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Contributions of Learning through Service to the Ethics Education of Engineering Students

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Abstract – **Previous studies have found that engineering students can learn about ethics, both microethical and macroethical, through service-learning courses and co-curricular community engagements. This research has sought to generate a national picture through survey responses of how ethical issues are taught in these settings. Based on survey results, individuals who taught courses that included service-learning (n=160) incorporated a median of 8 ethical topics. Among co-curricular engineering service groups like Engineers Without Borders, a median of 7 ethical topics were incorporated. Microethical topics were more common in service-learning courses compared to co-curricular activities. A smaller percentage of co-curricular activities such as professional societies (39%), honor societies (39%), and design competitions (21%) indicated that students learned about ethics through working with communities. A range of teaching methods complemented the community engagement activities, with discussions and lectures used in over half of all learning through service settings. Assessment of students' learning on ethical topics was nearly universal in service-learning courses (94%), but uncommon in co-curricular engineering service settings (less than 14%). These results provide ideas on ethics topics that can be infused into community engagement activities, complemented by various teaching and assessment methods.**

Index Terms – community engagement, macroethics, reflections, service-learning

BACKGROUND

At its heart, engineering is about improving people's quality of life and serving the greater good of society. To achieve these goals, engineers must be broadly educated about ethics. This includes both microethical and macroethical issues.[1] Microethical issues address the expected behaviors of individual engineers and relationships within the profession, and are largely defined through the codes of engineering ethics and include topics like safety in design projects.[2-4] The ethics education of engineers often focuses primarily on microethical issues. Of equal importance, however, is the consideration of macroethical issues – how the engineering profession as a whole impacts society at large. Engineers need to consider how their work impacts peoples across the spectrum of society, considering environmental, economic, social justice and other similar issues.[5]

Ethics education across both micro- and macro- issues should strive to develop more than just the cognitive domain but also include social, psychomotor, and affective domains.[6] The Four-Domain Development Diagram (4DDD) shows how these four dimensions interact to reinforce learning, including deeper levels of moral and ethical development.[6] For example, values and emotions are key elements in the consideration of ethics education to develop the affective domain in students.[7-11] Real world experiences can be powerful in catalyzing affective changes. As such, learning through service (LTS) approaches should be well-suited to teach ethics, particularly macroethics. LTS is an umbrella term used to describe situations where students learn through serving people and/or communities. LTS encompasses both service-learning (SL) and co-curricular community service including community engagement (CE) activities. Through LTS activities, engineers can come to see more clearly the needs of people and society, and understand the positive and negative impacts that engineering and technology can have. The LTS activities often include a social aspect as students work with teams and engage with communities, and may also encompass the psychomotor domain -- such as a home-build with Habitat for Humanity. The 4DDD includes interest, value, and autonomy as elements that motivate learning. Co-curricular activities are self-selected, and thus should be intrinsically more motivating based on autonomy and self-determination theories. Working with communities should also demonstrate value and stimulate interest. Thus, LTS seems ideally suited to engage all of the key elements of the 4DDD and therefore optimize ethical development.

SL has been defined as course-based, credit-bearing activity where learning goals are achieved through activities with communities. SL in humanities and social science disciplines are often placement-based, where students work on-site with community groups such as soup kitchens, homeless shelters, and hospitals. Within engineering, SL is more frequently enacted as project-based learning and/or design projects that benefit people and communities.[12] Examples of engineering SL projects include assistive technology devices, museum displays to teach science/engineering principles, software for non-profit groups and feasibility studies for community projects. Formally, SL requires that students reflect on their service experiences in order to maximize their learning. However, since engineering educators have frequently embraced community service without a full understanding of the rich SL literature, some do not include reflection.[13] Previous work has shown that SL can be a successful approach to teaching macroethics.[14-18]

Community service projects via co-curricular groups are also popular. Since 2000, a number of engineering service-oriented groups have become prominent; the largest of these is Engineers Without Borders-USA (EWB). EWB partners participants with developing communities around the world to improve quality of life. This is frequently in the form of water, sanitation, and energy projects. EWB began with chapters at universities, and has since expanded to include professional and high school chapters. There are about 200 university student chapters of EWB-USA.[19] Both macroethics and microethics educational benefits of an EWB in-country experience have been reported.[20] Engineers for a Sustainable World (ESW) has a similar focus on partnerships with developing communities, and there are about 50 university chapters.[21] Bridges to Prosperity (B2P) has similar goals, but is focused specifically on bridges, generally

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footbridges; this narrow focus lends itself to civil engineering, and there are about 12 university chapters.[22] Engineering World Health (EWH) is focused on leveraging biomedical engineering to improve healthcare delivery in the developing world; there are about 45 university chapters in the U.S.[23] Sometimes projects facilitated via these engineering service organizations form the basis for projects in credit-bearing courses,[22-23] somewhat blurring the lines between curricular and co-curricular activities – hence the term LTS.

Although previous research has demonstrated the benefits of LTS to achieving ethics educational outcomes, it is unclear how widely LTS is used to teach students about ethics or how robustly such initiatives are assessed. LTS seems particularly well-suited to macroethics education, since it is directly engaging students with communities so that needs and impacts become more visible. This question of the breadth of LTS as a teaching method for ethics is explored in this research through a national study.

RESEARCH QUESTIONS

The research questions explored in this study were:

1. What topics related to ethics do instructors believe they teach via LTS?
2. What teaching methods are used in different LTS contexts to teach ethical issues?
3. What methods are used to assess ethics education in LTS contexts?
4. What are the opinions of those who teach ethical issues via LTS with respect to the sufficiency of the ethics education of engineering students, and in general?

