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Engineering Ethics in Engineering Design Courses: A Preliminary Investigation

Dr. Andrew Katz, Virginia Polytechnic Institute and State University

Andrew Katz is an assistant professor in the Department of Engineering Education at Virginia Tech. He leads the Improving Decisions in Engineering Education Agents and Systems (IDEEAS) Lab, which uses multi-modal data to characterize and improve decision-making processes throughout engineering education ecosystems.

Ms. Isil Anakok, Virginia Polytechnic Institute and State University

Ms.Anakok is Ph.D. student in the Department of Engineering Education at Virginia Tech. She has a Ms. degree in Mechanical Engineering at Virginia Tech, and Bs. in Mechatronics Engineering from Kocaeli University, Turkey.

Mr. Umair Shakir, Virginia Polytechnic Institute and State University

Umair Shakir is a Ph.D. student in Engineering Education. Prior to pursuing doctoral studies, he worked in the construction industry for five years in Pakistan and Dubai, UAE. He then joined the School of Civil Engineering, The University of Lahore, Pakistan as an Assistant Professor. He is working on a cross-national comparative study of engineering ethics and education systems in North America, Europe, and China. His passion also includes revitalization of the education system of developing countries for the welfare of underprivileged people. Currently, he is developing a financial support model for the education of low socioeconomic status students of south Asian countries, especially Pakistan.

Dr. Homero Murzi, Virginia Polytechnic Institute and State University

Homero Murzi is an Assistant Professor in the Department of Engineering Education at Virginia Tech with honorary appointments at the University of Queensland (Australia) and University of Los Andes (Venezuela). He holds degrees in Industrial Engineering (BS, MS), Master of Business Administration (MBA) and in Engineering Education (PhD). Homero is the leader of the Engineering Competencies, Learning, and Inclusive Practices for Success (ECLIPS) lab. His research focuses on contemporary, culturally relevant, inclusive pedagogical practices, industry-driven competency development in engineering, and understanding the experiences of Latinx and Native Americans in engineering from an asset-based perspective. Homero has been recognized as a Diggs Teaching Scholar, a Graduate Academy for Teaching Excellence Fellow, a Diversity Scholar, a Fulbright Scholar, and was inducted in the Bouchet Honor Society.

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Abstract

Engineering design entails countless decisions. A subset of those decisions involves ethical dimensions. While the answers to those decisions may not be self-evident, practice and education can help improve engineers' decision quality during design processes.

This research paper helps answer the question: what topics are engineering students exposed to when they learn about ethics in their design courses? Specifically, in what ways do design and ethics co-occur in engineering design courses?

To answer this question, we collected course information from 60 universities and five disciplines. In particular, we looked at the program requirements for the top 60 engineering degree-granting universities. Across each university, we focused on the five most popular engineering programs. According to ASEE By the Numbers, in 2018 these disciplines were: chemical, civil, electrical, mechanical engineering, and computer science. For each program at each university (where applicable, since some universities did not have a degree program in one of these disciplines), we collected information about any course that mentioned ethics (or a lexical derivative) in either its title or course description. Examples include courses called "Introduction to Engineering Ethics" or "Professional Seminar" that mentioned ethics in its course description.

From this collection of courses, we analyzed the course description using a text network mapping approach as a coarse, high-level overview of the language used to describe the intersection of ethics and design. The text networks technique begins with a mapping co-occurring words and phrases. With this initial accounting, we then formed a graph of nodes and edges to illustrate the network. Finally, we identified text network communities to capture persistent themes or topics.

From our results, several lessons emerged. First, not unexpectedly, engineering ethics appears differently in design courses conditional on the specific discipline. Second, almost regardless of discipline, issues of professionalism - what it means to be a member of a profession - also appear with these same issues. Third, these design courses tend to include not only design but also an array of other topics that traditionally fall under the umbrella of "professional skills" such as communication and teamwork. Future work based on these results can take this high-level evidence from course descriptions and look for more systematic variation within engineering design courses to provide more fine-grained details about observed intersections of engineering design and ethics in engineering classrooms.

