Macroethics Education in Engineering and Computing Courses

Angela R. Bielefeldt[1], Daniel Knight[1], Christopher Swan[2], Nathan Canney[3]
[1]University of Colorado Boulder, [2]Tufts University, [3]Seattle University

Abstract

For engineering to reach its full potential to benefit society, students must be prepared to engage in broad considerations of macroethical issues, including the collective responsibility of the profession toward issues such as sustainability, poverty, and bioethics. This research explored the extent to which faculty report educating engineering and computing students to consider macroethical issues in their courses; over 1100 survey responses were received. Over 50% of the respondents taught students about professional practice issues and the societal impacts of engineering and technology in one or more of their courses; only 12% did not include any topics related to social or ethical issues in their courses. Faculty most commonly reported teaching these topics in senior capstone design (41%); 30% also taught these issues in graduate level courses. The majority of the respondents felt that both undergraduate and graduate student education on these issues was not adequate (67% and 80%, respectively).

Keywords

Ethics; societal impacts; sustainability.

Background

There is general consensus that engineers need to perform their duties in an ethical manner, carefully considering the broader positive and potentially negative consequences of their work.[1] This professional responsibility encompasses a broad range of topics. Topics that have traditionally fallen under the definition of ethics often focus on microethical concepts - personal and business related requirements that are commonly outlined in various professional codes of ethics.[2,3] However, engineers should also consider their broader responsibilities to society as a whole in areas such as sustainability– encompassing what has been termed macroethics.[4]

There are numerous published examples of specific courses where students are taught about ethical issues – including traditional microethics and broader macroethical issues such as engineers' responsibilities to society.[5] These topics are required in some form in accredited programs given current ABET Engineering Accreditation Commission (EAC) and Computing Accreditation Commission (CAC) requirements.[6-7] However, a broad understanding of how and where engineering and computing students are taught to consider these issues, and whether or not this education is adequate appears lacking. For example, recent modifications to the ABET EAC criteria specific for civil engineering programs seemed to reflect consensus that ethics education may have been insufficient.[8] In order to provide greater clarity to understanding the scope of both micro- and macro- ethics education, a national study was conducted.

Research Questions

The questions that are explored in this paper are:

RQ1: What topics related to ethics, including macroethics / societal impact issues, are most commonly taught to engineering and computing students?

RQ2: In what types of courses are topics related to ethics and social impact issues taught to students?

RQ3: To what extent do engineering and computing faculty feel that undergraduate and graduate students in their program receive sufficient education about ethics and societal impact issues?

For each of these research questions, it was also of interest to determine if there were differences between different disciplines.

Methods

An online survey was used to gather information from engineering and computing faculty. The survey questions were developed based on published literature,[9-12] followed by a pilot phase at three institutions that included preliminary versions of the survey questions in an online format and follow-up interviews with some individuals experienced in teaching engineering ethics.[13] This process resulted in changing the terminology used in the survey to avoid the word macroethics, due to lack of clarity among survey respondents, among other revisions. Two revised surveys were then created using the online Qualtrics platform. Both surveys began with an informed consent statement, approved by the University of Colorado Boulder IRB. If the respondent consented to participate in the survey, a series of questions were then displayed. These were primarily multiple-select and multiple choice items. The "curricular" version of the survey started with questions on courses (what, where, how ethics issues were taught), then opinions on the adequacy of ethics education, then ethics education via co-curricular activities, and concluded with demographic questions. The "co-curricular" version of the survey included the same questions, but presented them in a different order; it started with questions on informal learning activities, then teaching in courses, then opinions on education sufficiency, and concluded with demographics. For the purpose of this study, a key demographic question was "engineering disciplines where you teach societal context and/or ethics"; 26 disciplines were indicated and faculty were free to check as many disciplines as applied, as well as 'other'.

Email invitations to participate in the survey were distributed to a number of lists. The email indicated that the purpose of the study was to explore how faculty teach engineering and computing students about ethics and the social impacts of technology via both courses and co-curricular activities. The curricular survey link was emailed to lists including the American Society for Engineering Education (ASEE) ethics division and community engagement division. The link was also posted on the Online Ethics Center (OEC) for Engineering and Science website. The first author self-compiled a list of names from among NSF grantees and published authors with evidence of interest in ethics education; these 1165 people received personalized invitations to the survey. The initial lists may have included individuals from non-engineering disciplines, such as those from philosophy who teach and/or study engineering and computing students. An initial email invitation and one follow-up reminder were sent. The email to the

curricular survey had a subject line of "societal impacts and ethics education study". Those invited to take the curricular survey likely do not represent "average" faculty attitudes toward the importance of ethics and societal impact issues, and are more likely to believe that these issues are important. During the period from Feb. 17 to April 1, 304 responses were received (another six did not consent to participate in the survey).

