WIP: Synthesizing Exemplary Engineering Ethics Education Efforts

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***Abstract*— This Work-In-Progress paper seeks to continue the development of a framework with which to organize engineering ethics instructional approaches. We build on a recent coding framework that was developed as part of a systematic review of US post-secondary engineering ethics education literature. We apply and iterate on the framework by analyzing the 2016 National Academy of Engineering report, "Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs," which includes two-page synopses of 25 exemplary ethics programs. By applying the framework to these exemplars, we aim to identify prominent instructional approaches utilized across NAE exemplars and the extent to which NAE exemplars' instructional approaches differ from those identified in the prior systematic review. This WIP has three preliminary outcomes: (1) identification of trends in instructional design approaches across the NAE exemplars, (2) comparison of the instructional design approaches of NAE exemplars with the prior systematic review, and (3) identification of next steps needed to develop a more holistic picture of how ethics is taught in US post-secondary engineering contexts. Example revisions to the coding framework involved combining community-engagement and real-world exposure, broadening micro-insertion to sociotechnical integration, and coding for explicit mentoring components of instruction. A future research step involves further specification of these codes to detail how the NAE exemplars applied select instructional approaches, including heuristics, ethical theories, and case studies, and real-world engagement.**

Keywords*— ethics, ethics education, systematic review

I. Introduction

In the US, there exist myriad approaches to teaching ethics in post-secondary engineering education. These variations are evident in the 2016 National Academy of Engineering (NAE) report that featured 25 "exemplary education activities and programs" [1-25]. These "NAE Exemplars" are the focus of this study, wherein we seek to identify instructional trends across these exemplary programs and to compare how these align with other prominent instructional strategies for teaching ethics in US engineering education curricula.

In the US, a few instructional approaches have been prominent for at least two decades. As Herkert [26] argued in 2000, "The pedagogical framework of engineering ethics education has evolved primarily toward utilization of case studies and codes of ethics, in some instances supplemented by an introduction to moral theory" (p. 303). These assertions were corroborated by Haws in 2001 [27] in a synthesis of 42 ASEE articles published between 1996 and 1999. That work extended Herkert's list. Specifically, Haws identified six prominent instructional approaches: (1) codes of ethics, (2) Humanist Readings, (3) theoretical grounding or moral theory, (4) ethics heuristics, (5) case studies, and (6) service learning.

In 2018, Hess and Fore [28] synthesized 26 journal articles which focused on ethics instruction in a US post-secondary context and that were published between 2000 and 2018. This study supported the findings by both Haws and Herkert and added additional nuance. **Codes of ethics** and **case studies** continued to be the most prominent instructional approaches, appearing in 85% and 81% of the 26 studies, respectively. Other approaches identified by Haws surfaced but were less common, with **heuristics**, **philosophical ethics** (or what Haws called theoretical grounding), and **community-engagement** (or service-learning) appearing in 46%, 42%, and 8% of articles, respectively. Hess & Fore [28] did not code for humanist readings but did explicitly code several additional approaches. In order of pervasiveness, these included **discussion or debate** (77%), individual **written assignments** (54%), **team projects or papers** (38%), **presentations** (27%), **peer mentoring** (12%), **developing heuristics** (12%), **developing a case study** (12%), **micro-insertion** (8%), **real-world exposure** (8%), **developing a code of ethics** (8%), and playing a **game** (8%).

Due to widespread variation in how instructors implemented **ethical theory** and **case studies**, Hess and Fore further sub-coded these two items (note: some articles were not sufficiently explicit to further code all sub-aspects). Of the 11 articles that incorporated philosophical ethics, six used a **consequentialist** framework (e.g., Mill's utilitarianism), five utilized a **deontological** framework (e.g., Kant's categorical imperative), five included a justice-based-framework (e.g., Rawls' social contract theory), three articles incorporated virtue, and no effort had students engage with an ethic of care. Hess and Fore also applied Huff and Frey's [29] framework to further code case studies. Of the 21 of 26 articles that utilized case studies, they were sub-coded as follows: eight were **historical or real**, seven were **hypothetical or fictitious**, and four involved **real cases made hypothetical**; six were **thick** (i.e., included many details)

whereas seven were **thin** (i.e., included limited details); eight were **big news** (e.g., macro-ethics-related) and seven were **small news** (e.g., micro-ethics related); finally, six studies used **evaluative** case studies (i.e., reasoning as an external agent) and 12 used **participative** aspects (i.e., reasoning as if one were a stakeholder).