1. Introduction

In the current socio-technical era, engineers are driving stakeholders of the society who impact the lives of the people by designing commodities, for example, infrastructures, home appliances, and vehicles. Engineers' decision making during the design process of these products usually entails considering conflicting interests. A textbook scenario is an engineer making a decision between the cost of environmentally safe disposal technology and the profit-maximization of the employer. This simple scenario intrigued the following two-prong issues for engineering educators: 1) what should be the underpinnings/justification of the decision-making process of an engineer? 2) when and in what context should an engineer learn these decision-making processes? Engineers should anchor their decisions on ethical/moral basis, and learn and practice these ethical-decision-making skills in their early professional development phase. Undergraduate education is one of the first formal places in the professional development of an engineer. Engineering students would be able to far-transfer ethical decision-making skills in their industry career if they learn and practice in context. Capstone design courses/projects in undergraduate degrees are the most conducive learning opportunity for engineering students to learn and practice ethical decision making in an engineering design context that simulates real-world scenarios.

Engineering ethics importance has been recognized by organizations such as the National Society of Professional Engineers (NSPE), the National Academy of Engineering (NAE), and the Accreditation Board for Engineering and Technology (ABET). For example, in the past, the NAE convened committees to envision the engineer of 2020 engineering two decades in advance [1], [2]. They predicted the demands and changes in engineering with growing complexity in applications that truly interest society globally [1]. It stated that the codes of ethics are the elements of changes and professional expertise. Engineers of 2020 are asked to understand sustainable engineering practice and adapt solutions in an ethical way [1]. While guidance from the NAE continues to inform the engineering education communities, they also recommended how to educate the engineers of 2020 [2].

To meet today's professional education requirements, degree-granting institutions aim to provide globally recognized and competent degrees. In the US, ABET is one of the organizations that carry out the accreditation process with these institutions and creates standards in disciplines. In engineering accreditation criteria by ABET, the importance of engineering ethics education is recognized by setting ethical responsibilities as one of the student outcomes [3]. This criterion informed institutions to incorporate ethics in curriculums. While some institutions prefer standalone ethics classes, some of them integrate engineering ethics in curriculums by integrating ethics within technical and nontechnical courses [4]. Relevant to the present work, engineering design courses have become one of the settings in which engineering ethics adapted.

Engineering education is based on two components: material knowledge and process knowledge [5]. To learn how to design in engineering, students should develop both materials and processes to prepare themselves for experiences outside the classroom. Material knowledge is developed with theoretical and analytical skills that are provided in engineering courses in curriculum. The process knowledge component is where engineering ethics matters in design courses because it focuses on how students apply their material knowledge in their practices and how they make decisions during the design process. Moreover, process knowledge can be more subjective and implicate moral judgments while material knowledge may not be related to ethics directly. Thus, engineering ethics and design can be linked to process knowledge and considered together. Bringing ethics into the design process helps students identify ethical issues, and holistically solve problems with a consideration of societal impact [6]. Thus, the design process should be conceptualized, and ethical questions should be addressed within the design context itself. In other words, responsibilities and moral behavior of designers, sociotechnical context, control mechanisms and regulations, and the use of the context of design are components that cannot be considered separately in the design process.

2. Background

2.1 Engineering Ethics and Design

Why does ethics matter in engineering design courses? One simple reason is that future engineers will face ethical dilemmas as they design future solutions to challenges in their careers. Since future engineers learn about engineering practice in their undergraduate education, they should learn their roles and responsibilities in society and how their design decisions can have social and environmental ramifications. Design courses are an advantageous opportunity to prepare future engineers analytically, practically, and morally. Integrated ethics content can encourage students to practice "what is right to do and how will my decisions impact the sociotechnical and societal norms within society?" The process of seeking answers for these questions can help students to recognize the ethical and moral conflicts as a part of design problems. In a complex design process, there are often conflicts, and these potential conflicts should be considered simultaneously by design engineers [7].

