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Teaching Ethics as Design

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ABSTRACT

This paper introduces an approach to teaching ethics as design in a new course entitled Design Ethics, team-taught by a philosopher and an engineer/designer. The course follows a problem-based learning model in which groups of students work through the phases of the design process on a project for a local client, considering the design values and the ethical values in play in each decision along the way. Their acquisition of ethical thinking skills and moral imagination are assessed with a novel approach, which uses Latent Semantic Analysis to computationally analyze their responses to short answer ethical design questions before and after the course. Students also completed an ethical thinking survey and self-efficacy assessment. Results show statistically significant differences for a number of metrics, and promise for further research into teaching ethics as design.

Key words: design ethics, engineering ethics, design education

INTRODUCTION

The particular challenge for engineering degree programs is to support the formation of engineers who are not only competent technicians but also responsible professionals, aware of both the ethical dimensions of engineering practice and the broader implications of technological innovation. This basic responsibility has been encoded in the current version of the ABET accreditation criteria for engineering degree programs (EC2000) implemented in 2001 (ABET Engineering Accreditation Commission 2015, Besterfield-Sacre et al. 2000). Criterion 3f requires "an understanding of professional and ethical responsibility" and Criterion 3h requires "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" (ABET Engineering Accreditation Commission 2015).

At Georgia Institute of Technology, a number of engineering programs responded to the EC2000 by adopting the "inoculation model": require students to complete one course in the humanities or social sciences designated as providing an adequate dose of ethics instruction.

A well designed course in professional ethics may well contribute something to the ethical development of students (Drake et al. 2005), at least in making them aware that technical choices have implications for the basic needs and legitimate expectations of others (Weston 2012). Since the introduction of the revised ABET criteria in 2001, though, a number of authors have urged a more integrated approach to developing the whole range of technical and professional skills required of engineers (Felder and Brent 2003, Shuman, Besterfield-Sacre, and McGourty 2005). It may be especially important that programs design courses so that each of the learning outcomes is addressed in more than one or two courses (Felder and Brent 2003). So, outcomes associated with ethical responsibility might be taken up in a stand-alone course in ethics *and* in core engineering courses *and* in the capstone design course, just as other professional skills might be integrated into what is otherwise a stand-alone ethics course.

As a step toward the goal of greater integration of ethics-related outcomes into the curricula of engineering programs, we developed and delivered a free-standing, semester-length course in *design ethics*, in which students worked in groups on a design project for a client, with frequent, structured opportunities to reflect on the ethical values at stake in their design decisions. We also conducted a pilot test of a novel assessment method using Latent Semantic Analysis (LSA) (Foltz 1998, Landauer 1998) to detect changes in the cognitive schemas students bring to bear on ethical questions.

BACKGROUND

Ethics and Design

A course in design ethics is conditioned on the long-recognized parallel between ethical problem-solving and the design process (Whitbeck 2011, Bero and Kuhlman 2011, Feister et al. 2016).

From one side, according to Whitbeck (Whitbeck 2011), ethical problems have important features in common with "non-trivial" design problems. In both domains, problems are open-ended, perhaps even messy, in that "there is rarely, if ever, a uniquely correct solution or response." This is not to say there is no basis for choosing: some options are simply unacceptable and, of those that remain, some are better than others; any two responses to a problem situation "may each have advantages of different sorts."

From the other side, decisions made in the design process are often caught up in ethical implications, including decisions made in establishing the requirements of a design and in making tradeoffs among requirements (van Gorp and van de Poel 2001). Distinguishing good design from bad design is in part a function of the direct and indirect impact of the design process and its products on other people: the design team, the firm, the client, end users, bystanders, the wider public, and even future generations. Current interest in "human-centered design" has such concerns at its heart, building design requirements from a deep understanding of human needs, and validating concepts with those human stakeholders to ensure those needs will ultimately be met by the design solution (Institute 2012, IDEO.org 2015).

Navigating (Berry et al. 2015) non-trivial problems in ethics and in design calls for more than static judgment, mechanical procedures or simple decision rules. Rather, it calls for a suite of cognitive skills associated with moral imagination (Werhane 1999, Johnson 1993).

The idea of moral imagination springs from the recognition awareness of and responsiveness to the ethical values at stake in particular situations is not so much a matter of identifying discrete facts about the situation then applying abstract principles in an act of judgment (Johnson 1993). Rather, it is a matter of making sense of the situation through various cognitive schemas that serve to filter, sort and connect various features of the situation. Such sense-making is a function of imagination, which Werhane describes as "the ability to form mental images of real or unreal phenomena or events and to develop different scenarios or different perspectives on these phenomena or events" (Werhane 1999).

