Variations in Reflections as a Method for Teaching and Assessment of Engineering Ethics

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Abstract

Personal reflections integrated into teaching and assessment practices are becoming somewhat more common in engineering education. Reflections may be particularly effective as part of ethics education, to increase engineering students' moral development and critical thinking about ethical issues. On a large survey, 48% of 1122 engineering educators who taught ethics and/or societal impact issues reportedly used reflection in their teaching or assessment. Reflection use varied in different course types, co-occurred to varying extents with different teaching methods, and appeared to be more commonly associated with different ethics/societal impact related topics. Based on interviews with educators who teach ethics and/or societal impacts to engineering students, it became apparent that reflection is an imprecise term that encompasses a broad diversity of activities (from class-wide discussion to individual reflective essays on personal experience or case studies). Examples of reflective prompts used for written essays and journals are provided. These examples of reflection activities may help engineering educators determine the best ways to integrate reflection into their teaching practices. The different types of reflection described in the literature -- including critical, dialogic, and descriptive – provide a framework to contrast different goals for student reflection.

Background

Reflection has been used to facilitate student learning in higher education [1-4], including engineering [5-8]. Rogers [2] examined many theories and definitions related to reflection and summarized that reflective thought is a "cognitive and affective process or activity that requires active engagement by the individual while examining one's responses, beliefs, and premises, resulting in integrating new understating gained into one's experience, learning, and/or enhanced personal and professional effectiveness." (p. 39) Reflective practices help create meaning from experiences by taking the time to consider an event through a specific lens. Reflection is also believed to promote deep learning [9]. A search in ASEE PEER for manuscripts with "reflection" in the title yielded 195 results, including 102 from papers at the annual conference in 2015-2019 [10]. However, it is unclear to what extent reflection is standard practice in engineering education versus being explored as "novel". The value of reflection has been particularly linked with service-learning, as a critical step in achieving particular learning goals and/or helping the learner create meaning from the community engagement experience [11-14].

In the context of ethics education, reflection appears to have the potential to promote growth of ethical reasoning [15]. Reflective journals have been used to measure students' "ability to critically analyze ethical dilemmas" in a business ethics course [9]. Medical ethics education has also used reflection (e.g. [16-18]). For example, Sholikhah et al. [18] found a weak positive correlation between personal reflection ability and the principled morality score in the Defining Issues Test (DIT) among Indonesian medical students. Reflection has also been used in ethics education in engineering [19-21]. For example, critical reflection is described as being important in helping students to make sense of the ethical dilemmas that they encountered in their engineering internships [21].

Reflection encompasses a variety of different practices with different goals [22-23]. Hatton and Smith [24] note reflection is "often ill-defined" and the term may be "used rather loosely to embrace a wide range of concepts and strategies." For example, a reflection "toolkit" included a number of concrete activities for reflection, which ranged in length from 15 seconds (ask a question, give time for silent, individual contemplation) to 2 hours (discussion, written reflection, journaling) [25]. This disparity in reflection practices becomes clear as one reads the literature.

Ordering the complex diversity of reflective practices has taken a variety of forms. Three types of reflection were contrasted by Packard [23]:

- Cognitive: focused on new knowledge and skills, gaining understanding
- Affective: exploring feelings
- Process: examining what was learned from the process itself

One can imagine how different prompts or questions can help lead students to the three different forms of reflection above (e.g. "discuss your feelings" for affective). Another categorization from Hatten and Smith [24] citing Habermas [26] compared three types of reflection:

- Technical: thinking to improve efficiency and effectiveness of actions
- Practical: thinking about goals, assumptions, outcomes, and actions
- Critical: include moral and ethical criteria in analyzing actions, including equity and broader context (historical, social, cultural, political)

Again, the structure of a reflective activity can help target these considerations.

Hatten and Smith [24] developed a hierarchical typology of reflection-on-action writing, with descriptive reflection being the most basic, followed by dialogical reflection, and critical reflection. Descriptive reflection describes an event and explains or provides a rationale for actions [27], with a goal of seeking best practice. Key words associated with this reflection-on-action were "social efficiency, developmental, and personalistic" [24, p. 45]. In contrast, dialogic reflection was characterized as "deliberative, cognitive, narrative" while critical reflection was characterized as "social reconstructionist; seeing as problematic, according to ethical criteria, the goals and practices of one's profession". This framing sets up critical reflection as naturally congruent with ethics education. However, these definitions have not been uniformly applied throughout the literature.

Dialogic reflection is commonly conceptualized as a dialogue between two or more people, contrasted with typical solitary forms of reflection. However, dialogic reflection is also a term that can be applied to an internal dialogue (such as temporally between an earlier and later self) [28]. Three descriptions of dialogic reflection include:

- "the participant involves himself or herself in a process in which he or she disrupts and reconceptualizes their views in relation to their narrative" [28, p. 4]
- "demonstrating a discourse with oneself that leads to an exploration of possible reasons" [29]
- "hearing one's own voice (alone or with another) exploring alternative ways to solve problems in a professional situation" [24]

The types and descriptors of reflection are not mutually exclusive, such that a reflection activity could be both dialogic and critical.