Researchers conceptualize the design process and propose moral reflections with distinct approaches that are informed by empirical research in socio-technical contexts [6]. While some empirical studies look into moral judgments closer, others consider moral reasoning from a broader perspective so as to contextualize these judgments in a more realistic setting [8]–[10]. In college settings, undergraduate students' decisions are shaped by their "course, school, physical space and available resources" during the design process [11]. Even if the school setting causes some limitation of conceptualizing the design process due to students still having their first design experiences in classrooms, it can often be an appropriate place for them to start wrestling with these topics altogether rather than in their traditional, discrete classes and settings.

Although ethics and design research may typically focus on one or the other, several studies have focused on the conceptualization of engineering design and engineering ethics from different perspectives. For example, Feister et al. [12] showed that ethics, competency, and knowledge are interrelated and they are the distinct components of design works. This intercorrelation of components has been investigated in-depth as to how ethics is combined with engineering design as well as what is covered in ethics (micro/macro ethics), how ethics is assessed and taught in engineering design courses. Leone [13] emphasized the importance of covering professional ethics broadly in design projects that professional engineers would serve as mentors and faculty members would serve as technical supports. Others have argued that assigning credit or points for an ethics section in design projects would help students to spend time on solving ethical issues. Moreover, working on real-world design applications help students in the decision-making process in collaborative settings [14], [15]. Various teaching platforms have brought different ways of applying ethics in design classes. Integrated decision-making tools or modules have helped researchers to investigate how students process ethical issues within the design process and how students struggle with identifying these conflicts [16]–[18]. Paralleling ethics education with a design process has been applied and outcomes from that study suggested that students have difficulties asking normative questions within moral judgments and ethical practices in design courses help them to improve their decision-making skills [19]. This result can underscore the importance of students practicing working through these ethical dilemmas in their courses so that they are better prepared to face ethical dilemmas in their careers.

2.2 Variations of Engineering Ethics Education

To meet organizational, institutional, and societal requirements, many engineering programs have been including engineering ethics in their engineering curricula. Engineering ethics courses that are separated from technical courses are not preferred due to the burden of extra credits in curriculums, the lack of connection between social and technical knowledge, and there is a potential for the topic to remain a theoretical exercise divorced from applications students may face as engineers rather than preventing developing decision-making skills practically [20]–[23]. Thus, integrating engineering ethics into science and technology courses has been supported stronger to make professional responsibilities parts of professional engineering education [24], [25].

Standalone ethics classes in social science colleges are offered and some engineering colleges prefer to require them as an elective course for engineering students [26]. However, this type of ethics courses may be suboptimal for engineering professionals and programs. Tang et al. [21] argued due to the high number of required credits and lack of engineering faculty who are experts in ethics are the reasons why engineering programs do not prefer to offer standalone ethics courses within their programs. Unfortunately, students might have difficulty bringing two areas of knowledge together when they learn topics like ethics and design separately. The importance of engineering ethics may not be understood by students in a separate course, especially when it is taken from other disciplines, e.g., philosophy or religion. This may translate to a lack of moral reasoning skills of future engineers when they work in real-world practices. To illustrate this point, prior work has suggested that a standalone ethics course did not have significant moral reasoning improvement [22].

Integrating ethics in engineering courses and how to teach and practice engineering ethics created pedagogical challenges, resistance from faculty (unprepared to teach ethics), and a lack of student interest [27], [28]. However, adding up more credit hours in engineering curriculums is more challenging due to the high credit requirements for degree completion. Integrating engineering ethics in design courses is more curriculum-friendly. These challenges and the variations of how to integrate ethics into curricula have been studied for several years. While there is no standard way for integration, researchers do tend to agree that ethics knowledge and the ability to consider ethics in the design process can be built into the curriculum across years so that students gain experience and practice in their courses [29].

Although one might suggest engineering design courses should incorporate engineering ethics as a normative stance, there are still open questions from a descriptive perspective about what actually transpires in contemporary engineering education. Therefore, in order to know how best to make prescriptive suggestions, researchers, educators, and administrators first need to answer the descriptive question about the present state of ethics education in design courses. This study helps to answer that question, posed as the following research question:

> RQ: Which topics are covered in design courses that include engineering ethics?