METHODS

The data for this study were derived from two online surveys; one focused on co-curricular settings and the other on curricular settings for ethics education. The surveys were developed based on a literature review and an iterative approach where pilot versions of the surveys were tested at three institutions. An open-ended question on the pilot surveys about the survey itself (‘please share any feedback on this survey – length, type of questions, etc.’) and interviews with faculty members after taking the pilot surveys also informed changes. Both surveys included questions about both courses and co-curricular settings, but the questions were presented to respondents in a different order. More details of the survey development process and questions can be found in Bielefeldt et al.[24] All research was conducted in accordance with methods approved by the University of Colorado Boulder Institution Review Board for research with human subjects.

From the co-curricular survey, engineering service groups was selected as a category of LTS activities of interest. EWB, EWH, and B2P sent out invitations to the survey via email to their faculty advisor lists. In addition, the first author emailed self-compiled lists of faculty advisors of these organizations and ESW; these advisor lists were compiled from online information. At some institutions, student chapters and/or projects are combined or collaborative among these groups (generally EWB-B2P, infrequently ESW-EWB). Response rates from these engineering service groups ranged from 30 to 40%. Community service activities may also be conducted via other non-engineering service (non-ES) co-curricular activities such as engineering professional societies, honor societies, design competitions (such as the US Environmental Protection Agency P3[25]), and Research Experience for Undergraduates (REU) sites (via community-situated

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research[26]). Survey invitation emails were sent to advisors and mentors for these co-curricular groups; the overall response rate among these groups averaged 20%. In all, just over 5000 people were invited to take the co-curricular survey between mid-February and April 2016, and nearly 1050 responses were received by May 22, 2016. More information on the distribution and overall responses to the co-curricular survey can be found in Knight et al.[27]

The second online survey targeted student learning about ethics via curricular settings. Survey invitations were emailed to individuals on self-compiled lists of authors of journal and conference papers on ethics, and NSF grantees with abstracts that included the term ethics. The response rate to these invitations was around 20%. The Engineering Projects in Community Service (EPICS)[28] group sent an invitation to the survey to their list of domestic faculty. General invitations were also sent to lists from four divisions of the American Society for Engineering Education (ASEE): engineering ethics, community engagement, liberal education & engineering and society (LEES), and educational research methods (ERM). Response rates to these general list invitations were very low; less than 4%. Some of these individuals may have already responded to the survey from an invitation that they received from another source. We also expect that many of the same individuals are members of many of the ASEE divisions.

Data from Qualtrics' surveying software representing 1448 responses through May 22, 2016, were exported into a spreadsheet. This included partial responses that were manually closed. First the data was cleaned. For example, upon inspection of the "other" category of co-curricular activities, the write-in comments in some cases indicated courses (such as capstone design) or activities that were considered by the research team to be professional societies (such as the Association for Computing Machinery and the National Society of Black Engineers). In these cases, the responses were reclassified. Comparisons between groups were made using chi-squared tests. Among the 1131 individuals who described the methods that they used to teach societal impact issues in one or more courses, 160 included SL in one or more courses (14%). Among the 160 individuals who taught via SL, 42 also mentored co-curricular engineering service groups (26%). The individuals who taught ethics via SL represented 119 institutions (including 6 from outside the U.S.). In all, 169 individuals mentored co-curricular engineering service groups at 114 institutions (including 8 outside the U.S.). Another 398 survey respondents mentored other types of co-curricular groups and reported that they worked with a community as a method to teach ethics; these individuals represented 214 different institutions.

The demographics of these three LTS groups (SL instructors, mentors of co-curricular engineering service groups, and mentors of non-ES co-curricular activities that participate in community engagement) are provided in Table I. Individuals could skip any questions throughout the survey, so the number of responses to the demographic questions is lower than the total number of responses. Respondents encompassed all engineering disciplines, including small numbers in disciplines not shown in the Table (aerospace, agricultural, architectural, biological, engineering physics, general, geological, materials, mining, nuclear, petroleum, plastics, pre-engineering, engineering management, engineering technology, and others). Note that the mentors of co-curricular engineering service groups represented a higher percentage of faculty who teach civil and/or environmental engineering students. SL instructors and other co-curricular groups that work with communities were more balanced across a diversity of disciplines. The academic ranks of the three groups were similar, but the mentors of co-curricular groups who worked with communities had fewer individuals who held additional roles such as deans, chairs, or directors. Gender distribution was similar among the three groups. PE licensure

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was significantly different between SL instructors and co-curricular mentors who worked with communities. Note that the number of SL courses, engineering service groups and co-curricular groups that work with communities that were described on the survey exceeded the number of individuals who mentored these activities, because some individuals described two activities of the same type that they mentored.

TABLE I
SURVEY RESPONDENT DEMOGRAPHICS

Characteristic	% SL course instructors	% Co-curricular engrg service group mentors	% Co-curricular CE mentors (non-ES groups)
Disciplines Taught	(n=159)	(n= 164)	(n=392)
Mechanical	28	16	23
Civil	26	49	23
First-year	21	20	14
Electrical	14	9	13
Computer	13	4	15
Environmental	13	32	10
Biomedical	9	13	12
Chemical	7	9	13
Industrial	7	1	8
Academic Rank	(n=159)	(n=165)	(n=395)
Professor	31	38	32
Associate professor	33	30	30
Assistant professor	13	13	19
Full time instructor	14	10	10
Additional roles			
Director of program or center	16	18	9
Department chair or head	13	9	9
Associate or assistant chair	8	5	6
Associate or assistant dean	4	8	5
ABET assessment coordinator	8	13	9
Other	14	12	9
Gender	(n=159)	(n=166)	(n=395)
Male	58	61	65
Female	38	35	33
Hold Professional Engineer license	(n=157)	(n=156)	(n=390)
Yes	36	47	66
No	64	53	34