Werhane elaborates that moral imagination has three distinct aspects, following an earlier distinction among reproductive, productive and creative imagination (Werhane 1999):

- In its reproductive function, it establishes the possibility of *ethical awareness*: "it enables us to become aware of the moral demands of particular events and the conceptual schemas or mental models operating in specific contexts";
- In its productive function, it establishes the possibility of *critical reflection*: it "accounts for our ability to reframe our experiences in different terms, so that we can evaluate our operative mental models and critique role demands"; and
- In its creative function, as free reflection, it establishes the possibility of *creative problem solving*: it "helps in developing fresh interpretations of particular scenarios and creating new perspectives."

The main objective for a course in design ethics, then, is to have students begin in the middle of a complex problem situation, providing them with tools and support as they work to make sense of the situation and respond to it. Among these tools should be the very idea of an ethical value, along with schemas and appropriate vocabulary for framing and reframing problem situations, developing options, and sorting and connecting ethical values implicated in those options.

Following Weston, we cast ethical values as "those values that give voice to the basic needs and legitimate expectations of others as well as our own" (Weston 2012). Also following Weston, and drawing from the wider philosophical tradition in ethical inquiry, we distinguish families or types of basic values. For purposes of our course in design ethics, we focused on two of these: utility values, which focus attention on the consequences of actions for the well-being of those affected; and autonomy values, which focus attention on decision makers' attitudes toward others, especially attitudes toward others who are capable of choosing and acting on their own behalf.

Teaching Design Ethics

In the Spring 2016 term, the two faculty authors team-taught a stand-alone course in design ethics at Georgia Tech. Administratively, the course was offered as a specially designated section of an existing course in engineering ethics cross-listed with an elective in Industrial Design. Altogether, 36 students enrolled in the course, including nine Industrial Design majors; the others were mainly engineering students, in various degree programs, seeking to fulfill an ethics requirement.

We designed the course on the model of problem-based learning, understood as a cognitive apprenticeship (Collins, Brown, and Newman 1987, Newstetter 2005), in which students are guided toward mastery of the specified cognitive skills in design and in ethical consideration as they work on a design project for a client.

The stated outcomes of the course focused mainly on cognitive skills that contribute to moral imagination, though the deep connection between those skills and those involved in good design work appears under the heading of contextual awareness and in some of the auxiliary outcomes. This is how the outcomes appeared in the syllabus:

Contextual Awareness

By the end of the term, you should be better able to

- Choose an appropriate scale for framing a problem situation and its implications;
- Characterize your role within the context of the design problem,
- Identify plausible opportunities for and constraints on choice and action given your role within the context of the design problem;
- Connect opportunities and constraints to wider systems and institutions on which they are conditioned;
- Describe how your role within the context of the design problem affects the implications of your choices and actions.

Critical Consideration

By the end of the term, you should be better able to

- Identify concrete instances of basic values – including ethical values – that are in play in responding to an open-ended design problem;
- Identify concrete instances of basic values – including ethical values – implicated in particular options for responding to an open-ended design problem, including values that tell for and against each option.

Theoretical Understanding

By the end of the term, you should be better able to

- Organize and connect concrete instances of basic values by appropriate use of theoretical frameworks;
- Use appropriate terminology for each theoretical framework;
- Draw appropriate connections among concepts within theoretical frameworks;
- Manage the connections among concepts between frameworks.

Auxiliary Outcomes

By the end of the term, you should be better able to:

- Generate a variety of distinct, practicable options for responding to a problem situation, which includes reframing the situation (Creativity);
- Organize written work for ease of understanding, using clear and precise language that is accessible to a general audience (Communication);
- Collaborate effectively with others (Collaboration);
- Reflect upon your experience and the ethical implications of your design process and practice at all stages (Reflection, Self-awareness);
- Synthesize your contextual awareness, critical consideration, and theoretical understanding through application to the practice of design (Synthesis); and
- Develop habits of detailed documentation of your process and knowledge gathering.

While the main purpose of the course was to foster moral imagination, the week-to-week structure and motive power of the course derived from a four-stage design process: 1) identifying the design opportunity, 2) engaging in design research, 3) developing a conceptual design, and 4) thinking through a plan for the lifespan of the design solution. Given constraints of a one-semester course, and the parallel task of considering ethical implications, we divided the term into three parts, corresponding to the first three stages of the design process; the fourth stage served as an abbreviated epilogue to the third stage at the very end of the term.

We divided students into six teams at the beginning of the term and provided them with overviews of the design process and the basics of ethical consideration. We then guided the teams, stepwise, through the design process, offering a range of tools and examples, with frequent pauses to connect design decisions with ethical implications. At least half of any given class session would be given over to teams engaging directly in their own design work.

At the end of each stage of the design process, student teams presented their decisions and outcomes from that stage, with feedback from the instructors, other students in the course, and representatives from the client company. At the end of the term, each team offered as its final product a conceptual design packaged in a polished, visually compelling design brief for presentation to the client.

