempts to navigate between both homogenization and fragmentation. A comprehensive description can be found in [1]. It does so through a "bottom-up" approach, beginning with case studies and then moving to ethical principles. While the ethical principles initially employed are broad and general (universalism), they become further refined in their application to case studies involving specific technologies, countries, and cultures (particularism). This gives engineers a sense of ownership and explanation as to the principles employed. Beginning with case studies and moving to principles helps to motivate the importance of ethics in engineering, in contrast to "top-down" approaches, where engineers learn about professional codes or ethical theories that they then apply to case studies. Team members have developed, delivered, and further refined this course over several years [1], [2]. It has taken the form of a semester-long, two-credit hour course. We have found that participants scored significantly higher in measures of ethical reasoning post- than pre-course and developed a greater concern with fairness and loyalty [3], [4]. These measures include the Engineering and Science Issues Test (ESIT) and Moral Foundations Questionnaire (MFQ) – both of which are further described in "Research Design and Methods."

However, given the limited time and space in engineering curricula, and limited number of qualified instructors to teach global engineering ethics, one goal of this project was to determine whether a course with reduced contents, delivered over a shorter period would be similarly effective. Engineering curricula are under ever greater pressure to include more technical contents, with courses that have traditionally formed the bedrock of liberal arts education – and higher education in the US, such as English, history, and philosophy – getting short shrifted. However, the importance of ethics – and other global competencies in engineering of which ethics would be a part – has been recognized as important by educators, administrators, and companies [5], [28]. Unfortunately, there are not enough faculty with expertise in global engineering ethics to meet this demand [29]. Engineering faculty have reported feeling incompetent discussing topics in engineering ethics, much less global engineering ethics [30].

A second goal of this project was to determine whether shorter versions of the ESIT and MFQ would be as effective in assessing ethical reasoning and moral dispositions as their original, longer versions. This second goal was motivated by the fact that, in ongoing research, the project team was having difficulty collecting adequate sample sizes, in part because it was taking so long for participants to complete full versions of the ESIT and MFQ. Additionally, it provided an opportunity to use the ESIT with foreign nationals. Previous research has found that foreign and non-native-English-speaking students score lower on measures on the ESIT than their US

counterparts, although the reasons are unclear [31]–[33]. Here we will be able to assess its used among exclusively foreign nationals.

To achieve the above-described objectives, students enrolled in a week-long course on global engineering ethics completed shortened versions of the ESIT and MFQ on the first and last days of the course. This information was analyzed and is presented below.

2 Research design and methods

2.1 Participants

Participants were students at Shandong University enrolled in the course "Global Engineering Ethics," which was delivered between July 17 and 21, 2022. The course met for three and a half hours per day, and the course content was streamlined. Whereas the original version of the course covers chapters one through eleven of *Global Engineering Ethics* [5], the shorter version covered chapters one, two, four, five, seven, and ten. Final course grades were based on three components: completing (1) course readings and reflection exercises; (2) in-class exercises/attendance; (3) a case-study assignment. The course was an elective but counted for credit in international education. Student at Shandong University are required to take at least 2 credits in international education to graduate.

Out of a total of 70 students who ultimately enrolled in the course, 73 students completed the survey on the first day of class – students subsequently dropped the course – and 47 students completed the survey on the last day of class. After excluding the responses of participants who did not consent to have their responses used for research purposes, as well as those who failed attention checks, we were left with a total of 57 responses (38 pre-course and 19 post-course, of which 21 marked "female" as their gender; mean age = 20.9). Participants represented a range of majors, not only engineering and the sciences but also the humanities and social sciences.

2.2 Procedure and measures

At the beginning of the first day of the class, students were prompted to click a link, taking them to the survey. A brief description of the survey and research was presented by the course instructor, and additional information was included at the beginning of the survey. To allow responses to be used for research purposes, participants had to click a box. This study was approved by the IRB at Colorado School of Mines. The survey consisted in three parts: (1) a shortened version of the ESIT; (2) a shortened version of the MFQ; (3) questions related to engineering ethics values and behaviors; (4) demographic items. To ensure meaning, all items were translated and back translated into Chinese, and then checked and revised. To control for the effects of language, participants were randomly presented with a version of the survey in Chinese or English.