RESULTS AND DISCUSSION

RQ1 - Topics

Among the individuals who used SL as a method to teach students about ethics, the median number of ethics-related topics taught was 8 (range 1 to 17). The median number of ethics-related topics associated with co-curricular engineering service groups was 7 (range 0 to 16). These values are similar and demonstrate rich incorporation of ethics-related topics in LTS activities. A wide breadth of ethics and social impact topics can clearly be incorporated into both SL and co-curricular LTS, as shown in Table II. Over half of these LTS activities included the following topics: societal impacts of engineering and technology, professional practice issues, sustainability, safety, engineering decisions under uncertainty. SL courses included more micro-ethical topics (e.g., engineering code of ethics) and topics associated directly with "ethics" (e.g., ethical theories), while there was a single macroethical topic of engineering and poverty that was

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more commonly addressed in co-curricular engineering service groups (sustainability was marginally more common among co-curricular LTS).

A number of co-curricular mentors indicated that their groups engaged in working with a community as a method to teach ethical issues. Write-in comments from these respondents indicated that these activities included working with Habitat for Humanity, tutoring high school students, K-12 outreach, volunteering at local hospitals, etc. Among the engineering service groups, 85% indicated that students learned about ethical issues by working with communities (less than the 100% expected), compared to 39% of engineering professional societies, 39% of engineering honor societies, 21% of design competitions, 16% of REU sites/research, and 37% of "others". Among the co-curricular activities where the faculty mentor indicated that they worked with communities, but not including the engineering service groups, the median number of ethics-related topics taught to students was 4 (range 1 to 18). This was fewer topics than among SL courses and engineering service groups. The extent to which specific ethics-related topics were included in these co-curricular activities that also included community involvement differed in nearly all cases from the extent that the topics were taught in engineering service groups (Table II), with the majority of macroethical topics more prevalent in the engineering service groups. This indicates that the types of community involvement in engineering service groups, which is typically a longer-term partnership to solve a community need, differs from the types of community involvement more typical of professional groups and other co-curricular activities (perhaps short-term engagement, individual-level vs. community level, etc.).

TABLE II

PERCENTAGE OF SL COURSES AND CO-CURRICULAR LTS ACTIVITIES THAT INCLUDED VARIOUS ETHICS TOPICS

Topics	% SL course instructors n=158	% Engrg service co-curr groups n=137	% Non-ES co-curr groups that work with communities n=411
Societal impacts of engineering and technology	77	77	56^{*}
Professional practice issues	69	61	75^{+}
Sustainability and/or sustainable development	66^{+}	83	38^{**}
Safety	59	72	43^{**}
Ethics in design projects	57^{+}	42	23^{**}
Engineering decisions in the face of uncertainty	55	61	37^{**}
Engineering code of ethics (e.g. NSPE)	55^{**}	24	40^{*}
Ethical failures / disasters	53^{*}	28	20^{+}
Environmental protection issues	48	56	27^{**}
Engineering and poverty	44^{**}	86	20^{**}
Risk and liabilities	43	53	29^{**}
Responsible conduct of research	41^{**}	17	28^{*}
Social justice	34	45	19^{**}
Ethical theories	32^{**}	2	7^{+}
Privacy and civil liberties	15	9	8
War, peace, and/or military applications of engrg	13^{*}	4	6
Other topic(s) related to social and ethical issues	11	3	10^{*}
Bioethics	9	9	3^{*}
Nanotechnology ethics	7^{*}	0	2^{+}
No topics related to the societal impacts of technology or ethics	0	1	0

Symbols in SL column, SL significantly different than co-curricular engineering service groups; symbols in non-ES co-curricular column represent differences compared to engrg service groups. Chi-test significance: ** $p<0.001$; * $p<0.05$; $^{+}$ $0.05<p<0.10$

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There were a few differences among various engineering service groups in the extent that ethics-related topics were taught (Table III). EWH included more bioethics, while EWB included more about engineering decisions in the face of uncertainty and risk and liabilities. These differences are not surprising given that EWH tends to focus on health related topics, while EWB tends to focus more on community infrastructure projects.

SL Course Types

Individuals were given an opportunity to describe up to two different courses where they taught engineering students about ethics-related issues. Fifteen individuals described two courses that included SL, and 145 described one course that included SL; thus, a total of 175 courses were in the dataset. The majority of the SL courses (58%) were required for undergraduate students in one or more engineering majors, many (41%) were electives for undergraduate engineering students; far fewer were graduate-level courses (1% required, 12% electives). Some courses fell into multiple categories, such as courses that are cross-listed for senior undergraduates and incoming graduate students. The graduate-level SL courses were most common for majors in civil (n=8), environmental (n=7), and mechanical (n=6) engineering. Examples of these graduate-level courses are: indoor air quality engineering, photovoltaic systems engineering, design for development, and engineering ethics and the public.