II. Study Purpose

The objective of this study was to build on a recent systematic review of US engineering ethics education literature [28] and triangulate these findings with a 2016 NAE report. While the two reviews included a few studies from the same university, the programs or interventions were distinct. Thus, merging these studies provided a unique opportunity to develop a more encompassing framework and overview of instructional approaches used in US engineering ethics instruction. We addressed two research questions.

- What are trends in instructional design approaches of the NAE exemplary ethics programs?
- How do these approaches compare with a prior systematic review of engineering ethics approaches?

While the prior review [28] included 26 articles, the NAE report includes two-page synopses of 25 ethics programs. In alignment with the prior review, the NAE exemplars describe courses and programs that are in the undergraduate context, but some exemplars include graduate-level students and one included post-graduates. Importantly, one exemplar had a faculty development focus [24]; we did not code this article.

III. Methods: Systematic Review Process

Hess and Fore [28] employed a 10-step systematic review process that built on Borrego et al.'s [30] systematic review procedures. The 10-steps include: (1) **Reviewing**: deciding to conduct a systematic review; (2) **Defining** the research question(s) and sub-question(s); (3) **Scoping** or identifying potential literature; (4) **Cataloguing** or accessing/importing data to the database; (5) **Exploring** or reading each article and identifying alignment with the existing coding framework; (6) **Coding** or applying coding framework to articles; (7) **Checking** or comparing codes across multiple coders; (8) **Quantizing** or calculating descriptive statistics of codes; (9) **Interpreting** or making meaning from the statistics; (10) **Narrating** findings.

Likewise, as the coding framework was pre-constructed, Steps 5 and 6 involved incremental changes, such as adding greater clarity to existing codes, modifying codes, and creating new codes. Step 7 included three separate phases. Phase 1 involved Authors 1, 2, and 3 applying the pre-constructed database and included three primary sub-steps. First, we reviewed, coded, and discussed codes. Here, we reviewed and discussed potential coding revisions after engaging with a subset of data including (1) Exemplars 1-5, (2) Exemplars 6-15, and (3) Exemplars 16-23 and 25 (note our numbering aligns with the order in which exemplars appear in the report). Second, after solidifying the revised coding framework, the first three authors coded 24 of the 25 exemplars. Next, the authors met to discuss disagreements and to finalize modifications to the coding structure. Third, authors individually reviewed the existing codes, identifying where they were alone in coding; here, authors added notes to substantiate their position or, when appropriate, modified (i.e., removed) their code. This last step led to a final discussion until we reached complete agreement.

Step 8 involved tabulating the descriptive statistics for the modified set of codes (see Table 1). As we modified the coding structure, we do not report tabulated comparisons to all aspects of the prior systematic review. For codes where changes were insubstantial, we also discuss high-level alignment as well as how the revisions might implicate the prior review. Finally, Steps 9 and 10 involve interpreting and narrating the results.

The following list of codes represents the modified 18-item coding scheme. Importantly, items were coded only if they were explicitly emphasized in the two-page synopsis. In instances where an instructional strategy was mentioned but no details were provided, we reviewed the provided references.