3. Methods

3.1 Data Collection

In this study, we focused on courses from the following five disciplines: chemical engineering (ChE), civil engineering (CivE), computer science (CS), electrical engineering (EE), and mechanical engineering (ME). We focused on these five because they were the top five most popular disciplines based on the total number of degrees granted in each discipline in 2017-2018 [30]. For each discipline, we sampled departments from the top 60 most popular US universities based on the total number of engineering students graduating from each university. In theory, this would equate to 300 departments in our sample in total (five departments from each of the 60 universities); however, some universities in this study sample did not offer all five disciplines. As a result, the total number of departments included in our study was 289 rather than 300. The final tally of departments for ChE, CivE, CS, EE, and ME is 54, 58, 60, 58 and 59, respectively.

This study operationalized the curriculum practices of the department with two observable entities: (i) courses required by the department for degree completion (regardless of the department offering it) and (ii) courses offered by the department related to major. In addition, this study only included undergraduate courses although many departments offered both graduate and undergraduate courses. To find courses for a particular department, we checked the latest available four-year plan of study at each department's website for the traditional students matriculating into undergraduate engineering degrees. Here, we want to acknowledge the growing population of transfer students in US engineering schools. This study did not include the curriculum requirements of transfer students since they have multiple entry and exit points in the engineering education ecosystem and follow multiple pathways for degree completion [31].

After selecting required or offered courses for a particular department, we looked at publicly available titles and descriptions of these courses in each university's course catalogue for the 2019-2020 academic year. We used publicly available information since it is free and consistently available which enabled us to collect data for all 289 departments included in this study. To identify those required or offered courses where "ethics" and "engineering design/capstone project" are mentioned together, we searched "ethics" (or a grammatical variant) and "engineering design" or "capstone" (or a grammatical variant) in the publicly available course titles and descriptions. Although this creates several potential limitations, as outlined in the Limitations section below, we nonetheless suggest that the selection of course descriptions for assessing the co-occurrence of ethics and engineering design instruction in a single course is a meaningful signal alongside others since topics which faculty and curriculum committees consider important are traditionally those that are mentioned in course titles and descriptions.

The final dataset of this study has information about course credit hours, course title, and course descriptions of 144 courses, although we do not include any analysis of credit hours here. Of those, 15 were from chemical engineering, 35 from civil engineering, 19 from computer science, 33 from electrical engineering, and 42 from mechanical engineering. These 144 courses came from 107 different departments.

3.2 Data Analysis

To answer this research question, we looked at courses that had the words “design” or “capstone” in either the course title or course description. It is important to remember that, although there were 107 departments in this filtered dataset, only courses that contained the word “ethic” (or a variant) were included in the initial data collection from 289 departments. This means that design courses that did not mention ethics were never included in the data collection to begin with and therefore were not included in the sample for this paper. We used a text network mapping approach as an alternative to more traditional qualitative analysis approaches.

This method lends itself to a visual representation of the analysis and is described in detail by Rule et al. [32]. The process is designed to identify latent topics or themes in a collection of documents. The general philosophy is to take a corpus of raw text and identify phrases that appear together. These co-occurring phrases then form communities, which provide a first-order approximation of themes in the corpus. In theory, each text entry (i.e., document, or in this case, course description) only contains a small subset of the topics in the corpus.

Technically, this process requires several steps. We performed two versions of this procedure. The first version excluded monograms (single-word phrases) since they have the potential to be less informative than multi-word phrases while the second version included monograms in addition to the multi-word phrases. For example, the multi-word phrase approach will focus solely on pairings such as “engineering students” or “engineering design” as opposed to just “engineering” by itself. For the multi-word phrase round of analysis, we identified phrases of two to six words in length. Next, we combined similar phrases under the same general form so that the variants would all count toward the same stem. For example, “work in teams” and “team work” or “process of engineering design” and “engineering design process” map to the same core entry (i.e., teamwork and engineering design process, respectively) in order to create a more accurate tally. We then enumerated the co-occurrences of each phrase with each other phrase and decayed the co-occurrence weight as a function of how many sentences apart the two phrases are. For example, if “codes of ethics” and “professional conduct” are in the same sentence, that is weighted more heavily than if they are three sentences apart.