We were especially fortunate to find a client eager to work with us and to interact with the students. At several points in the term, representatives from all the teams made site visits to the client's facility to gather data and solicit ideas directly from end users and other stakeholders in the design process.

Individual writing assignments served as the main vehicle for ethical consideration: at four points in the semester, immediately following team presentations and the design brief, each individual student submitted a substantial piece of writing examining the ethical dimensions of one of the design decisions made by the student's team. This assignment, dubbed a "consideration," required a thorough analysis of the context of the decision, a recounting of the team's decision along with an alternative option, and a thorough consideration of both the option and the alternative in terms of its ethical implications. The expectation was that students would identify and describe concrete instances of basic ethical values, clearly distinguishing utility values from autonomy values and using terminology appropriate to each.

An obvious question arises at this point: How can we expect students to learn ethics when so much of the course is focused on the practice of design? The answer, in part, is to place some trust in the cognitive parallel between design and ethics, a parallel we took some pains to point out in nearly every class session and in many conversations with students. A more robust answer is to emphasize that we provided students with scaffolding and with models to guide them through the process of ethical consideration.

Scaffolding is a distinguishing feature of problem-based learning. The metaphor is straightforward: to get someone to work at a higher level, physically or cognitively, it is useful to provide an artificial structure on which they can climb. In learning, scaffolding can take the form of a template or a procedure or some other means of reducing complexity, focusing attention and guiding responses (Wood, Bruner, and Ross 1976, Pea 2004). The hope is that, as students become more familiar and more comfortable with new patterns of cognition, the scaffolding can fade away.

In this case, we provided students with a template in tabular form for identifying and describing particular instances of basic values of different kinds (i.e., utility, autonomy). In the case of utility values, for example, the template guides the user to identify particular people or groups affected by a given option, to describe the particular way in which they are affected, to characterize it as a positive or negative effect, and to explain the causal connection between the option and its effects. We also modeled use of the templates through brief in-class activities and discussions and by providing a sample of a good consideration assignment.

ASSESSMENT METHOD

Assessment of student learning can take two main forms – self-reported and direct skills testing. Self-reported data, such as surveys asking students to evaluate their own abilities or opinions, can be insightful, but is limited in validity due to human tendencies to lie, exaggerate, give perceived desired answers, and be influenced by mood. Self-reported data is relatively low-cost to collect, and is therefore combined with direct testing to give a richer picture of the data. Here, self-reported measures include a Likert-scale survey regarding feelings about the importance of ethical thinking, combined with a self-efficacy survey inquiring about how equipped students feel they are to perform particular tasks related to ethical awareness and analysis.

Direct skills testing, in which students' ability or knowledge is tested with an objectively evaluated task, is more reliably valid, but again comes with its own drawbacks. The experimental findings are highly influenced by the choice and design of the task, the mode of analysis, and the results interpretations of the experimenters themselves. Here, we chose a direct skills test in which students consider a design problem using ethical awareness, and introduce computational text analysis to speed and reduce bias in the analysis of their responses.

Participants

According to the pre-data collection survey, a total of 34 undergraduate students participated in this study, 20 males and 14 females, ranging in age from 18 to 25 years, with one participant older than 26. The majority (79%) of participants had not taken an ethics class before. Areas of study of the participants included Aerospace (9%), Civil (12%), Industrial (15%), Materials Science (9%) and Mechanical Engineering (35%), as well as Computational Media (6%), Computer Science (3%), and Industrial Design (15%). Participants included students in years 1–5 of their undergraduate studies.

Instruments

To establish the effectiveness of the course in fostering the development of moral imagination as a set of cognitive skills, we designed a novel approach to learning assessment. Students' ethical sensitivity and understanding of theoretical frameworks was assessed with a written test, centered around a given, open-ended design problem about e-waste. Along with the following statement, two paragraphs background information about the design problem was provided:

The opportunity is to find better ways to manage our used and end-of-life electronics and avoid them ending up in landfills. You are on a team that has been assigned the task of designing a solution to manage e-waste and discarded electronics to safeguard human health and protect our environment.

Five open ended, short answer questions comprised the test, as follows:

1. *If I were working with a team of peers to address this problem, what is my role with regard to this context, and how does it affect the implications of the choices/actions I take?*
2. *What are some opportunities for solutions I can identify for approaching this problem?*
3. *What are some constraints I can identify in approaching this problem?*
4. *What are the ethical values at play in going about addressing this problem, from research stages all the way to implementation and deployment of a solution?*
5. *What are some formal ethical theories that relate to the values I identified in my answer to question 4?*

This written test was administered to the students at the beginning and end of the course, allowing them 30 minutes to complete the 5 questions each time. Students also completed a demographic survey and self-efficacy evaluation, which together took no more than 10 minutes. The self-efficacy evaluation included Likert Scale and 0-100 rating questions. The specific questions asked can be found in the figures in the Results section.