In previous studies, we found it took participants approximately 40 minutes to complete the above measures. The ESIT includes 6 scenarios, which are approximately 250 words on average, and 17 questions per scenario, for a total of 102 questions. The MFQ includes 32 Likert-scale items. To reduce the amount of time it took participants to complete these measures, they were

randomly presented with 2 of the 6 scenarios from the ESIT and their corresponding questions, and a shortened, 24-item MFQ. The shortened version tool approximately 15 minutes to complete.

2.2.1 ESIT

The ESIT was developed by Jason Bornstein and colleagues and is an engineering- and science-specific variant of the Defining Issues Test 2 (DIT2) [33]. The DIT2 includes short scenarios describing ethical dilemmas with follow-up questions. Participants read each scenario and must (1) decide on a course of action, (2) rate the importance of various considerations in deciding on that course of action, and (3) identify the four most important considerations [34]. Results of the rating and importance responses are used to calculate the importance of difference "schema" to decision-making [35], [36]. Schemas are three ways of conceiving and judging matters of right and wrong: the (1) preconventional schema, deciding on matters of right and wrong with regard to how they affect oneself; (2) conventional, deciding on matters of right and wrong with regard to rules or social conventions; (3) postconventional, deciding on matters of right and wrong with regard to ethical principles such as justice. The "P score" measures the prevalence of postconventional reasoning, whereas the "N2 score" measures the prevalence of postconventional reasoning relative to the absence of preconventional reasoning. The DIT2 belongs to developmental understandings of/frameworks for studying ethics, where postconventional reasoning is better than conventional reasoning, and conventional reasoning is better than preconventional reasoning. On this understanding, only judgments based on postconventional reasoning are truly ethical.

2.2.3 MFQ

The MFQ was developed by Jonathan Haidt and colleagues and belongs to Moral Foundations Theory (MFT) [37], [38]. The MFQ consists in a series of Likert-scale items. The first set of items asks participants to judge how relevant several considerations would be when deciding whether something is right or wrong, the "relevance" subscale. The second set of items asks participants to judge how much they agree with a given statement, the "judgment" subscale. Each statement corresponds to one of five "moral foundations," plus two attention-check items. These are care-harm, fairness-cheating, loyalty-betrayal, authority-subversion, and sanctity-denigration, where caring for others is good and harming others is bad, behaving fairly is good and cheating is bad, and so on. MFT is a social intuitionist theory of ethical reasoning. On this view, ethical judgments result from intuitions, closer in nature to emotions than reflective thought [39]. Different intuitions correspond to each of the foundations. Moral foundations result from biological evolution and aim at human survival [40]. The relative preference given to different moral foundations is a result of cultural evolution, affected by environments and history [38].

2.2.4 Hypotheses and planned analyses

1. It was hypothesized that students would score higher on measures of ethical reasoning, and care more about fairness and loyalty, after the course than before. These hypotheses are based on

the results of a prior study, showing students scored higher on these measures after a one-semester course on global engineering ethics [3], [4].

2. We planned to analyze relations between ESIT and MFQ study variables, to see how closely they are or are not related. This would help us to assess the efficacy of using shorter versions of the ESIT and MFQ.

3 Results

3.1 A shorter version of "Global Engineering Ethics"

To test hypothesis 1, independent sample t-tests were performed to compare mean pre- and post-course scores of preconventional, conventional, and postconventional reasoning, as well as fairness, care, loyalty, authority, and sanctity (Table 1). Independent- rather than dependent-sample t-tests were used, since there was an uneven number of responses pre- and post-course.

Table 1 Comparison of pre- and post-course ESIT and MFQ variables

	Before	After	Difference	Paired-sample t-tests			
	M	M		95%		t	*p*
				Lower	Upper		
Preconventional	0.05	0.06	0.01	-0.03	0.01	-1.05	0.29
Conventional	0.08	0.11	-0.03	-0.05	0.01	-1.36	0.18
Postconventional	0.17	0.15	-0.02	-0.01	0.04	0.81	0.41
Fairness	3.65	4.02	0.37	-0.83	0.09	-1.63	0.11
Care	2.98	3.17	0.19	-0.77	0.39	-0.65	0.51
Loyalty	3.39	3.55	0.16	-0.59	0.28	-0.71	0.48
Authority	2.71	2.45	-0.26	-0.19	0.71	1.16	0.25
Sanctity	3.05	2.82	-0.23	-0.36	0.83	0.79	0.43

These results provide no evidence for hypothesis 1, since none of the mean scores on ESIT or MFQ study variables were significantly different post- than pre-course.