With these co-occurrence weightings, we then form a graph consisting of nodes and edges. The nodes represent each phrase in the course descriptions (shown as triangles in figures 1 and 2). The edges connecting each node represent co-occurrences. Higher co-occurrence counts correspond to darker edge coloring. In order to identify consistent co-occurrences (which would suggest a coherent topic in the corpus of course descriptions), we trim edge weights below a certain threshold so that only the most consistent edges persist. This also prevents the graph from becoming inscrutable and appearing like a hairball, with most phrases connected to most other phrases.

For a final step, we used the Louvain community detection algorithm [33] to identify entire clusters of phrases in this sparser graph. These communities, or clusters, or phrases represent topics. These are shown as circles around collections of nodes and edges in the graph. The coloring is arbitrary and simply intended to differentiate between different clusters.

4. Limitations

The research has several limitations associated with the data collection and analysis procedures of this study. First, there is a limitation from the data collection - we only searched for variants of the word “ethic” in course titles and descriptions of courses required or offered by the departments. As a result, this selection method could miss synonyms and/or alternative terms of ethics, e.g., example moral or morality. A second limitation is the appearance of the word “ethic” in the course description or course title does not necessarily tell us anything about the ethics-related content taught or covered in the course. For example, typically, when a description mentioned teaching ethics, there was minimal elaboration on what that might entail. A third limitation is that we have no way to ascertain the degree to which publicly available course descriptions were the most updated descriptions of the courses as they are currently taught. While we did find the most up-to-date descriptions, there was no way to identify when that was written. A final limitation of the data collection is the potential for false positives and false negatives. More specifically, the appearance of the word “ethic” in the course description or course title did not guarantee that ethics would be discussed in the class by the instructor. This might constitute a false positive. Vice versa, any course which did not have a variant of the stem “ethic” in the course description or course title would not be included in the sample, even though ethics may indeed have been discussed in the class. This could constitute a false negative.

Regarding the analysis, there were also additional limitations. While we tried to limit the number of instances where meaningful phrases were split into their constituent parts, that could have happened. To mitigate this, a member of the research team read each of the descriptions and the term list to scan for potential omissions. Additionally, the process of paring back the connections in the network is an admittedly subjective one, balancing meaning and legibility. With a lower paring threshold, more edges persist in the network, which highlights the connections between the terms. Unfortunately, it also leads to a bird’s nest appearance that is difficult to parse, inadvertently rendering it meaningless. On the other end of the spectrum, raising the paring threshold too high can dissolve too many of the edges and lose some of the meaningful information in the network. Therefore, to balance the two, we tested a range from 0.15 to 0.55 to identify what we perceived to be an adequate balance between meaning and interpretability.

5. Results

Both the monogram inclusive and monogram exclusive networks identified similar numbers of clusters. Since the results look similar for each, we focus on describing the results for the monogram inclusive networks.

In the 144 courses, 251 unique meaningful terms were identified. These terms clustered into 20 different communities, as shown in Figure 1 and listed in Table 1 in the appendix. Something related to ethics appeared in nine of these clusters. With each cluster, a label listing the top disciplines associated with each cluster was added to the figure. To limit clutter in the figure, at most three departments could be associated with one cluster. The department label proceeds from most commonly associated to least commonly associated. For example, the cluster containing “algorithm design”, “computer ethics”, and “data manipulation” was commonly associated with CS courses and EE courses, with CS being more frequent than EE. In contrast, CivE was most associated with the cluster of design courses that discussed professionalism, regulations, and sustainability. The general trend is for most disciplines to be associated with several clusters with non-trivial overlap between where each discipline shows up with the other disciplines. This suggests that, although each discipline does have elements that are unique to how they approach the combination of ethics and design, they also share similarities.