Analysis

Self-efficacy evaluations were tabulated and compared as proportion of response types (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree) for the Pre vs. Post tests, shown in Figure 1. Averages, converting responses to numerical values (Strongly Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly Agree = 5) were also calculated and plotted for Likert Scale questions, shown in Figure 2. The twelve 0–100 scale questions were averaged by question and compared between the pre and post results, as shown in Figures 3 and 4.

We analyzed and compared responses to the short-answer questions in the written ethics test using Latent Semantic Analysis (LSA), a computational text analysis tool that allows for extraction of contextual similarity between documents (Deerwester et al. 1990, Foltz, Kintsch, and Landauer 1998, Landauer, Foltz, and Laham 1998). This required, first, transcription of responses into electronic text files and, second, the development of eight sets of ethical value terms: two sets of terms for each of four value types. The four value types were autonomy, utility, virtue, and a combination of all three. The first set of terms for each type was a condensed core list of terms, the second an expanded list using synonyms and troponyms.

LSA compares documents directly by using cosine similarity matrix, and gives similarity results as a value between –1 and 1. In this case, analysis yielded a cosine similarity value comparing students' responses to the open-ended questions on the instrument to the eight sets of ethical value terms sets.

RESULTS

Self-efficacy Results

Likert scale results (Figure 1) show a few different trends when comparing pre vs. post- test results. Trends show an increase in feelings that ethical consideration is important and should be integrated into engineering practice. Results show increased perceived understanding of what ethical consideration is, and increased feelings of responsibility for ethical consideration. In contrast, students reported stronger feelings that they were taking the course to satisfy a degree requirement

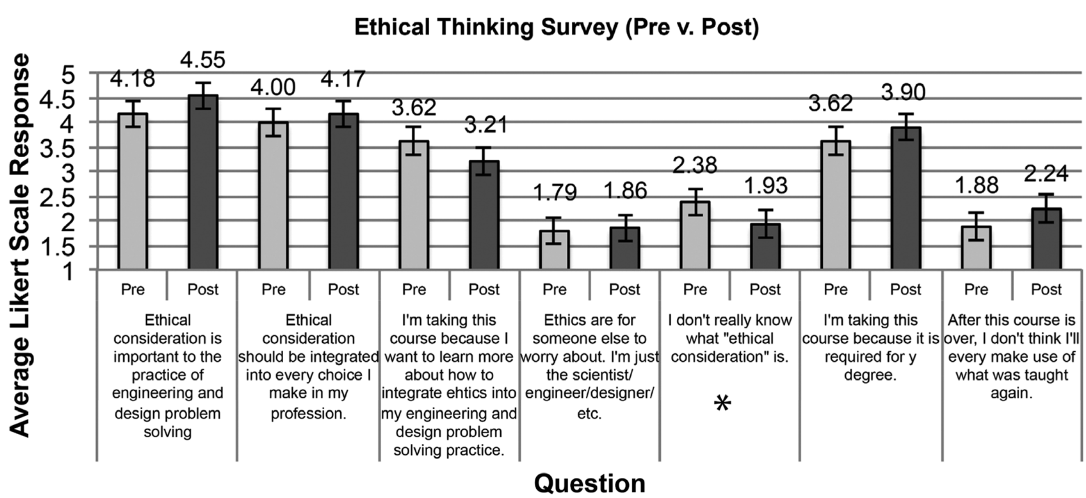

Figure 1. Ethical Thinking Survey - Pre-course v. Post-course, Likert Scale Question Results (1 = Strongly Disagree, 5 = Strongly Agree), Error Bars show ±1 Standard Error.