TABLE III

PERCENTAGE OF ENGINEERING SERVICE GROUPS THAT TAUGHT VARIOUS ETHICS TOPICS

Ethics Topics	All engrg service co-curr groups n=137	EWB n=87	ESW n=15	EWH n=14
Engineering and poverty	86	100	60	71
Sustainability and/or sustainable development	83	93	93	50
Societal impacts of engineering and technology	77	83	73	64
Safety	72	83	40	57
Engineering decisions in the face of uncertainty	61	76*	47	29
Professional practice issues	61	71	47	29
Environmental protection issues	56	67	73	21+
Risk and liabilities	53	68*	27	36
Social justice	45	52	33	21
Ethics in design projects	42	47	20	43
Ethical failures / disasters	28	33	20	21
Engineering code of ethics (e.g. NSPE)	24	29	20	14
Responsible conduct of research	17	13	13	29
War, peace, and/or military applications of engineering	6	5	13*	0
Privacy and civil liberties	9	7	13	21
Bioethics	9	5	13	43**
Other topic(s) related to social & ethical issues	3	2	13	0
Ethical theories	2	2	7	0
Nanotechnology ethics	0	0	0	0
No topics related to the societal impacts of technology or ethics	1	0	0	0

Chi-square test significance: ** $p<0.001$; * $p<0.05$; + $0.05<p<0.10$

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Respondents further characterized the undergraduate courses as shown in Table IV. The results show that SL as a method to teach ethics-related issues can be incorporated into any type of course. Among the SL courses required for undergraduate students, senior capstone design was the most common. The SL senior capstone courses were most common for mechanical (n=8), biomedical (n=5), civil (n=5), computer (n=5), and electrical (n=4) engineering majors. Specific examples of sophomore or junior level required engineering science or engineering courses include: thermodynamics, software engineering, human factors engineering, introduction to materials science and engineering, surveying, sustainability in civil and environmental systems, solid and hazardous waste management. Among the elective undergraduate courses, the most common type was a design-focused course in the sophomore, junior or senior year; examples of these courses are: hydrologic engineering, steel design, leadership in building energy efficiency, sustainable engineering and international development, engineering service project. The other group included EPICS courses (any year, community-focused design projects) and cross-listed senior/graduate courses.

TABLE IV
PERCENTAGE OF UNDERGRADUATE SL COURSE DESCRIPTORS (SINGLE BEST)

Undergraduate Course Type	% Required UG SL course n=100	% Elective UG SL course n=71
First year introductory course	11	6
First year design-focused course	14	4
Sophomore or junior level engineering science or engrg course	16	13
Humanities or social science course	4	11
Design-focused course in sophomore, junior, or senior year	10	30
Senior capstone design	29	4
Professional issues courses (any level)	5	10
Full course on engineering ethics (any level)	5	3
Other	6	20

Co-curricular Types

Among the responses for specific non-service oriented co-curricular groups, indications that students learned about the societal impacts of technology/ethics via working with communities varied. Example data are shown in Table V for co-curricular groups with more than 20 respondents. Working with communities as a method to teach students about ethical issues ranged from 14% for the American Institute for Aeronautics and Astronautics (AIAA; of n=22) to 100% for Associated General Contractors (AGC; of n=5). The civil engineering professional society exceeded the computing, chemical, mechanical, and electrical engineering professional societies and the civil engineering honor society in the prevalence that working with communities was reported as a method to teach students about ethical issues ($p < 0.05$). Tau Beta Pi also exceeded Chi Epsilon in the extent that working with communities was reported as a method to teach students about ethical issues ($p=0.006$).

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TABLE V
CO-CURRICULAR SOCIETIES WHERE WORKING WITH COMMUNITIES WAS A METHOD TO TEACH STUDENTS ABOUT ETHICAL ISSUES

Co-Curricular Group	# Advisors contacted	Response rate, %	% Working with communities
Professional society			
American Instit. of Aeronaut. Astronaut. - AIAA	190	12	14
Association for Computing Machinery - ACM	292	17	35
American Instit. of Chemical Engrs - AIChE	218	17	34
American Soc. of Civil Engrs - ASCE	285	27	53
American Soc. of Mechanical Engrs - ASME	166	21	29
Biomedical Engineering Society - BMES	86	24	43
Instit. of Electrical & Eletronics Engrs - IEEE	235	14	32
Instit. Of Industrial Engineers - IIE	90	27	42
Nat'l Society of Black Engineers - NSBE	143	17	50
Society of Hispanic Professional Engineers - SHPE	100	21	76
Society of Women Engineers - SWE	216	29	41
Honor Society			
Chi Epsilon (civil engineering)	132	27	39
Tau Beta Pi (all engineering)	295	27	47

RQ2 - Methods to Teach Societal Impact Issues

In the SL courses there were, on average, 6 different methods used to teach students about societal issues in addition to SL (range 1 to 14). The results indicate that a diverse range of teaching methods are typically incorporated into these SL courses. The most common types of methods beyond SL are shown in Table VI. Active and/or student-centered methods are among the most common, frequently complemented by other methods such as lectures. The variety of teaching methods may be particularly effective to help students with a breadth of learning styles. Somewhat surprisingly, reflections were described as a teaching method for only 46% of the SL courses; however, a higher percentage of the courses did require reflections (as indicated by the fact that 62% of the SL courses used reflections as an assessment method).

On the co-curricular survey, only four teaching methods were provided as response options: lectures, presentations, and/or guest speakers; discussions; working with communities; and design projects (that is why all of the other methods appear as N/A in Table VI). All four of these methods were fairly common across both SL courses and co-curricular activities. Individuals were invited to list other methods, as well as to 'Briefly describe how engineering students learn about broader impacts and/or ethics in this informal education setting.' Under the other methods, write-in responses for engineering service groups included conferences (4; EWB-USA hosts a number of regional and a national conference each year), reflection (1), and others. However, a number of others described reflection activities in the broader response, including via "group reflection nightly on the trip". There were additional descriptions of symposia/conferences for both engineering service groups and other co-curricular activities. The responses frequently elaborated on the types of activities involved with working with communities and the design process.