The co-curricular survey link was distributed to 5106 individuals who were current or former advisors and/or mentors of: professional societies (including the American Society of Civil Engineers (ASCE), Society of Automotive Engineers (SAE), Institute of Electrical and Electronics Engineers (IEEE), Society of Women Engineers (SWE), American Institute of Aerospace and Aeronaturical (AIAA), American Institute of Chemical Engineers (AIChE), American Institute of Mechanical Engineers (ASME), National Society of Black Engineers (NSBE), Society of Hispanic Professional Engineers (SHPE), and others), engineering honor societies (including Tau Beta Pi, Chi Epsilon, Upsilon Pi Epsilon, Pi Tau Sigma, Omega Chi Epsilon, Eta Kappa Nu, and others), engineering service groups (Engineers Without Borders, Engineers for a Sustainable World, Engineering World Health, Bridges to Prosperity), engineering design competition mentors (US EPA P3, ASCE Concrete Canoe, Human Powered Vehicle, Solar Decathlon, Shell EcoMarathon, IEEE Solar Splash), and Research Experience for Undergraduates (REU) PIs/co-PIs; for more information see a conference paper focused on this study.[14] The email that invited these individuals to participate in the research had a subject line such as "ASCE student chapter advisor". The email informed faculty that survey was geared to explore whether faculty mentoring these activities taught students about societal impact and/or ethical issues via these activities, but also encouraged those who believed students did not learn about these issues via the activity to participate in the survey. The respondents to the co-curricular survey are less likely to hold a bias toward the importance of ethics and societal impact issues, and are more likely to represent average engineering faculty members. Among the 971 respondents to the co-curricular survey from Feb. 17 – April 1, 2016, not all completed the questions related to the curricular research questions in this paper; between 802 to 924 completed the course-based questions.

The response rates among the groups invited to participate in the survey were variable. For the four engineering service groups, the response rate ranged from 24-38%. For the professional and honor societies, response rates ranged from 20-43% for 14 groups, 10-19% for 18 groups, and below 10% for 5 groups (the survey timeframe for 4 groups only included an initial email, and no follow-up reminder). For design competition mentors, 5 of 6 groups had response rates of 23-33%; one group had a response rate of 15%. For the REU PIs and/or co-PIs, the response rate was 18%. For the curricular survey, the response rate among authors was 25%, among NSF grantees was 13%, and the general list emails to ASEE divisions was 3-4%. Because the same individuals were likely members of multiple ASEE divisions, as well as potentially receiving individual survey invitations, an overall response rate cannot be readily calculated. The respondents represented a wide range of institutions; the highest degree awarded at the institutions were: 7% from Bachelor's, 13% from Master's, and 80% from PhD; 71% public and 29% private. The lowest representation of respondents among the large engineering disciplines appears to be electrical engineering (compared to reported ASEE tenured/tenure-track faculty, at most about 2.5% of electrical engineering faculty responded compared to 5.6% mechanical, 6.4% chemical, and 8.4% civil).

The data from the two Qualtrics surveys were exported to Excel. Chi-squared tests were conducted to determine if the responses from the two surveys were significantly different, and to compare responses among disciplines. Significance was inferred when the probability was 0.05 or less. Disciplines with over 100 responses to the course topic question were explored, with the exception of environmental engineering: mechanical (n=246), civil (n = 238), computer (n=180), electrical (n=138), chemical (n=122), and biomedical (n=115). Environmental engineering was not considered sufficiently distinct from civil engineering, as 58% of the 134 environmental respondents also indicated civil. Some overlap was also found among other disciplines, but they were considered sufficiently distinct for analysis. For electrical engineering, 41% of the respondents also taught computer engineering. For computer engineering, 32% also taught electrical engineering. For biomedical, 23% also taught mechanical, 19% chemical, and 18% electrical. Individuals teaching other engineering disciplines are also represented among the respondents, including aerospace, agricultural, architectural, biological, engineering management, geological, general, industrial, materials, mining, nuclear, and petroleum.