*indicates statistically significant difference between pre and post-course data

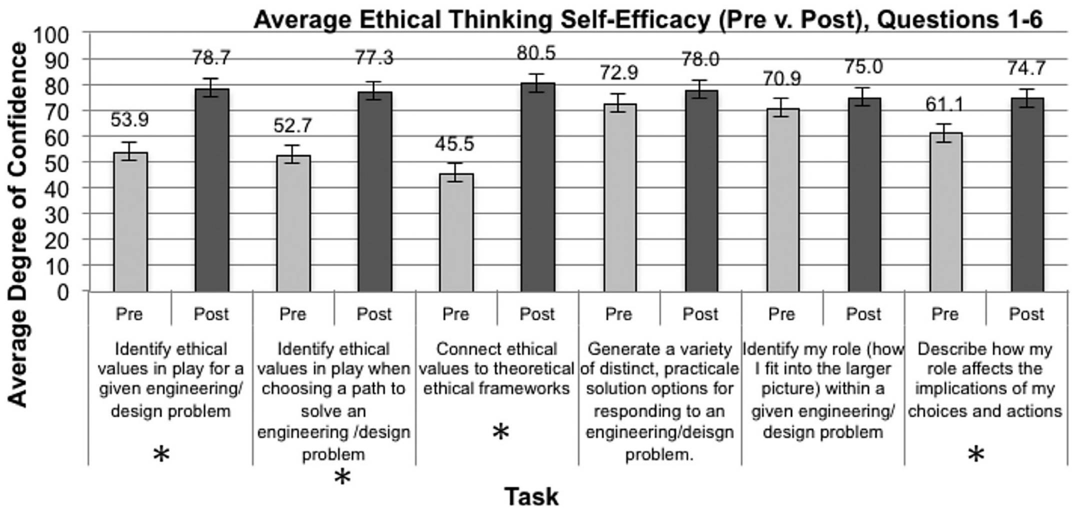

Figure 2. Average Ethical Thinking Self-Efficacy, Pre-course v. Post-course, 0–100 Scaling Questions 1–6, Error Bars show ±1 Standard Error.

*indicates statistically significant difference between pre and post-course data

in the post-test, and stronger feelings that what was learned in the course would *not* be used in the future. Levene's test confirmed homogeneity of variances for the data. A paired samples t-test was performed to assess the significance of the changes between pre and post-course data. The data for the 2-tailed t-test indicated that difference between the pre and post values (M = 0.55, SD = 1.15) for question 5 in Figure 1, "I don't really know what 'ethical consideration' is." was statistically significant (t(28) = 2.58, p = 0.015). All other differences between pre and post data in Figure 1 were not statistically significant.

The results from the 0-100 scale questions (Figures 2 and 3) showed a decrease in feelings of self-efficacy for identifying choices and actions, given one's role in a situation. All other questions showed an increase in feelings of self-efficacy, the largest of which were in the areas of identifying ethical values at play in a problem situation and path forward, and in connecting ethical values to theoretical frameworks.

A paired samples t-test was again performed after confirming homogeneity of variances using Levene's test. Five questions were found to have significant differences between the pre and post-course values; marked with an asterisk in Figures 2 and 3, these were questions 1, 2, 3, 6, 7, 8, and 10. The other pre and post-course values were not found to be different with statistical significance. The details of the statistical test results are shown below in Table 1.

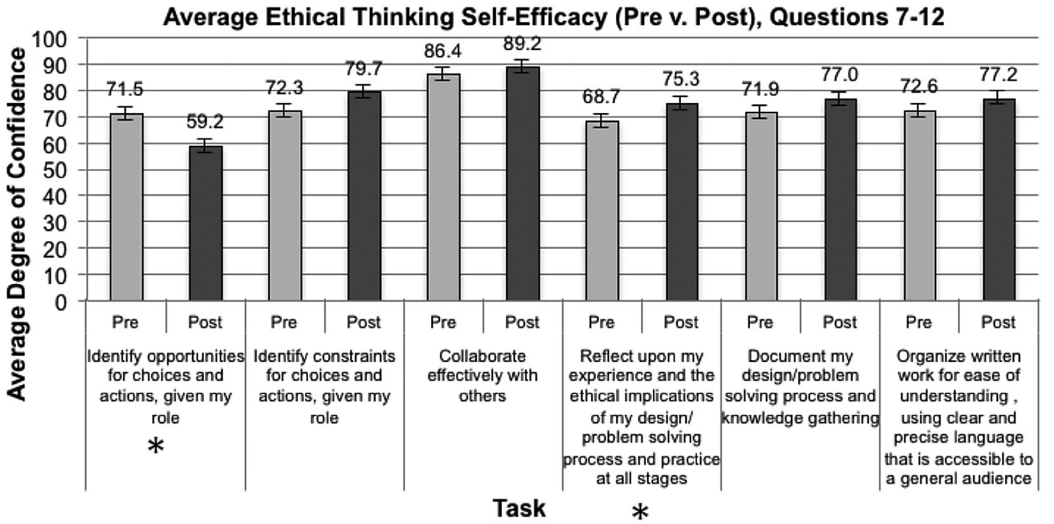

Figure 3. Average Ethical Thinking Self-Efficacy, Pre-course v. Post-course, 0-100 Scaling Questions 7–12, Error Bars show ±1 Standard Error.

*indicates statistically significant difference between pre and post-course data

Table 1. Paired Samples T-Test Results Comparing Pre and Post Data for Ethical Thinking Self-Efficacy Questions.