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Table VI
Other Methods Used to Teach Students about Societal Issues

Teaching Method	% SL courses n=175	% Eng service co-curr groups n=172	% Non-ES co-curr groups who work with communities n=445
SL, community engagement, LTS / working with a community	100	84	100
(In-class) discussions	73	68	61
Project based learning	63	N/A	N/A
Case studies	61	N/A	N/A
Lectures	61	51	69
Engineering design	57	82	40
Examples of professional scenarios	51	N/A	N/A
Reflections	46	N/A	N/A
Guest lectures (e.g., philosophers, social scientists)	43	N/A	N/A
Videos, movie clips	35	N/A	N/A
In-class debates and/or role plays	34	N/A	N/A
Think-pair-share	19	N/A	N/A
Problem solving heuristics	19	N/A	N/A
Humanist readings	17	N/A	N/A
Moral exemplars	12	N/A	N/A
Other(s)	7	8	6

N/A = not asked on the survey

RQ3 - Assessing Student's Ethics Education

A number of different methods were used to assess students' understanding of societal impacts/ethical issues in SL courses, as shown in Table VII. The average number of different methods used was 3, with a range of 0 (do not assess these outcomes) to 8.

TABLE VII
METHODS TO ASSESS STUDENTS' KNOWLEDGE OF THE SOCIETAL IMPACTS OF TECHNOLOGY AND/OR ETHICS

Assessment Method	% SL courses
Individual reflective essays	62
Group-based written assignment	49
Individual homework assignment, essay, and/or papers that are graded with a rubric	47
Team ratings	29
Test and/or quiz questions	25
Other (describe)	22
Surveys	16
Individual homework assignments where questions have fairly straight forward right and wrong answers (similar to Fundamentals of Engineering type questions)	14
Individual standardized assessment method (DIT, EERI, ESIT, or similar)	2
Do not assess these learning outcomes	6

The most popular assessment methods in SL courses were individual reflective essays and group-based written assignments (likely various types of design reports and/or memos from team projects). 'Other' methods included feedback from community and/or clients, oral presentation

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assessment, etc. Some of the 'other' responses also elaborated on assessment method options that were presented, such as final reports (which could be considered a group-based written assignment in a design course), essay-type examinations (which is a type of test question), case analyses (which could be an individual homework assignment graded with a rubric), etc.

The majority of the co-curricular environments did not assess ethics learning outcomes, including 86% of the engineering service co-curricular groups and 89% of the non-ES co-curricular groups that work with communities raising concerns about determining the impact of these activities. Among the few that did, open-ended responses reported reflections, journals, surveys, and design documentation.

Satisfaction with ability to assess the outcomes of societal context and ethics education in SL courses ranged from very dissatisfied (1; 2%) to very satisfied (7; 9%) with an average of 4.9 (where 5 = somewhat satisfied). There was a higher average satisfaction level among those who used 4 to 8 different assessment methods, as compared to those who used fewer assessment methods (Figure 1). The fact that some individuals were only moderately satisfied with their ability to assess the outcomes of ethics education despite a somewhat high number of assessment methods used is not surprising given the difficulty of assessing deeper affective and cognitive learning outcomes around macroethical issues.

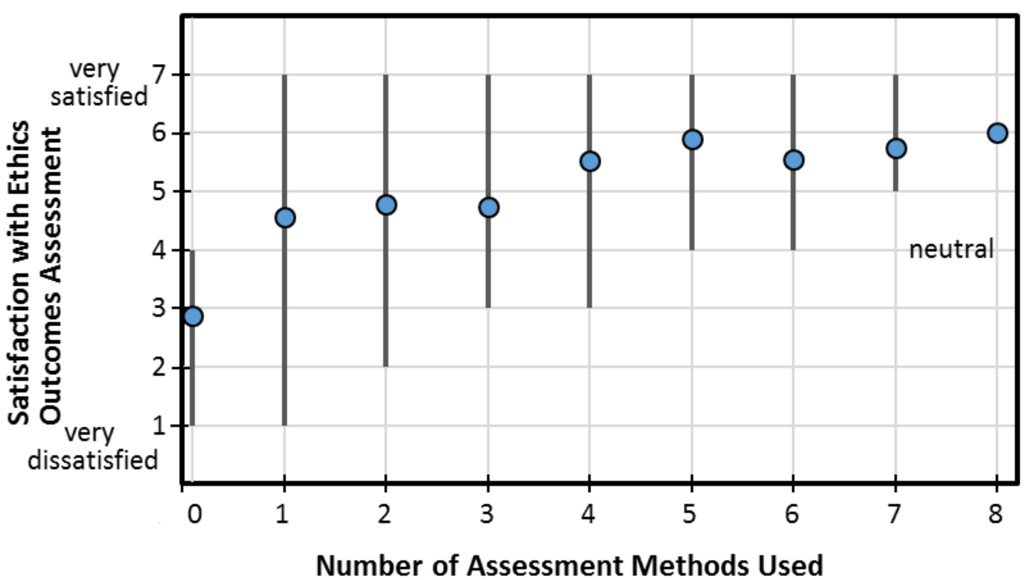

FIGURE 1
AVERAGE AND RANGE OF SL INSTRUCTOR SATISFACTION WITH ABILITY TO ASSESS THE OUTCOMES OF ETHICS EDUCATION IN THEIR COURSE.

RQ4 - Sufficient education of engineering/computing students on societal impact/ethical issues?