Results

The survey respondents were presented with 18 potential topics related to ethics and broader societal impact / macroethical issues (as well as "other" and "none"), and asked to identify which were incorporated into one or more of their courses; results are summarized in Figure 1. There were 1228 responses to this question. There were two topics that were incorporated into one or more courses by over 50% of the respondents: professional practice issues and societal impacts of engineering and technology. Both of these topics are very broad and vague, and as-such it is not surprising that these topics are quite common. More specific topics were less prevalent. Four topics were taught by 40-49% of the respondents, and four additional topics were taught by 30-39 of the respondents; eight topics were taught in courses by less than 20% of the respondents.

Research Question #1: Topics. Only 12% of the respondents indicated that they did not teach any of these topics in their courses. In reality, it is possible that a much higher percentage of engineering and computing faculty do not include ethics-related topics in any of their courses. But given the survey invitation, those individuals were unlikely to respond to the survey. In this case, the co-curricular survey invited all mentors/advisors to take the survey on the basis of their co-curricular involvement. The survey invitation also stated "Even if you don't believe the students learn about the societal impacts of technology or ethics through activities with [insert co-curricular name here], please take a minute to indicate that on the survey." Thus, a larger percentage of the co-curricular survey respondents (13.5%) answered the course-based ethics survey question negatively (compared to 8.2% on the curricular survey). The additional 54 individuals who began the co-curricular survey but did not answer the curricular question (5.5%) may also have not taught those topics in their courses and thus skipped the question (among those, most stopped taking the survey entirely at that point).