		Paired Samples Test							
		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	St. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Q1Pre - Q1Post	–26.600	22.754	4.145	–35.097	–18.103	–6.403	29	0.000*
Pair 2	Q2Pre - Q2Post	-23.933	21.197	3.870	–31.848	–16.018	–6.184	29	0.000*
Pair 3	Q3Pre - Q3Post	–35.300	26.992	4.928	–45.379	–25.221	–7.163	29	0.000*
Pair 4	Q4Pre - Q4Post	–7.767	25.917	4.732	–17.444	1.911	–1.641	29	0.112
Pair 5	Q5Pre - Q5Post	–5.200	25.519	4.659	–14.729	4.329	–1.116	29	0.274
Pair 6	Q6Pre - Q6Post	–15.033	20.679	3.775	–22.755	–7.312	–3.982	29	0.000*
Pair 7	Q7Pre - Q7Post	10.867	25.355	4.629	1.399	20.334	2.347	29	0.026*
Pair 8	Q8Pre - Q8Post	–8.400	19.676	3.592	–15.747	–1.053	–2.338	29	0.026*
Pair 9	Q9Pre - Q9Post	–2.567	15.867	2.897	–8.492	3.358	–0.886	29	0.383
Pair 10	Q10Pre - Q10Post	–6.800	19.973	3.647	–14.258	0.658	–1.865	29	0.072*
Pair 11	Q11Pre - Q11Post	–6.567	25.309	4.621	–16.017	2.884	–1.421	29	0.166
Pair 12	Q12Pre - Q12Post	–5.133	24.180	4.415	–14.162	3.896	–1.163	29	0.254

*indicates statistically significant difference between pre and post-course data

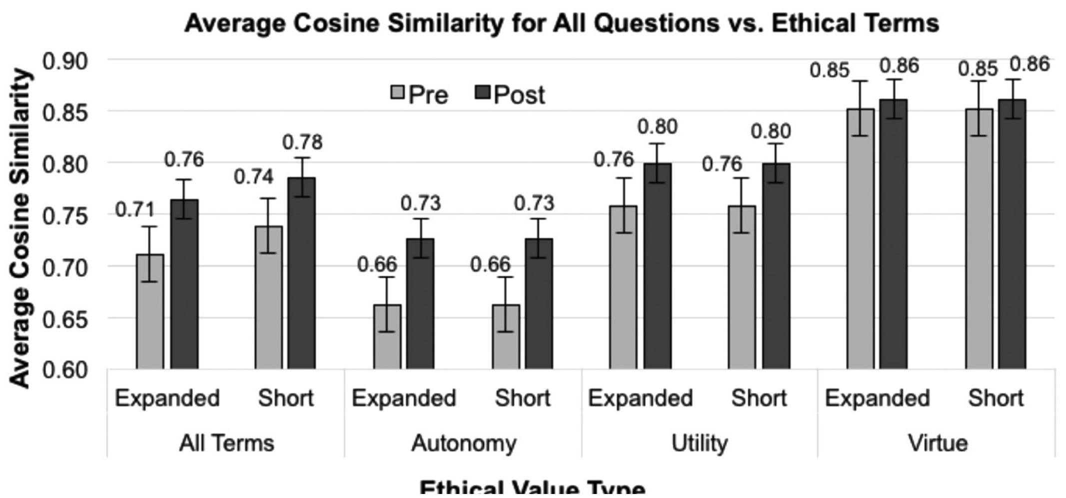

Figure 4. Average Cosine Similarity between Student Ethical Responses and Ethical Value Terms, Pre-course v. Post-course, Error Bars Show ± One Standard Error

Written Ethics Test Results

Figure 4 shows the average cosine similarity values across students for the pre and post-tests, comparing all question responses to each of the 8 ethical term sets. In short, student responses had more similarity to theoretical term sets in the post-test, indicating a potential increase in ethical sensitivity and sophistication of thought with respect to the theoretical frameworks.

A paired samples t-test was performed to test statistical significance of the results shown in Figure 1. Results indicate that the pre (M = 0.66, SD = 0.19) and post (M = 0.73, SD = 0.22) scores (identical for expanded and short) are significantly correlated (t(32) = 0.36, p = 0.039) for the autonomy terms, in both the expanded and short terms list analyses. The pre (M = 0.66, SD = 0.19) and post (M = 0.73, SD = 0.22) autonomy values (identical for expanded and short) are different with a significance value of (t(32) = –1.47, p = 0.15). The results for the other pre vs. post pairs indicate they are not significantly different or correlated.

DISCUSSION

It would be fair to say the results of the Ethical Thinking Self-Efficacy Survey are mixed, when examining the differences between and pre and post-course responses from students.

In the Ethical Thinking Survey (Figure 1), the only significant difference was in knowing what an ethical consideration is (question 5). Responses to questions 1 and 2 in this survey indicate a positive trend in student's sense of the importance of ethical thinking in the engineering and design process. However, responses to questions 3, 4, 6, and 7 indicate either no change or more negative responses in the post-test regarding motivations for taking course and predictions about future use of the knowledge acquired during the course. It should be noted that the trends in differences between pre and post-course data for all questions except question 5 were not statistically significant.