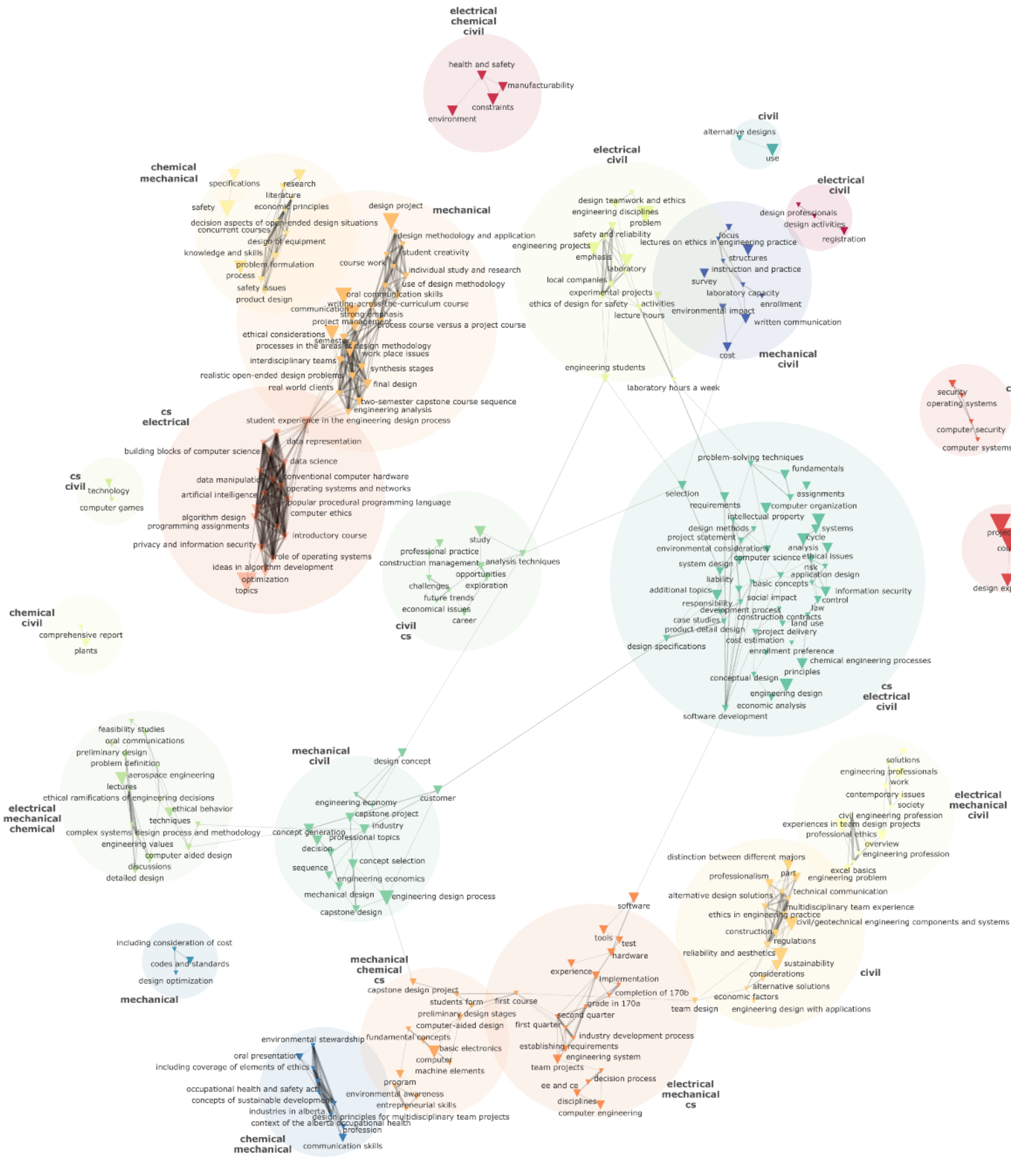

Figure 1. Text networks of engineering design course descriptions

Overall, they show the same trend: certain disciplines overlap each other in how they talk about design and ethics in their course descriptions while also possibly having aspects that are specific to that discipline. For example, CivE and ChE mention regulatory issues as part of the considerations in design courses. In CS and EE courses, topics like algorithm design and computer ethics are predictably more prevalent. All disciplines also discuss portions that are more general to engineering work as a profession, such as communication or professional practice. This demonstrates how design courses in engineering can sometimes become a catchall for an array of topics that programs may not cover elsewhere.