Survey respondents were asked to indicate whether or not they believed that undergraduate and graduate students in their program received sufficient education on societal impacts (likely corresponding to macroethics) and ethical issues (more indicative of microethics); results are

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summarized in Table VIII. Twenty-four percent of the SL instructors felt that undergraduates received sufficient education on both these topics, and 11% felt this way about graduate education. Opinions were similar among the mentors of engineering service groups, but somewhat more of the mentors of other types of co-curricular groups that worked with communities felt that the ethics and broader impacts education of undergraduate and graduate students was sufficient. The highest rankings across the board went to, "no not enough" education on ethical issues with the greatest concerns for graduate student education. It should be noted, however, that the response pool to this survey may be biased toward engineering educators who value ethics education generally. This likely over-inflates the proportion of faculty who believe that there should be more ethics education in engineering programs as compared to the entire engineering education community.

TABLE VIII
OPINIONS ON THE SUFFICIENCY OF STUDENT EDUCATION ON ETHICAL ISSUES

	Undergraduate Students			Graduate Students		
Response Option	% SL instructors n=149	% Eng serv gp mentors n=150	% mentors of nonES co-curr gps that wwc n=325	% SL instructors n=109	% Eng serv gp mentors n=124	% mentors of nonES co-curr gps that wwc n=253
Yes, but too much; time could be better spent on other topics	1	1	1	0	0	0.4
Yes, a sufficient amount	23	25	35	11	13	23
A sufficient amount of ethics, but insufficient on the broader impacts of technology	15	18	18	3	6	9
A sufficient amount on the broader impacts of technology, but not enough ethics	11	14	10	12	12	12
No, not enough	50	42	37	74	69	56
Not applicable / unsure	(6)	(8)	(13)	(31)	(23)	(31)

There were a number of very meaningful comments shared by the survey respondents who taught SL courses in response to the question "please share your thoughts about the education of engineering students regarding broader impacts and ethical issues" (69 respondents, 43%). A number of comments discussed the importance of these topics and the lack of enough student education on these issues. Along these lines, one response noted, "infusing considerations of the impacts of engineering design decisions for communities at risk or the greater population is profoundly missing from engineering education. We need education models for how to both educate engineering students in the fundamentals while understanding how creating idealized models of problems that can be quantified can end up with scenarios of significant social injustice or worse, huge negative ramifications." Some included recommendations of how to best teach these topics (inclusion in all technical courses, threaded through curriculum, case studies, integration with humanities/social science perspectives, etc.). For example, "No doubt it is extremely important for students to understand broader impacts and ethical issues. However, learning about it is very different than doing it / living it. I firmly believe that students learn best through experiential activities and as educators we must create educational ecosystems for them to have broader impacts and learn how to make good decisions and live with them." Others noted that some faculty and students do not value these topics, "The teaching of broader impacts and ethical issues always requires a "champion" faculty in the department. Not all faculty are on board with teaching this information, given the amount of fundamental engineering concepts that need to be covered." Some comments referred to accreditation requirements, and others to lifelong learning aspects. The comments also reflect the need for more than "coverage" or consideration of topics, but rather developing deeper levels of sophistication, motivation and behavior related to ethical issues. One participant noted, "It is necessary but insufficient for engineering students to only learn about broader impacts and ethical issues from other engineers. I believe the role of humanities and the arts is critical for the education of engineering students regarding broader impacts and ethical issues."

DISCUSSION

The results reveal that a number of engineering faculty members consider LTS as good opportunities to teach students about ethical issues. Previous research has found that LTS can achieve a broad diversity of learning outcomes,[12] and as-such may be considered an efficient pedagogy to meet a variety of learning goals. However, there are some ethical concerns with LTS approaches that have been voiced in the literature. International development work is particularly challenging. Community engagement opportunities should not be viewed as places where students "try their best" but could provide non-optimal solutions to their community partners; this learning curve is unacceptable given the often critical nature of the services being provided. One of the responses to the current survey reflects this concern:

> The engineering to help work is very problematic because students often learn from mistakes they make. One year they paired with an ESW chapter on another campus that agreed to design trailers to be used as housing in Haiti... not realizing that (a) the group in Haiti that approached them was a missionary org using trailers to convert people to their religion and (b) there was no practical way to get the trailers to people in Haiti with logistical mess in the port and NGO frenzy going on there. They learned a lot by pulling out of the project. They learned they didn't have the cultural or language knowledge to work there. They learned the housing they were going to design was likely to be substandard and potentially hazardous for inhabitants.... and so on.

The detailed review processes now in place at EWB-USA ideally ensure that licensed professional engineers with development skills approve both the processes and designs that will be implemented with partner communities[29]; this is an important process to ensure that our ethical responsibilities as engineers are met to provide the best appropriate and sustainable solutions to community partners.

Further, in order to successfully achieve ethics learning outcomes it should not be assumed that student "exposure" to the needs of communities and people is sufficient. Engineering students need to be coached to respect others, and to reflect – to humbly listen to others intently and in an open-minded way. They need to consider themselves partners with members of the community, and not enter the work with a "deficit" model of the community with which they are partnering.[30-32] Some students may view the situation as one of "travel philanthropy" or "voluntourism", but this mindset can also result in many problems.[33-34] One of the survey respondents shared this insight: "Modeling an ethical approach to international collaboration and exposing students to the power of a legacy of relationships built on trust and respect provides an example that may be more influential than a case study or lecture. A gentle analysis of the inherent ethical challenges of conventional engineering service projects helps students to develop the empathy that is necessary for ethical behavior." The survey results found little assessment of ethical learning outcomes in co-curricular settings, despite mentor beliefs that these environments were teaching students about these issues; this presents an opportunity for improvement and study.