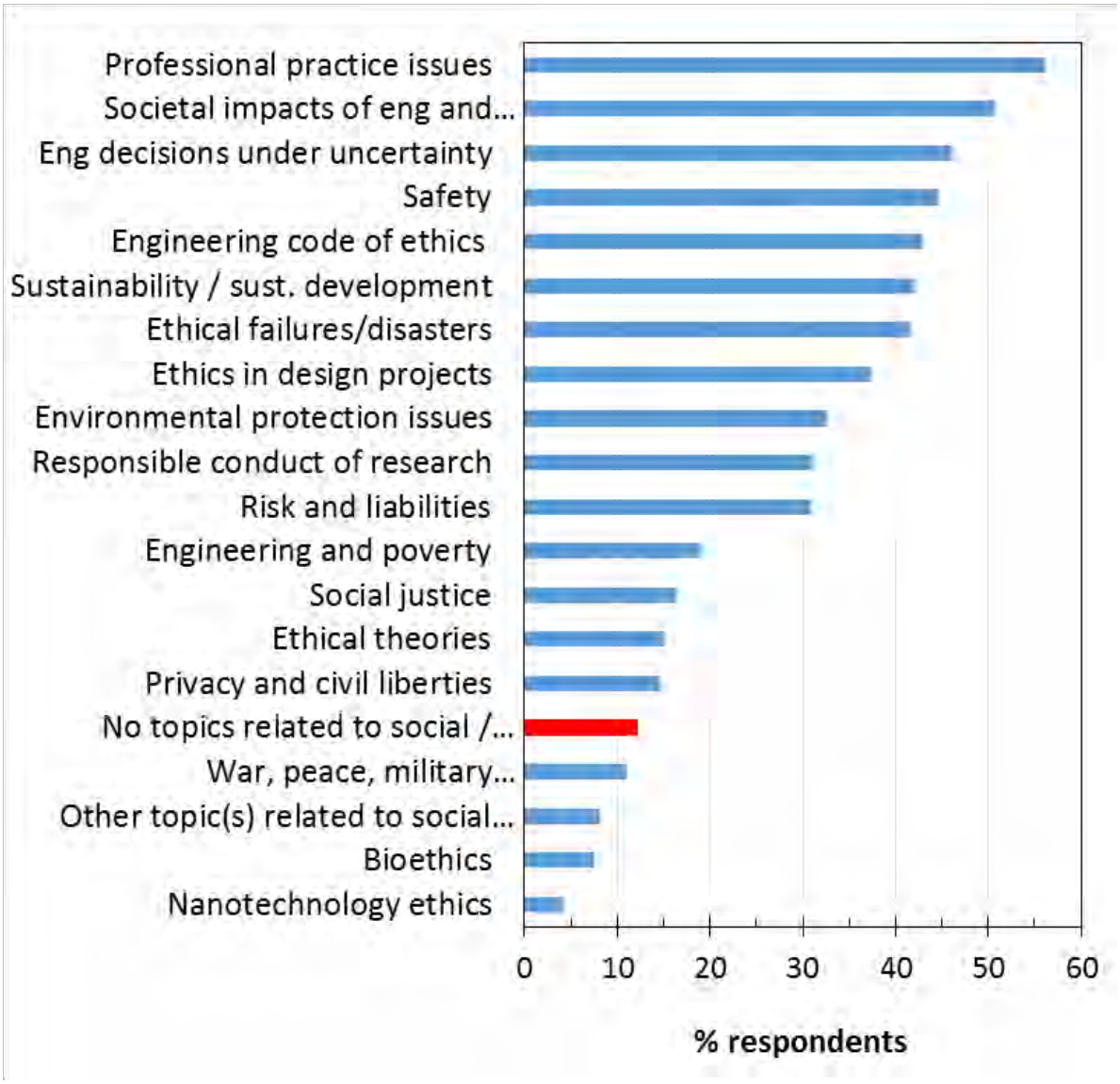

Figure 1. Percentage of respondents who teach these topics in one or more of their courses

It was found that there were differences in the frequency that some topics were identified between individuals who responded to the curricular versus the co-curricular survey. On average, respondents to the curricular surveys indicated 7 of these topics that they taught in their courses, compared to only 5 topics among the co-curricular survey respondents. Among the individual topics, 12 of the 20 topics had significantly different representation among the curricular and co-curricular respondents (Table 1). The only topic taught more frequently among respondents to the co-curricular survey was 'risk and liabilities.' Also "no topics related to the societal impacts of technology or ethics in any courses" was reported by 14% of the co-curricular respondents but only 8% of the curricular respondents.

Table 1. Contrast in topic prevalence among different respondent groups

Topics	Significantly higher, % higher	Highest discipline, %	Lowest discipline, %
Professional practice issues	Curricular 18		
Societal impacts of engineering and technology			
Engineering decisions in the face of uncertainty		Chemical 64	Computer 39
Safety		Chemical 72	Computer 37
Engineering code of ethics	Curricular 14	Civil 59	Biomed 41
Sustainability and/or sustainable development		Civil 63	Biomed 24
Ethical failures/disasters	Curricular 17	Chemical 54	Mech 43
Ethics in design projects			
Environmental protection issues		Chemical 57	Computer 16
Responsible conduct of research		Biomed 57	Civil 24
Risk and liabilities	Co-curricular 10		
Engineering and poverty	Curricular 33	Computer 30	Mech 20
Social justice	Curricular 27	Computer 26	Mech 12
Ethical theories		Biomed 27	Mech 17
Privacy and civil liberties	Curricular 26	Computer 33	Mech 10
No topics related to social / ethical issues	Co-curricular 5	Biomed 14	Civil 4
War, peace, military applications of engineering	Curricular 21	Computer 28	Civil 4
Other topics related to social, ethical issues	Curricular 16	Computer 16	Civil 4
Bioethics	Curricular 9	Biomed 42	Civil 5
Nanotechnology ethics	Curricular 6	Biomed 14	Mech 2

* For columns 2, 3, and 4, only statistically significant results are shown; colors help highlight particular majors

After combining the curricular and co-curricular responses, potential differences in six disciplines were explored. Overall, mechanical respondents averaged the lowest number of topics per respondents (5.8), while chemical averaged the highest (7.0). Comparing the prevalence of topics among the six disciplines, there were differences among 16 of the 20 response options. All disciplines were similar in the extent that four topics were taught in courses: professional practice issues, societal impacts of technology, ethics in design projects, and risks/liabilities. Table 1 shows the disciplines with the highest and lowest percentage of respondents teaching the topics with significant differences. Some findings were not surprising; biomedical engineering students were the most likely to be taught about bioethics (42%), followed by chemical engineering (12%), with other disciplines at 6% or less. The prevalence of the six disciplines across two topics, environmental protection and safety, are shown in Figure 2. This shows that different topics related to ethics appear to vary in the extent to which they are taught to students in different disciplines. This is clearly appropriate, as some topics have greater relevance in some disciplines.