Regarding ethics, the topic shows up in a variety of areas. One area is around safety. Related to this is a cluster around risk and legal liability. Another is around computer program design and privacy. A third is around professional ethics. A fourth is project management and professional conduct with clients. A fifth is more general to engineering as a profession. A sixth is around ethical ramifications of decisions in complex systems. These clusters featuring ethics were only a fraction of the total number of clusters. Other clusters revolved around environmental health and safety, security, economic issues, and design optimization under cost constraints. Overall, these results presented a unique way to visualize how ethics and design may appear together in design courses alongside the broader constellation of topics covered in engineering design courses (conditioned on whether a course mentioned ethics in some way to begin with).

6. Discussion

The ethics appeared in nine different clusters, which should not be surprising given that this dataset originally came from a data collection method specifically trying to identify courses that mention ethics in some way. Moreover, these data do not necessarily tell us about the actual content of ethics discussions when they are covered in design courses. Rather, this simply tells us which other topics appear alongside ethics when it is covered in design courses.

On the positive side, while there may be a circumscribed view of ethics in design courses presented by these results, these courses were only a subset of the design courses taught by the sampled departments. In theory, ethics may be appearing much more prevalently in design courses without being called out in course descriptions. In that scenario, these results would be underreporting how ethics and design appear together in design courses.

Focusing on the presented results, one can observe that ethics appeared integrated into different aspects and considerations of the design process. Such considerations include environmental, legal, and professional obligations. On this note of professionalism and additional considerations, these kitchen-sink approaches to design courses may be symptomatic of an approach to teaching engineering design that tries to contextualize engineering practice as much as possible while also fulfilling some of ABET’s student learning outcomes. These results also support the suggestion from Main et al. [34] that engineering education research refrain from always treating engineering as one monolithic culture or discipline. By breaking the results out by discipline and identifying which disciplines tended to be most associated with the different text clusters, we can see overlaps between CivE and ME or between EE and CS. The combination of similarities and differences across disciplines makes sense from the perspective of both shared activities and cultures in engineering while also entailing notable differences.

7. Conclusion

When looking across design courses' official descriptions in ChE, CivE, CS, EE, and ME at 60 universities in the US, one can observe several general trends. First, engineering ethics appears within design courses differently depending on which discipline one considers. Second, despite these discipline-specific differences, almost regardless of discipline, design courses also contain issues of professionalism - what it means to be a member of a profession - also appear with these same issues. Third, these design courses tend to include not only design but also an array of other topics that traditionally fall under the umbrella of "professional skills" such as communication and teamwork. However, the combination of possible false positives and false negatives makes extrapolating beyond this exploratory research difficult. Future research will focus on a more systematic and in-depth exploration of the integration of ethics into design courses in the formation of engineers. Future work based on these results can take this high-level evidence from course descriptions and look for more systematic variation within engineering design courses to provide more fine-grained details about observed intersections of engineering design and ethics in engineering classrooms.

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Appendix

Table 1. Terms and clusters

cl	term	cl	term	cl	term	cl	term
0	selection	2	safety issues	6	environment	12	safety and reliability
0	case studies	2	concurrent courses	6	health and safety	12	activities
0	system design	2	process	6	constraints	12	experimental projects
0	Project statement	2	literature	6	manufacturability	12	ethics of design for safety
0	risk	2	problem formulation	7	design experience	12	local companies
0	liability	2	decision aspects of open-ended design situations	7	course	12	lecture hours
0	assignments	2	product design	7	project	12	engineering students
0	conceptual design	2	design of equipment	8	solutions	12	laboratory
0	design methods	2	research	8	civil engineering profession	12	engineering projects
0	software development	2	knowledge and skills	8	Overview	12	laboratory hours a week
0	Product detail design	2	economic principles	8	experiences in team design projects	12	design teamwork and ethics
0	design specifications	3	implementation	8	work	12	problem
0	application design	3	computer engineering	8	contemporary issues	12	engineering disciplines
0	computer organization	3	disciplines	8	society	12	emphasis
0	ethical issues	3	experience	8	professional ethics	13	environmental stewardship
0	economic analysis	3	tools	8	distinction between different majors	13	oral presentation
0	control	3	decision process	8	Excel basics	13	concepts of sustainable development
0	information security	3	grade in 170a	8	engineering professionals	13	context of the Alberta Occupational Health