There was some evidence to support the notion that LTS may be one element of effective ethics education of students, in alignment with the Four Domain Development Diagram[6] for learning. SL should involve working with community partners (the social domain), frequently included reflection (to activate the affective domain), and may have included hands-on projects (psychomotor domain). Many of the courses that included service-learning also included a number of other methods associated with ethics instruction and/or assessment. Assessment via homework and/or tests/quizzes is indicative of the cognitive domain. Use of group-based written assignments and team ratings as ethics assessment methods indicate social dimensions to learning. The in-class discussions, in-class debates, and think-pair-share pedagogies all would activate the social domain; engineering design includes cognitive and often psychomotor elements. The co-curricular LTS with engineering service groups also commonly included working with communities (the social domain), discussions (social and potentially affective), and design projects (cognitive and psychomotor domains). The co-curricular LTS has the added benefit of being self-selected, where autonomy typically leads to enhanced motivation for learning; this would also be true for elective SL courses. Although instructors may perceive that their ethics instruction in LTS settings is effective, student perspectives on ethics education via LTS should also be examined.

SUMMARY AND CONCLUSIONS

The results indicate a breadth of opportunities to teach students about macroethical issues via LTS. A single set of best practices did not emerge; rather, the results demonstrate many possibilities in a wide range of courses and co-curricular activities. Instructors who teach SL courses frequently include a rich diversity of ethics and societal impact topics, with a median of eight topics. Co-curricular groups focused on engineering service also typically incorporate a number of ethics-related topics, with a median of seven; in general, co-curricular service groups appear to focus somewhat less on microethical topics than SL courses. Opportunities for LTS are also infused into a number of non-ES co-curricular groups, with many engineering professional societies and honor societies working with communities in various ways; these also provide opportunities for students to develop a better understanding of the complexities of macroethical issues. The service and community engagement approaches to teach students about ethical issues seemed complementary to a variety of other teaching methods, in both courses and co-curricular activities. Discussions, case studies, and lectures were commonly used to teach ethics in SL courses. While 94% of SL courses assess the outcomes of ethics education, assessment was uncommon in co-curricular settings (only 14% engineering-service groups and 11% of non-ES groups that work with communities assess ethics learning outcomes). Additional assessment in co-curricular activities would help determine their value for developing outcomes. On average, SL courses used three different methods to assess ethics education outcomes. Individual reflective essays were the most prevalent assessment method used; this method is fully congruent with best practices for SL. The majority of survey respondents that work with communities felt that both undergraduate and graduate education was lacking in instruction on either ethics, macroethics, or both. Based on the survey comments, a number of faculty feel that ethics education that extends beyond cognitive learning outcomes to impact affective domains toward improved ethical behavior is both critical and lacking. LTS methods are likely to be well suited to achieve these goals, particularly when coupled with directed student reflection activities.

Thus, we encourage those who are engaging with communities via SL courses or co-curricular activities to view these as teachable moments with respect to engineering ethics. Thoughtfully considering the ethical dimensions of the projects and experiences prior to engaging with community partners can help to ensure the best outcomes from both the community and student learning perspectives. Thoughtfully discussing and reflecting on ethical dimensions arising during and after the community engagement experience will further develop students' ethical reasoning abilities. These community engagement opportunities may be particularly powerful in catalyzing future ethical behavior among engineers, as they can encompass cognitive, affective, social, and psychomotor domains of learning[6] in a situation that is motivating as students see that their contributions can have real benefits to their community partners.

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References

1. Brock E. Barry and J.R. Herkert. "Chapter 33. Engineering Ethics," in *Cambridge Handbook of Engineering Education Research*, ed. A. Johri and B.M. Olds (New York: Cambridge University Press, 2014).
2. National Society of Professional Engineers (NSPE), *NSPE Code of Ethics for Engineers*. 2007. http://www.nspe.org/resources/ethics/code-ethics , Accessed May 31, 2016.
3. American Society for Engineering Education (ASEE). ASEE Code of Ethics. https://www.asee.org/member-resources/resources/Code_of_Ethics.pdf Accessed May 31, 2016.
4. American Society of Civil Engineers (ASCE), *Code of Ethics*. 2006. http://www.asce.org/uploadedFiles/About_ASCE/Ethics/Content_Pieces/CodeofEthics2006.pdf Accessed May 31, 2016.
5. ABET, *Criteria for Accrediting Engineering Programs. Effective for Reviews During the 2016-2017 Accreditation Cycle* (Baltimore MD: ABET, 2015).
6. Linda Vanasupa, J. Stolk, and R.J. Herter, "The Four-Domain Development Diagram: A Guide for Holistic Design of Effective Learning Experiences for the Twenty-First Century Engineer," *Journal of Engineering Education* 98 (2009): 57-81.
7. American Society of Civil Engineers (ASCE), *Civil Engineering Body of Knowledge for the 21st Century – Preparing the Civil Engineer for the Future. Second Edition*. (Reston VA: ASCE, 2008).