- **Codes of Ethics**: reviewing codes of ethics
- **Developing codes, guidelines, or values**: Developing one's own code of ethics, rules, standards, or values
- **Exposure to tools, processes, or heuristics**: Reviewing/applying ethical reasoning process
- **Developing tools, processes, or heuristics**: Developing or reflecting on one's own ethical tools, processes, or heuristics
- **Exposure to theoretical or philosophical ethics**: Engaging with philosophical ethics or ethical theories
- **Case study**: Engaging with ethical case studies
- **Developing case study**: Developing an ethical case study, potentially for use within one's own class
- **Discussion or debate**: Discussing ethics in class among peers (only coded if this was an explicit instructional strategy)
- **Written assignment**: As a team or individually, any writing assignment of any length that is connected to learning goals
- **Presentation**: As a team or individually, presenting research, case study, or a position on an ethics topic
- **Project**: As a team or individually, writing a paper or engaging in a project that features an ethics component
- **Real-world engagement**: Any interactions or engagement with practitioners or community members
- **Sociotechnical integration**: Integrating ethical/social issues into or alongside technical or engineering content (this was an expansion of the former micro-insertion [31] code)
- **Role-play**: Any form of acting as a character (e.g., within a case study, simulation activities, games)
- **Lecture or instructor presentation**: In-class content, lectures, or presentations of concepts or materials.
- **Conducting research**: Conducting research explicitly on ethics or exploring ethical issues as part of a research project
- **Peer mentoring**: Coaching or leading peers in ethics-related activities; providing critical peer feedback.
- **Receiving mentoring** from others

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IV. Results

A. RQ1: Trends in Instructional Approaches of Exemplars

Table 1 summarizes the number of coded NAE exemplars, the relative percentage, the relative percentage from 26 articles coded by Hess and Fore [28], and the exemplars associated with each code. Six instructional strategies were present in more than half of the exemplars. In order of pervasiveness, these include written assignments (n = 20), case studies (n = 17), exposure to tools, processes, or heuristics (n = 16), sociotechnical integration (n = 15), discussion or debate (n = 14), and exposure to theoretical or philosophical ethics (n = 14). Half of the exemplars included real-world engagement or lecture. Less than half of the studies included codes of ethics (n = 11), projects (n = 11), presentations (n = 10), conducting research (n = 8), receiving mentoring (n = 6), developing codes, guidelines, or values (n = 5), developing tools, processes, or heuristics (n = 4), developing a case study (n = 4), role-play or simulation (n = 2), or peer mentoring (n = 1).

TABLE I. Frequency of Instructional Approaches (*indicates code was significantly revised from [28])

Code Title	**n**	**% exemplars**	**% [28]**	**Coded NAE Exemplars**
Written assignment	20	83	*	[1-6, 8-13, 15, 17-22, 25]
Case study	17	71	81%	[2-4, 6-11, 13, 17-20, 22, 23, 25]
Exposure to tools, processes, heuristics	16	67	46%	[1-3, 5-7, 9, 11, 13-15, 19-22, 24, 25]
Sociotechnical integration	15	63	*	[4, 5, 9-11, 13, 16-23]
Exposure to theoretical or philosophical ethics	14	58	42%	[1, 2, 6, 7, 10, 12-15, 17, 18, 20, 22, 25]
Discussion or debate	14	58	77%	[2, 4, 6, 8, 9, 11, 13-15, 19-21, 23, 25]
Real-world engagement	12	50	*	[1-4, 8, 12-16, 19, 22]
Lecture	12	50	*	[1-3, 7, 10, 13, 15, 17, 19, 21, 22, 25]
Codes of ethics	11	46	85%	[1, 4, 8, 10, 12-14, 18-20, 25]
Project	11	46	*	[2, 4, 6, 10, 13, 14, 16, 18, 20-22]
Presentation	10	42	27%	[1, 2, 4, 6, 13, 14, 16-18, 21]
Conducting research	8	33	*	[2-5, 12, 17, 18, 21]
Receiving mentoring	6	25	*	[2, 4, 6, 12, 16, 20]
Developing codes, guidelines, or values	5	21	8%	[1, 9, 12, 13, 15]
Developing tools, processes, or heuristics	4	17	12%	[6, 13, 15, 18]
Developing case study	4	17	12%	[2, 6, 14, 21]
Role-play	2	8	*	[4, 23]
Peer mentoring	1	4	12%	[2]