0	chemical engineering processes	3	hardware	8	engineering profession	13	profession
0	requirements	3	engineering system	8	engineering problem	13	industries in Alberta
0	Enrollment preference	3	Second quarter	9	economic factors	13	communication skills
0	cost estimation	3	EE and CE	9	civil/geotechnical engineering components and systems	13	Occupational Health and Safety Act
0	cycle	3	first quarter	9	technical communication	13	including coverage of elements of ethics
0	analysis	3	completion of 170b	9	alternative solutions	14	program
0	responsibility	3	industry development process	9	professionalism	14	entrepreneurial skills
0	land use	3	software	9	Part	14	First course
0	intellectual property	3	establishing requirements	9	sustainability	14	computer-aided design
0	development process	3	team projects	9	multidisciplinary team experience	14	fundamental concepts
0	problem-solving techniques	3	Test	9	engineering design with applications	14	machine elements
0	systems	4	engineering analysis	9	ethics in engineering practice	14	Students form
0	Additional topics	4	design project	9	team design	14	environmental awareness
0	computer science	4	ethical considerations	9	considerations	14	Design principles for multidisciplinary team projects
0	construction contracts	4	design methodology and application	9	alternative design solutions	14	capstone design project
0	social impact	4	use of design methodology	9	construction	14	preliminary design stages
0	principles	4	course work	9	reliability and aesthetics	14	basic electronics
0	project delivery	4	Strong emphasis	9	regulations	14	computer
0	engineering design	4	semester	10	capstone project	15	opportunities
0	law	4	project management	10	engineering economics	15	study
0	fundamentals	4	real world clients	10	concept selection	15	career
0	environmental considerations	4	final design	10	mechanical design	15	construction management
0	basic concepts	4	oral communication skills	10	design concept	15	professional practice
1	Design process and methodology	4	two-semester capstone course sequence	10	concept generation	15	future trends

1	ethical ramifications of engineering decisions	4	processes in the areas of design methodology	10	sequence	15	challenges
1	discussions	4	student creativity	10	engineering economy	15	economical issues
1	techniques	4	writing-across-the-curriculum course	10	decision	15	exploration
1	preliminary design	4	synthesis stages	10	industry	15	analysis techniques
1	engineering values	4	student experience in the engineering design process	10	professional topics	16	computer systems
1	aerospace engineering	4	process course versus a project course	10	capstone design	16	security
1	detailed design	4	communication	10	engineering design process	16	computer security
1	Lectures	4	Realistic open-ended design problems	10	customer	16	operating systems
1	feasibility studies	4	interdisciplinary teams	11	laboratory capacity	17	design activities
1	problem definition	4	individual study and research	11	focus	17	design professionals
1	ethical behavior	4	work place issues	11	Instruction and practice	17	registration
1	oral communications	5	operating systems and networks	11	cost	18	plants
		5	data science	11	survey	18	Comprehensive report
5	ideas in algorithm development	5	programming assignments	11	written communication	19	specifications
5	building blocks of Computer Science	5	popular procedural programming language	11	Lectures on ethics in engineering practice	19	safety
5	artificial intelligence	5	computer ethics	11	Enrollment	20	codes and standards
5	data manipulation	5	privacy and information security	11	environmental impact	20	including consideration of cost
5	topics	5	conventional computer hardware	11	structures	20	design optimization
5	optimization	5	data representation			21	alternative designs
5	role of operating systems	5	algorithm design			21	use
5	introductory course			22	computer games	22	technology