8. D.R. Lynch, J.S. Russell, J.C. Evans, and K.G. Suterer. "Beyond cognition: The affective domain, values, and the achievement of the vision," *Journal of Professional Issues in Engineering Education and Practice* 135 (2009): 47-56.
9. A. Gupta, A. Elby, and T.M. Philip, "How engineering students think about the roles and responsibilities of engineers with respect to broader social and global impact of engineering and technology," *American Society for Engineering Education (ASEE) Annual Conference & Exposition Proceedings*, Seattle WA, Paper ID #13146, 13 pp. 2015.
10. T. Heikkero, "How to address the volitional dimension of the engineer's social responsibility," *European Journal of Engineering Education* 33 (2008): 161-168.
11. W.E. Kastenberg, "Ethics as analysis and ethics as feelings: the interplay of cognition and emotion on ethics education in biology, engineering and medicine," *Ethics in Biology, Engineering & Medicine – An International Journal* 5 (2014): 301-312.
12. Angela R. Bielefeldt, K.G. Paterson, and C.W. Swan, "Measuring the value added from service learning in project-based engineering education," *International Journal of Engineering Education* 26 (2010): 535-546.
13. B.G. Tucker, D.O. Kazmer, A.R. Bielefeldt, K. Paterson, O. Pierrakos, A. Soisson, and C. Swan, "The Reflective Learner: Perspectives of Engineering Faculty Engaged in Learning Through Service," *International Journal for Service Learning in Engineering* 9 (2014): 29-45.
14. M.S. Pritchard and E. Tsang, "Service learning: A positive approach to teaching engineering ethics and social impact of technology," *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Session 3630, 2000.
15. J. Duffy, D. Kazmer, L. Barrington, J. Ting, C. Barry, X. Zhang, D. Clark and A. Rux, "Service-learning integrated into existing core courses throughout a college of engineering," *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Paper 2007–2639, 34 pp., 2007.
16. J. Duffy, W. Moeller, D. Kazmer, V. Crespo, L. Barrington, C. Barry and C. West, "Service-learning projects in core undergraduate engineering courses," *International Journal for Service Learning in Engineering* 3(2), 2008: 18–41.
17. L.A. Silvovsky, F.R. DeRego, L.H. Jamieson, and W.C. Oakes, "Developing the reflection component in the EPICS model of engineering service learning," *Frontiers in Education Conference Proceedings*, Nov. 5-8, 2003. DOI: 10.1109/FIE.2003.1265905.
18. G. Kremer and D. Burnette, "Using performance reviews in capstone design courses for development and assessment of professional skills," *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Paper 2008–1041, in presentation slides (2008). http://www.ent.ohiou.edu/~me470/Resources/ASEE2008_ presentation_PerformanceReviews.ppt
19. Engineers Without Borders – USA. http://www.ewb-usa.org/ Accessed June 1, 2016.
20. M. McCormick, C. Swan and D. Matson, "Reading between the lines: evaluating self-assessments of skills acquired during an international service-learning projects," *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Pittsburgh, PA, June, 2008.
21. A.T. Dale, E.R. Lennox, R.E. Best, D. McKahn, J.L. Hess, and M.K. Jensen, "Connections without command: ESW's Service Learning Approach," *International Journal for Service Learning in Engineering*, 2014. fall special edition, 48-61.
22. S. Reichle, A. Bang, and C. Considine, "International service-learning projects for senior capstone projects," *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, 2009. Paper AC 2009-1875. 11 pp.
23. R. Malkin and L.J. Calman, "Service-learning in biomedical engineering: Engineering World Health (EWH)," *International Journal for Service Learning in Engineering*, 2014, fall special edition, 39-47.
24. A.R. Bielefeldt, N.E. Canney, C. Swan, and D. Knight, "Efficacy of Macroethics Education in Engineering," *American Society for Engineering Education (ASEE) Annual Conference & Exposition Proceedings*. June 2016, New Orleans LA. 21 pp. DOI: 1018260/p.26919.
25. US Environmental Protection Agency, *People, Prosperity and the Planet (P3) Student Design Competition*. https://www.epa.gov/P3 Accessed June 1, 2016.
26. K. Lancaster, L. Hossfeld, E. O'Donnell, and H. Green, "The challenges and rewards of community-based research and scholarly engagement," *Prospectives on Undergraduate Research and Mentoring*. 1.1. 2011. http://blogs.elon.edu/purm/files/2011/10/PURM-1.1-Lancaster-et-al2.pdf Accessed June 1, 2016.

27. D. Knight, A.R. Bielefeldt, N.E. Canney, and C. Swan, "Macroethics Instruction in Co-Curricular Settings," *Frontiers in Education (FIE) Conference Proceedings*. Oct. 13-14, 2016. Erie PA.
28. C.B. Zoltowski and W.C. Oakes, "Learning by doing: reflections of the EPICS program," *International Journal for Service Learning in Engineering*, 2014, fall special edition, 1-32.
29. D. Sacco and J. Knight, "TACs, ARCs and Project Process at EWB-USA," *International Journal for Service Learning in Engineering*, 2014, fall special edition, 33-38.
30. D.R. Shabazz and L.M. Cooks, "The pedagogy of community service-learning discourse: from deficit to asset mapping in the re-envisioning media project," *Journal of Community Engagement and Scholarship* 7 (2014): 71-83. http://jces.ua.edu/the-pedagogy-of-community-service-learning-discourse-from-deficit-to-asset-mapping-in-the-re-envisioning-media-project/
31. B.G. Tucker, D.O. Kazmer, A.R. Bielefeldt, K. Paterson, O. Pierrakos, A. Soisson, and C. Swan, "Principles of sustaining partnerships between higher education and their larger communities: perspectives from engineering faculty engaged in learning through service," *International Journal for Service Learning in Engineering*, 2013, Fall special edition, 48-63.
32. K.G. Paterson, A.R. Bielefeldt, C.W. Swan, G. Rulifson, D. Kazmer, and O. Pierrakos, "Designing value into engineering learning through service activities using a blueprint model," *International Journal for Service Learning in Engineering*, 2013, Special Edition Fall, 64-83.
33. M. Novelli, "Are travel philanthropists doing more harm than good?" *The Conversation*. 2015. http://theconversation.com/are-travel-philanthropists-doing-more-harm-than-good-44629 Accessed May 31, 2016.
34. M. Honey, *Travelers' Philanthropy Handbook* (Washington D.C.: Center for Responsible Travel, 2011). http://www.responsibletravel.org/docs/Travelers'_Philanthropy_Handbook_by_CREST.pdf Accessed May 31, 2016.