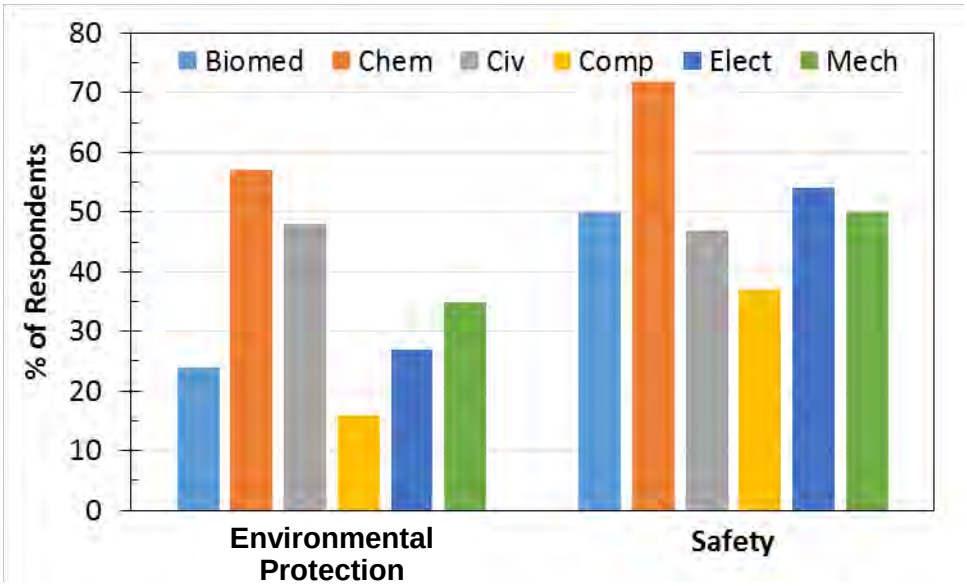

Figure 2. Percentage of individuals teaching different disciplines who teach topics related to environmental protection or safety in one or more of their courses

Research Question #2: Courses. The second research question explored the types of courses where individuals reported teaching topics related to ethics and societal impacts; 1081 responses were received (this question was not displayed to those who indicated that they did not teach any topics related to ethics or societal impacts). On average, each person indicated 2.3 different courses. At some research intensive institutions this may represent the majority of courses taught, where typical teaching loads are about three to four courses per academic year.[15-17] In contrast, at Bachelor's institutions and/or among full time instructors, teaching loads may be six to eight courses per year.[15-16] The most prevalent course types are shown in Table 2. About 40% of respondents indicated that ethics-related topics were incorporated into their senior capstone design and sophomore/junior level core engineering science/engineering courses that they taught. The results might largely reflect the extent to which these courses were taught by the respondents, rather than the predominance of ethical topics in these type of courses more generally. For example, it is assumed that one or more of these topics is likely incorporated into nearly all senior capstone design courses; the fact that 41% of the survey respondents (or more) taught capstone design is surprisingly high. In contrast, there are typically many more sophomore/junior level engineering science/engineering courses in curricula. Comparing the two surveys, respondents to the co-curricular survey more widely indicated that they integrated ethics topics in senior capstone design, and sophomore or junior level engineering science/engineering courses or design-focused courses.

There were differences between disciplines in the extent to which half of the course types were reported (Table 2). For example, 41% of those who taught civil engineering students reported teaching design-focused courses in the sophomore, junior, or senior year that included ethics topics, compared to only 27% of those teaching chemical engineering or computing students. Perhaps these types of courses are less common in those curricula overall, or when offered they may be less likely to include ethics-related issues. Which reason accounts for the difference is a question for future research. Few reported teaching a full course on engineering ethics, but this

was more common among computer engineering and the least common among chemical engineering. All disciplines included ethical issues with similar frequency in senior capstone design courses, sophomore and junior core engineering science or engineering courses, first year introductory courses, first year design courses, and humanities and/or social science courses.

Table 2. Types of courses where topics related to ethics are taught

Course type	% all responses	Higher response type, % higher	Highest discipline, %	Lowest discipline, %
Senior capstone design	41	Co-curr 20		
Sophomore or junior core engineering science or engineering course	40	Co-curr 15		
Design focused sophomore, junior, or senior course	31	Co-curr 14	Civil 41	Comp, chem 27
First year introductory course	31			
Graduate level course	30		Biomed 41	Elect 18
Professional issues course	17	Curricular 8	Civil, comp 25	Mech 15
Other	12	Curricular 11	Chemical 18	Civil 7
First year design	12			
Humanities and/or social science course	9	Curricular 9		
Full course on engineering ethics	7	Curricular 12	Computer 15	Chemical 7

* For columns 3, 4, and 5, only statistically significant results are shown

Different topics also appeared to be associated with particular course types. For example, in full courses on ethics, the engineering code of ethics (81%), ethical failures/disasters (82%), societal impacts of technology (82%), ethical theories (60%), and privacy/civil liberties (35%) were much more common than in other course types (37-64%, 45-65%, 57-70%, 18-30%, and 10-19%, respectively). Responsible conduct of research was the most common in graduate-level courses (52%) and much less common in all other types of courses (36-45%). However, many of the other topics were least widely reported in graduate-level courses; it is likely that a portion of the respondents did not teach any graduate level courses, since 7% of the respondents indicated that they taught at institutions where the highest degree awarded was a Bachelor's degree (of n=1161). Overall, the greatest number of topics (9.8, on average) were taught by individuals who taught full courses on engineering ethics; the fewest topics (6.4, on average) were taught by individuals who reported teaching graduate-level courses.