B. Comparsion to Prior Review

Table 1 includes relative percentages for this study as well as from the prior review [28]. As this study included several revisions to the prior coding framework, direct comparisons were not possible for eight codes. Here, we note framework revisions followed by a comparison across studies.

a) Revisions to Coding Framework

Of the 18 codes (see Table 1), four were new additions and four involved substantive revisions from the prior review. New codes included (1) lecture, (2) conducting research, (3) receiving mentoring, and (4) role-play. The role-play code was initially an expansion of the "game" code from the prior review. However, no codes in this study emphasized "games" in the sense of the last study. For context, the two articles coded as using "games" in the prior study included an Ethics Bowl [32] and "ethics challenge game" [33]. Thus, in future iterations we cautiously suggest using both "game" and "role-play" codes.

Four codes were substantively revised from the prior review. First, Hess and Fore coded for micro-insertion, which involves embedding ethics directly into disciplinary curricula through a slight alteration of technical content or problems [see 31]. The prior review only coded this in two instances, and in our initial review of the exemplars, it was also uncommon. Thus, we broadened this code to capture a prominent emphasis among exemplars: sociotechnical integration. Second, the prior review featured two codes that we combined. Specifically, the prior review coded separately for "real-world exposure" (coded twice) and "community-engagement" (also coded twice); here we combined these distinct emphases into a single overarching code entitled "real-world engagement." Finally, for two codes, we removed an emphasis on team or individual activities. Specifically, the prior review coded for "Team project/position paper" and "individual written assignment." Here, we instead coded for any instances of writing and projects, whether they were team-based or individual activities.

b) Comparing Findings Across Studies

Of the 10 codes that we could compare across studies, six were **more common** among exemplars than in the prior review, including (1) exposure to tools, processes, or heuristics (67% vs. 46%), (2) exposure to theoretical or philosophical ethics (58% vs. 42%), (3) student presentations (42% vs. 27%), (4) developing codes, guidelines, or values (21% vs. 8%), (5) developing a case study (17% vs. 12%) and (6) developing tools, processes, or heuristics (17% vs. 12%). Four instructional approaches were **less common** among exemplars than the prior review: (1) codes of ethics (46% versus 85%), (2) discussion or debate (58% versus 77%), (3) case studies (71% versus 81%), (4) peer mentoring (4% versus 12%). While we could not directly compare all codes, we posit that the presence of sociotechnical integration among exemplars is much higher. Also, the prior review coded the combined set of codes, "community-engagement" and "real-world exposure" in only three instances (note: one article was coded for both strategies). Here, the "real-world engagement" code was present in half of the exemplars, the further supporting our hypothesis that experiential aspects of instruction were much more prominent among exemplars than the 26 articles reviewed by Hess & Fore.

V. Closing Discussion

In this study, we implemented and expanded on a prior framework for classifying instructional strategies utilized in US ethics education in engineering [28]. The prior study coded 26

articles published between 2000-2018 from four journals. The dataset here was comprised of 24 of 25 exemplary programs [1-23, 25] featured in the 2016 National Academy of Engineering Report, Infusing ethics into the development of engineers. The results summarized the frequency of instructional strategies utilized among NAE exemplars, the revisions to the coding framework, and how the exemplars compare to the prior study.

Among NAE exemplars, written assignments were the most common instructional strategy. There was wide variation in types of writing assignments spanning from individual reflections to term papers. Sometimes, writing assignments were continuous (i.e., spanning a course or program), whereas other times writing occurred at a single point in time.

Case studies were the second most prominent type of instructional strategy utilized by NAE exemplars. Case studies were prominent in prior literature reviews [26-28]. However, case-based instruction varies widely. Hess and Fore [28] utilized Huff and Frey's [29] five-part taxonomy for categorizing case studies which simplifies Davis's [35] 15-part framework. As a next research step, we will bring these frameworks to further scrutinize the case studies employed.