The results from the Ethical Thinking Self-Efficacy Survey (Figures 2 and 3) indicated significant differences between pre and post-course responses for 7 out of 12 of the self-evaluations, including questions 1, 2, 3, 6, 7, 8 and 10. All but one of these questions show significant increases in self-efficacy regarding some aspect of ethical thinking. Significant increases in self-efficacy were observed with respect to identifying ethical values in play for a given design problem, when choosing a path to solve that design problem, in connecting ethical values to theoretical frameworks, in identifying constraints for choices and actions, and in reflecting upon experiences and the ethical implications of their design process at all stages. Questions 4, 5, 9, 11, and 12 showed trends toward increases in self-efficacy, but these were not found to be statistically significant.

Question 7 was the only one showed a significant decrease in self-efficacy between pre and post-course responses, asking students to reflect on their ability to "identify opportunities for choices and actions, given [their] role," This is an especially disappointing result, given that the central goal of a course in professional ethics is to lead students to see and understand the connection between taking on a particular professional role and the responsibilities that come with that role.

One way to address this apparent shortcoming is to continue to refine the design of the stand-alone course, finding a better balance between the design task and the ethical considerations that weave through it. We noted above that we placed a great deal of trust in the structure of the work in the course, and in the scaffolding we provided, to prompt students to connect design decisions with ethical values. The self-reported data suggest this trust was not altogether misplaced, but that we may need to do more to foster an understanding of role responsibility and its importance in our students' future careers.

It is also possible that the mixed results reflect a more general problem with stand-alone courses in engineering ethics that are separate from the engineering curriculum proper: there may be a strong presumption on students' part that the content of an ethics course is not *really* relevant to their careers, since their degree programs do not value it enough to teach it themselves (see Barry and Herkert 2014). If anything, the data suggest this presumption somehow becomes stronger as the semester proceeds!

We offered Design Ethics as a stand-alone course so it would fit into the current practices of Georgia Tech, where most engineering students are required to take a stand-alone course outside their major to fulfill their ethics requirement. However, we have also thought of our course as establishing proof of concept that ethics and design can fit together seamlessly, which opens the door to integrating ethics education directly into design-based engineering courses, up to and including capstone courses. There are institutional and cultural challenges to be overcome to bring about such an integration, but it is the long-term goal toward which we strive.

A third possibility is that the negative results in the self-report data are an artifact of the survey instrument itself. Self-report data are ultimately of limited use in ethics education assessment, and may be especially sensitive to the way questions are framed. In future research, we could vary the questions in a quasi-experimental setup to identify and account for such artifacts.

Our purpose in developing a new assessment instrument based on latent semantic analysis is precisely to avoid the limitations of self-report data, looking instead for more direct indicators of cognitive change.

In this pilot test of the LSA-based instrument, results indicate trends toward improved ethical thinking and moral imagination, as exhibited by changes in language and vocabulary. While none of the differences are statistically significant, the autonomy terms comparison showed a significant correlation, and marginal significant difference between pre and post-course evaluations. As expected, the virtue terms comparison showed almost no difference between pre and post-course evaluations, since the course didn't explicitly address the ethics of virtue, but rather focused on autonomy and utility values.

These results could be interpreted in a couple of ways. It may be that utility theory comes more naturally to students, in terms of ease of understanding and use of language around the concepts – this is corroborated by the first author's prior extensive experience in teaching engineering ethics. Thus, it may be that since autonomy theory is more unfamiliar and harder to conceptualize, the increase in language specific to the theory is more easily detected with this assessment design. Alternatively, it could be that in teaching ethics through design, autonomy theory is indeed more effectively imparted to the students, and utility theory less so. Future data collection will attempt to address these potential explanations with new evidence.

SUMMARY AND FUTURE WORK

The integration of ethics and design holds promise as a way of fostering the development of professional skills among engineering students. Next steps include further iterations of the freestanding course in design ethics as well as adapting the approach to integrate ethics education directly into design-focused engineering courses.

The LSA-based assessment procedure also holds promise as a flexible and scalable tool for detecting changes in students' moral cognition, though the instrument stands in need of refinement and validation.

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REFERENCES

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

Barry, Brock E., and Joseph R. Herkert. 2014. "Engineering Ethics." In *Cambridge Handbook of Engineering Education Research*, edited by Aditya Johri and Barbara M. Olds, 673–692. New York, NY, USA: Cambridge University Press.

Bero, Bridget, and Alana Kuhlman. 2011. "Teaching Ethics to Engineers: Ethical Decision Making Parallels the Engineering Design Process." *Science & Engineering Ethics* 17 (3):597–605. doi: 10.1007/s11948-010-9213-7.