Research Question #3: Adequacy of Ethics Education. The third research question explored the extent to which respondents felt students in their program received adequate education on ethical issues. First, the individuals who indicated they did not know (in the case of undergraduates) and/or it did not apply (in the case of graduate students) were removed from the data set (for undergraduates, 13% of respondents to the co-curricular survey, 13% of respondents to the curricular survey; for graduate students, 32% of the co-curricular survey respondents and 30% of the curricular survey respondents). The results for those who provided an opinion for undergraduates in their program (n=1047) are summarized in Table 3.

Table 3. In your opinion, do undergraduate engineering/computing students in your program receive sufficient education on the societal impacts of technology and ethical issues?

Response	All, %	Higher response type, % higher	Highest response discipline, %	Lowest response discipline, %
Yes, but too much; the time could be better spent on other topics	1	Co-curr 2	*Mechanical 3*	*Chem, Elect 0*
Yes, a sufficient amount	32	Co-curr 13	*Elect, Chem 36*	*Biomed 29*
A sufficient amount of ethics, but insufficient on the broader impacts of technology	16	Co-curr 6	*Civil 19*	*Chemical 11*
A sufficient amount on the broader impact of technology, but not enough ethics	12		*Chemical 18*	*Mechanical 9*
No, not enough	39	Curricular 24	*Computer 41*	*Biomed 33*

Italics = differences not statistically significant in chi-square test

The most respondents felt that the education of undergraduate students on ethical issues was not adequate (51%, based on adding the 'no, not enough' and the '…but not enough ethics' responses), nor was education on broader impacts (55%, based on adding the 'no, not enough' and the '…but insufficient on the broader impacts of technology' responses). Only 33% felt there was sufficient education of undergraduate students on these issues (combining the too much and sufficient categories). Significantly more of the curricular survey respondents felt that education in both microethics and macroethics was insufficient (57%; compared to only 33% of the co-curricular survey respondents). There were not statistically significant differences between disciplines in these opinions.

For graduate students, there was again general consensus that education on ethical issues was not sufficient (Table 4). Among those who responded to the co-curricular survey, 22% believed there was adequate ethics education for graduate students, compared to only 12% of the curricular survey respondents. There were also significant differences between disciplines for the perceived adequacy of graduate education on ethical issues ($p = 0.003$). This adequacy perception is expected to be influenced by knowledge of the extent to which these issues are covered in the curriculum, as well as a person's individual opinion on what would constitute sufficient education. It is expected that faculty have different beliefs on what constitutes sufficient education on microethics and macroethical issues.

Table 4. In your opinion, do graduate engineering/computing students in your program receive sufficient education on the societal impacts of technology and ethical issues?

Response	All, %	Higher response type, % higher	Highest response discipline, %	Lowest response discipline, %
Yes, but too much; the time could be better spent on other topics	1		*Computer 3%*	*Civil 0%*
Yes, a sufficient amount	18	Co-curr 10%	*Electrical 28%*	*Mechanical 15%*
A sufficient amount of ethics, but insufficient on the broader impacts of technology	9		*Biomed 15%*	*Computer 6%*
A sufficient amount on the broader impact of technology, but not enough ethics	10		Civil 14%	Electrical 1%
No, not enough	62	Curr 17%	*Computer 66%*	*Biomed 49%*

Italics = differences not statistically significant in chi-square test

Summary and Discussion

The survey respondents reported teaching a wide range of topics related to ethics and societal impact issues. The frequency that most of these topics were cited varied between those who responded to the curricular and co-curricular surveys, and also varied among different engineering disciplines. The topics related to ethics were taught in a variety of different undergraduate courses, as well as graduate-level courses. The types of courses reported varied between the respondents to the curricular and co-curricular surveys. For about half of the course types, the frequency also varied among disciplines. In general, over half of the faculty believe that there are deficiencies in the education of engineering and/or computing undergraduate and graduate students in their programs on ethical and/or societal impact issues.