Exposure to tools, processes, and heuristics were the third most common coded instructional strategy here, and these were much more prominent among NAE exemplars than in the prior review. The original spirit of this code was to classify stepwise ethical reasoning processes. Yet, we also applied this code when instructors promoted any singular tools or processes (e.g., cost-benefit analysis, listening) for making ethical decisions. This code was sometimes a challenge due to its alignment with "theoretical or philosophical ethics," described next.

More than half of the NAE exemplars exposed students to philosophical or ethical theory. This code was one of the most challenging given its significant overlap with the tools, processes, and heuristics code. In our analysis, this code was reserved for any conceptual explorations of ethical frameworks. Thus, pragmatic application of ethical theory would not necessitate coding this item. In many instances, this code and the tools, processes, heuristics were applied, but not all. Moreover, our conceptualization of "ethical theory" was challenged in some instances, particularly when articles engaged with engineering paradigms or ethics frameworks on a philosophical level that were not explicitly "philosophy," such as corporate social responsibility or macro-ethics [13].

Sociotechnical integration was an expansion of the previous code entitled, "micro-insertion." As a new code, it was not possible to compare this code to the prior study. However, this instructional strategy was featured in over half of the exemplars. This code also varied widely. For example, Eggleson et al. [23] integrated "technical, moral, legal, and societal aspects of science/technology" through role-play, whereas Colorado School of Mines integrated sociotechnical considerations throughout the curriculum [22].

Notably, half of the exemplars more feature "real-world" instruction. As we condensed two codes from the prior review (community-engagement and real-world exposure), it was not possible to directly compare frequencies across studies. However, the two codes listed were only present in 3 of 26 articles, thus suggesting that exemplars were partially defined by a greater focus on this type of experiential learning.

Whereas Hess and Fore [28] identified codes of ethics in 85% of the articles that they reviewed, less than half of the NAE exemplars incorporated codes of ethics. Given the historical prominence of codes of ethics in engineering instruction [26, 27], this finding came as a surprise. There are several potential reasons for this finding. Two possible reasons include (1) codes were not an innovative aspect of these programs and thus, even if implemented by instructors, they may not have been emphasized or (2) some exemplars feel that codes of ethics (particularly in isolation) are insufficient for teaching ethics [3].

Finally, there were multiple new codes added to this study from the prior review. One new code was, "lecture." However, perhaps surprisingly, lecture was only coded in half of the exemplars. It is possible that this was not explicitly mentioned by many exemplars; however, it is also possible that some exemplars are exemplary because of an emphasis on non-lecture based activities, such as the "UnLecture" from the University of Cincinnati [8]. Second, we made a more explicit distinction between offering peer mentoring and receiving mentoring as an explicit aspect of instruction. Notably, we reserved coding of the latter when mentorship was an explicit focus and was targeted towards ethical learning. Thus, this code was reserved for mentorship experiences that more closely represent apprenticeship-style learnings as emphasized in situated learning theory [34]. Lastly, we added a role-play code. Originally, this was an expansion of the "game" code from Hess and Fore [3] but given that the two instances where this code was applied in this study were specifically character immersion role-play activities, we removed the game emphasis.

VI. Limitations & Future Work

There are two primary next steps to this investigation. First, given the short nature of the exemplars, there may be aspects of instruction that authors did not mention. While we visited references listed at the end of the exemplar's studies when disagreements arose among the coders, we did not do this for all exemplars. Thus, in the future, as we code more in-depth on specific codes, we will also integrate other products disseminated from these programs. Second, we did not 'dig deeper' into any codes. Hence, one next step involves more closely coding specific techniques, including case studies, ethical theories, heuristics, and real-world integration. As an example, case studies were described in myriad ways. Thus, as in Hess and Fore [28], we will more closely scrutinize cases using Huff and Frey [29], but here we will also bring in other more expansive frameworks such as Davis's framework [35].

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