3.2 Shorter versions of the ESIT and MFQ

To assess the efficacy of using shorter versions of the ESIT and MFQ, we calculated Pearson correlations of the mean scores of preconventional, conventional, and postconventional reasoning on the ESIT (Table 2), and those of fairness, care, loyalty, authority, and sanctity on the MFQ (Table 3). Ideally, these relations would be assessed using confirmatory factor analysis. However, the sample sizes of the current study are too small.

Table 2 Correlations between ESIT variables

Conventional	-0.23 (0.07)	
Postconventional	-0.46***	-0.57***
	Preconventional	Conventional

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

Table 3 Correlations between MFQ variables

Care	0.73***			
Loyalty	0.49***	0.45***		
Authority	0.14	0.06	0.12	
Sanctity	0.47***	0.38**	0.52***	0.37**
	Fairness	Care	Loyalty	Authority

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

These results provide support for the efficacy of using a shorter version of the ESIT. Measures of postconventional reasoning were significantly negatively correlated with those of conventional and preconventional reasoning. Measures of conventional and preconventional reasoning were also negatively correlated, but this relation only approached significance at the 0.07 level. These results are comparable to previous studies using the ESIT [3], [4], showing that a shorter version of the ESIT can differentiate between preconventional, conventional, and postconventional reasoning.

MFQ measures were all positively correlated and, in many cases, to a significant degree. These results speak against using a shorter version of the MFQ.

4 Discussion and shortcomings

First, it does not appear as though a shorter, one-week course on global engineering ethics results in the same benefits as a longer, one-semester course. These gains included higher rates of postconventional and lower rates of preconventional reasoning, as well as a greater concern with fairness and loyalty. This is discouraging, since resources to deliver a semester-long course on global engineering ethics are not always available. However, this information is valuable, since it contributes to knowledge about what is required to effect measurable change in global engineering ethics education.

More work is needed to design a shorter version of global engineering ethics, examining how structural changes in this course – for example, changes in curriculum, duration, and delivery mode – neutralized the effects of learning experiences on students' moral reasoning and dispositions. Another question worth further exploring includes whether the ESIT and MFQ are the most appropriate measures to capture changes in students' moral development – in other words, is it possible that the curriculum and structure of the shorter version of the course affected other aspects of students' morality than moral reasoning and dispositions? To examine such

questions, qualitative research methods – including interviews and participatory observations – would be useful. For instance, conducting in-depth interviews with students might help to better understand if and how diverse aspects of moral competencies may or may not be affected by their participation in this course. After acquiring qualitative data, we might have a better sense of other measures that could be used to capture changes in students' moral development.

Next, it appears as though a shorter version of the ESIT could be used to assess the impact of engineering ethics education, although not a shorter version of the MFQ. This is encouraging, since it takes considerably more time to administer the full version of the ESIT, although not as much time to administer the full version of the MFQ. Additionally, the ESIT is a measure of engineering and science ethical reasoning, specifically. By contrast, the MFQ simply provides information regarding how people think about ethics.

These conclusions could be strengthened by addressing shortcomings of the current study. First, pre- and post-course comparisons were conducted in a non-pairwise manner. This limited our ability to discern the effect of ethics education. Going forward, it would be better to conduct pre- and post-course comparisons on a pairwise basis, using dependent-sample t-tests. Second, the sample size used for this study was relatively small. This limited our ability to conduct statistical procedures – specifically, confirmatory factor analyses.

5 Conclusion

Engineering is more cross-cultural and international than ever before, motivating the importance of and raising challenges for global engineering ethics education. To address these challenges, the course "Global Engineering Ethics" was developed. The course was initially developed and delivered as a one-semester course, and students scored higher on measures of ethical reasoning, fairness, and loyalty after completing the one-semester long course. Since educational institutions do not always have the resources available to deliver global engineering ethics education, a shorter, one-week version of "Global Engineering Ethics" was delivered at Shandong University in the summer of 2022. Additionally, since measures used to assess global engineering ethics take considerable time, shorter versions of these measures were piloted as part of this study. The shorter version of "Global Engineering Ethics" did not result in the same gains as the longer version. However, we did find that a shorter version of the ESIT could be used to assess ethical reasoning, although a shorter version of the MFQ should not be used to assess moral dispositions. Finally, this study suffers from shortcomings that will be addressed in future work.

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