This paper presented the results from a large national survey. However, a number of limitations should be acknowledged. First, those who chose to respond to a survey about the education of engineering and computing students on ethics and societal impacts issues likely care more about these issues than those who were not invited to participate and/or did not choose to participate in the survey. Those invited to take the curricular survey were more likely to be biased toward the importance of these issues, given the lists to which the invitation was distributed. For the co-curricular survey, individuals are not expected to be biased toward societal impact or ethics education. Seeing the differences in the responses between the two surveys reinforces the notion that the curricular survey respondents were more likely advocates for societal and ethical education of engineering and computing students as compared to co-curricular mentors who may be more representative of faculty in general. Unlikely to be significantly represented among the survey respondents are those faculty who care more about research than student education. The survey is on-going and additional respondents may reflect a wider array of experiences and attitudes. For example, if it is determined that particular disciplines and/or institutional types are not well represented, more targeted efforts will be devoted to encourage responses from those groups.

A second limitation of the survey results is the blurred line linking particular ethics-related topics to particular courses. For two of the research questions presented in this paper, individuals

considered the myriad of courses that they taught. Tenure-track faculty at undergraduate/ teaching-focused institutions and/or full time instructors may routinely teach six courses. Perhaps they integrate ethical and societal impact issues into only half of those courses, and among those three courses different topics in different courses. That level of detail is unknown. We also don't know who among the respondents might teach a type of course and *not* include ethics/societal impact issues.

The surveys include a lot of additional information that was not analyzed and presented in the current paper. The goals of the larger study include identifying exemplars for teaching different topics in different courses using various pedagogies and assessment methods. Thus, many survey respondents provided some of this basic information for one or two of their courses. In response to an open-ended question, a number of the survey respondents indicated that societal impact and ethics issues should be integrated into courses across the curriculum. Given the large number of examples provided by survey respondents, it appears that there are opportunities to infuse these topics into any course. Touching on these issues frequently, even if not in-depth, may reinforce to students that considering societal impacts is an important part of the common activity of engineers in all settings. This approach may also be less intimidating to engineering faculty, as for the most part they have not been formally trained in teaching ethics. The list of topics described in this paper provide basic ideas, some of which are more common for particular disciplines.

A series of interviews are planned to explore promising macroethics education approaches, and a smaller number of examples will be selected as case studies for detailed study (including student and alumni interviews, classroom observations, etc.). The National Academy of Engineering has recently compiled a list of case studies of ethics education, and this may also give faculty who are interested in examples of effective teaching approaches.[18] Thus, resources are already available and more are being generated to support faculty with an interest in teaching students about societal impact and ethical issues.

Acknowledgement

This material is based on work supported by the National Science Foundation under Grant #1540348, #1540341, and #1540308. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

1 National Academy of Engineering, Emerging Technologies and Ethical Issues in Engineering, National Academies Press, Washington D.C., 2003.

2 National Society of Professional Engineers (NSPE), "NSPE Code of Ethics for Engineers," online at: http://www.nspe.org/resources/ethics/code-ethics, accessed May 9, 2016.

3 American Society for Engineering Education (ASEE), "American Society for Engineering Education Code of Ethics," https://www.asee.org/member-resources/resources/Code_of_Ethics.pdf, accessed May 9, 2016.

4 Barry, B.E., and J.R. Herkert, "Engineering Ethics," Chapter in Cambridge Handbook of Engineering Education Research, A. Johri and B.M. Olds, Eds., Cambridge University Press, New York NY, 2014, pg. 673-692.

5 National Academy of Engineering and the Center for Engineering, Ethics, and Society, Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs, National Academies Press, Washington D.C., 2016.

6 ABET Engineering Accreditation Commission, Criteria for Accrediting Engineering Programs, Effective for Reviews During the 2016-2017 Accreditation Cycle, ABET, Baltimore MD, 2015.

7 ABET Computing Accreditation Commission, Criteria for Accrediting Computing Programs, Effective for Reviews During the 2016-2017 Accreditation Cycle, ABET, Baltimore MD, 2015.

8 American Society of Civil Engineers (ASCE), Commentary on the ABET Program Criteria for Civil and Similarly Named Programs, Effective for the 2016-2016 Accreditation Cycle, ASCE, Reston VA, October 16, 2015. http://www.asce.org/uploadedFiles/Education_and_Careers/University_Curriculum_Development/Content_Pieces/CEPC%20Commentary%20(Oct%2016%202015).pdf, accessed May 9, 2016.