Berry, Roberta M., Aaron D. Levine, Robert Kirkman, Laura Palucki Blake, and Matthew Drake. 2015. "Navigating Bioethical Waters: Two Pilot Projects in Problem-Based Learning for Future Bioscience and Biotechnology Professionals." *Science and Engineering Ethics*: 1-19. doi: 10.1007/s11948-015-9725-2.

Besterfield-Sacre, Mary, Larry J. Shuman, Harvey Wolfe, Cynthia J. Atman, Jack McGourty, Ronald L. Miller, Barbara M. Olds, and Gloria M. Rogers. 2000. "Defining The Outcomes: A Framework for EC-2000." *IEEE Transactions on Education* 43 (2):100–110.

Collins, Allan, J.S. Brown, and S.E. Newman. 1987. Cognitive Apprenticeship: Teaching the Craft of Reading, Writing and Mathematics. In *Technical Reports*. Champaign, Ill. : Centre for the Study of Reading, University of Illinois.

Deerwester, S., S.T. Dumais, G.W. Furnas, and T.K. Landauer. 1990. "Indexing by Latent Semantic Analysis." *Journal of the American Society for Information Science* 41 (6):391–407.

Drake, M., P. Griffin, R. Kirkman, and J. Swann. 2005. "Engineering Ethical Curricula: Assessment and Comparison of Two Approaches." *Journal of Engineering Education* 94:223–231.

Feister, Megan Kenny, Carla B. Zoltowski, Patrice Marie Buzzanell, and David H. Torres. 2016. "Integrating Ethical Considerations in Design." American Society for Engineering Education Annual Conference and Exposition, New Orleans, LA, June 26-29.

Felder, Richard M., and Rebecca Brent. 2003. "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria." *Journal of Engineering Education* 92 (1):7–25.

Foltz, P.W., W. Kintsch, and T.K. Landauer. 1998. "The Measurement of Textual Coherence with Latent Semantic Analysis." *Discourse Processes* 25 (2-3):285–307.

Foltz, P.W., Kintsch, W., Landauer, T. K. 1998. "The Measurement of Textual Coherence with Latent Semantic Analysis." *Discourse Processes* 25 (2–3):285–307.

IDEO.org. 2015. *The Field Guide to Human-Centered Design*. San Francisco: IDEO.

Institute, LUMA. 2012. *Innovating for People: Handbook of Human-Centered Design Methods*. Pittsburg, PA: LUMA Institute.

Johnson, Mark. 1993. *Moral Imagination: Implications of Cognitive Science for Ethics*. Chicago: University of Chicago Press.

Landauer, T.K., P.W. Foltz, and D. Laham. 1998. "An Introduction to Latent Semantic Analysis." *Discourse Processes* 25 (2-3):259–284.

Landauer, T.K., Foltz, P.W., Laham, D. 1998. "An Introduction to Latent Semantic Analysis." *Discourse Processes* 25 (259–284).

Newstetter, Wendy C. 2005. "Designing Cognitive Apprenticeships for Biomedical Engineering." *Journal of Engineering Education* 94:207–213.

Pea, Roy D. 2004. "The Social and Technological Dimensions of Scaffolding and Related Theoretical Concepts for Learning, Education, and Human Activity." *Journal of the Learning Sciences* 13 (3):423–451.

Shuman, Larry J., Mary Besterfield-Sacre, and Jack McGourty. 2005. "The ABET "Professional Skills" — Can They Be Taught? Can They Be Assessed?" *Journal of Engineering Education* 94 (1):41–55.

van Gorp, A., and I. van de Poel. 2001. "Ethical Considerations in Engineering Design Processes." *IEEE Technology and Society Magazine* 20 (3):15-22. doi: 10.1109/44.952761.

Werhane, Patricia Hogue. 1999. *Moral imagination and management decision-making*. New York: Oxford University Press.

Weston, Anthony. 2012. *A 21st Century Ethical Toolbox*. 3rd ed. Oxford: Oxford University Press.

Whitbeck, Caroline. 2011. *Ethics in Engineering Practice and Research*. 2nd ed. Cambridge: Cambridge University Press.

Wood, David, Jerome S. Bruner, and Gail Ross. 1976. "The Role of Tutoring in Problem-Solving." *Journal of Child Psychology & Psychiatry & Allied Disciplines* 17 (2):89–100. doi: 10.1111/1469-7610.ep11903728.

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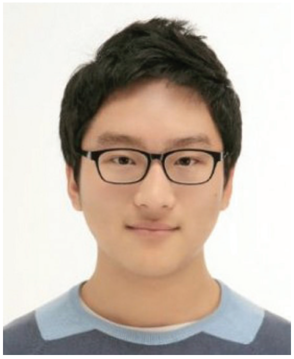

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