9 Spradling, C., L-K. Soh, and C.J. Ansorge, "A comprehensive survey on the status of social and professional issues in United States undergraduate computer science programs and recommendations," Computer Science Education, Routledge Publ, 2009, 19 (3), 137-153.

10 Finelli, C.J., M.A. Holsapple, E. Ra, R.M. Bielby, B.A. Burt, D.D. Carpenter, T.S. Harding, and J.A. Sutkus, "An assessment of engineering students' curricular and co-curricular experiences and their ethical development," Journal of Engineering Education, American Society for Engineering Education, 2012, 101 (3), 469-494.

11 Hess, J.L, "Global portrayals of engineering ethics education: a systematic literature review," American Society for Engineering Education (ASEE) 120th Annual Conference & Exposition Proceedings, Atlanta GA, 2013, Paper ID #6396, 18 pp.

12 Haws, D.R., "Ethics instruction in engineering education: a (mini) meta-analysis," Journal of Engineering Education, American Society for Engineering Education, 2001, 90 (2), 223-229.

13 Bielefeldt, A.R., N.E. Canney, C. Swan, and D. Knight, "Efficacy of Macroethics Education in Engineering," American Society for Engineering Education (ASEE) Annual Conference & Exposition Proceedings, 2016, New Orleans LA.

14 Knight, D., A. Bielefeldt, N. Canney, C. Swan, "Macroethics Instruction in Co-curricular Settings: The Development and Results of a National Survey," Frontiers in Education (FIE) Conference Proceedings, 2016.

15 Eagan, K., E.B. Stolzenberg, J. Berdan Lozano, M.C. Aragon, M. Ramirez Suchard, and S. Hurtado, "Undergraduate Teaching Faculty: The 2013-2014 HERI Faculty Survey," Higher Education Research Institute at UCLA, Los Angeles CA, 2014.

16 Ball, J. "A delicate balance: Are professors teaching too little?" Citizen-Times, April 7, 2015, http://www.citizen-times.com/story/news/local/2015/04/07/delicate-balance-professors-teaching-little/25421041/, accessed May 9, 2016.

17 McClelland, L. and D. Deffenbacher, "Teaching loads of tenured and tenure track faculty," April 2006, http://www.colorado.edu/pba/facstaff/report.pdf , accessed May 9, 2016.

18 National Academy of Engineering, "Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs," National Academies Press, Washington DC, 2016. 68 pp.

Angela Bielefeldt

Professor Bielefeldt is a professor in the Department of Civil, Environmental, & Architectural Engineering at the University of Colorado Boulder, where she also serves as the ABET assessment coordinator. She routinely teaches a first-year introductory course for civil engineering, which includes learning modules on ethics and sustainable engineering. She has recently begun to teach a Professional Issues in Civil Engineering course, which reinforces ethics and societal impact issues for senior undergraduate students. Her engineering education research encompasses learning through service, social responsibility, sustainability, ethics, and retention issues for diverse students. She is also a licensed P.E.

Daniel Knight

Daniel Knight is the Program Assessment and Research Associate at Design Center (DC) Colorado in the College of Engineering and Applied Science at the University of Colorado Boulder (CU). He holds a B.A. in psychology from Louisiana State University, and an M.S. degree in industrial/organizational psychology and a Ph.D. degree in education, both from the University of Tennessee. Dr. Knight's research interests are in the areas of retention and program evaluation in engineering education. He also routinely teaches ethics in the context of design to students in the first year engineering projects course at CU.

Christopher Swan

Chris Swan is the Associate Dean of the Jonathan M. Tisch College of Citizenship and Public Service and an associate professor in the Civil and Environmental Engineering department at Tufts University. He has additional appointments in the Department of Education and the Center for Engineering Education and Outreach at Tufts. His current engineering education research interests focus on learning through service-based projects and using an entrepreneurial mindset to further engineering education innovations. He also researches the development of reuse strategies for waste materials.

Nathan Canney

Dr. Canney teaches civil engineering at Seattle University. His research focuses on engineering education, specifically the development of social responsibility in engineering students. Other areas of interest include ethics, service learning, and sustainability education. Dr. Canney received bachelor's degrees in Civil Engineering and Mathematics from Seattle University, a masters in Civil Engineering from Stanford University with an emphasis on structural engineering, and a Ph.D. in Civil Engineering from the University of Colorado, Boulder. He is also a licensed P.E.