Critical reflection is referred to most commonly in the literature, but with the widest array of meanings. In some cases it is "no more than constructive self-criticism of one's actions with a view to improvement" [24, p. 35]. Kuennen [30] described critical reflection as the "process of moving thought from an existing situation to an emerging situation, connecting initial understanding with deeper understanding, transposing intuitive types of knowledge into conscious types of knowledge, and linking theory, research, and practice"; nursing education is explored, but the idea of "reflective professional practice" is also applicable to engineering. Another definition of critical reflection was provided by Clarkeburn [9]: "Critical reflection primarily consists of an activity which seeks to reveal underlying values and beliefs, which the agent is often unaware of, but which guide actions and thinking processes." Some have also linked critical reflection to ideas of power relationships within society [16]. Critical reflection "gives reasons for decisions or events that take into account the broader historical, social, and/or recent political contexts" [29, p.106]. Hatton and Smith [24] also support this more robust definition of critical reflection, setting it up as a goal for teacher education and fostering continuous improvement through professional practice.

A large study of higher education faculty in the U.S. (21,771 respondents across 143 institutions) explored the use of various teaching practices, including those related to ethics and reflection [31]. Demographic differences were found in these practices. For example, women more often than men gave assignments requiring students to discuss the ethical or moral implications of a course of action (47% vs. 38%) and required reflective writing/journaling in all or most of their courses (31.9% vs. 21.6% men). Differences were also found by rank (e.g. 41% full professors giving an ethics assignment vs. 47% of instructors; 23% full professors including reflective writing vs. 33% of instructors) and institution type (ethics among 44% private / 36% public university faculty, reflection 26% private / 23% public university faculty). The study did not report the intersection between ethics assignments and reflective writing, and only 4.4% of the faculty respondents were affiliated with an engineering department. However, the results indicate that it could be worthwhile to explore demographic variables in relation to teaching practices in engineering that use reflection for ethics education.

Educating caring professionals may be particularly well suited to reflective practices [28]. Brown and Sawyer [28] focus primarily on teaching and nursing professions and dialogic reflection in their exploration of "innovative practices of reflection on professional education intended to expand approaches for professionals to work with diverse others" (p. 1). Engineering is sometimes framed as a caring profession [32-34]. Engineering educators have advocated for teaching students about care ethics [35-39], bolstering the commitment to engineers ethical obligations to serve public welfare and strive for sustainability. Reflective practices may align with goals to foster care for society among engineering professionals.

In sum, an exploration of the literature around the practice of reflection leads one to view reflection as a potentially beneficial form of pedagogy and/or assessment associated with engineering ethics education. However, the contexts in which reflection may be most effective and the specifics of implementation are unclear.

Research Questions

The questions explored in this research are:

RQ1. Is the use of reflection in engineering ethics education commonly associated with particular topics, course types, and/or other pedagogies?

RQ2. Is the use of reflection in engineering ethics education more common in particular disciplines, among particular demographics of engineering educators, or institutional settings?

RQ3. How has reflection been used to teach engineering ethics? What types of reflection are used?

Methods

This research was embedded within a larger study on ethics education in engineering and computing, approved by the local IRB for human subjects research. The broad study aimed to examine ethics education in engineering, with a focus on macroethics. Macroethics are associated with the societal and environmental impacts of the engineering profession [40-41], and in the context of this research the acronym ESI is used to encompass the breadth of engineering ethics (both macroethics and microethics) and societal impacts. This relationship of societal impacts as a part of engineering ethics is congruent with the current ABET Engineering Accreditation Commission Criterion 3 student outcome 4 [42], "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impacts of engineering solutions in global, economic, environmental, and societal contexts." While the large study did not have explicit research questions related to reflection in engineering education, the data gathered for that study were explored post-hoc to answer the three research questions in this paper.

A survey instrument was developed to ascertain the ethics education practices of individuals who teach engineering students (described previously [43-44]; see excerpts in the Appendix). These survey results were used to answer RQ1. The survey asked individuals to indicate which ESI topics they taught in any of their courses; this included a list of 18 topics and "other". A later question on the survey asked individuals to report aspects of the course where they believed they were most effective in teaching ESI, reporting the methods they used to teach and assess ESI in the course. Reflection was included as an option among potential methods used to teach ESI (among 15 total options and 'other'), and *individual reflective essay* was included among the list of potential methods used to assess ESI educational effectiveness (among 8 choice options plus 'other' and 'do not assess'). Survey takers were then given the option to describe a second course with ESI instruction. The data set used in this study was reduced to include only individuals who indicated that they taught one or more ESI topics in any of their courses and described one or more of those courses (n=1122; representing about 400 institutions primarily in the U.S.). Statistical comparisons among the number of ESI topics, ESI teaching methods, and ESI teaching methods among those who did and did not use reflection were conducted using heteroscedastic, 2-tailed t-tests with differences inferred when p values were below .05. Statistical comparisons on the frequency that specific ESI topics, teaching methods, or assessment methods were used by those using or not using reflection were made via chi squared tests, with differences inferred when p values were below .05.

To answer RQ2, the end of the survey included demographic items such as: engineering disciplines taught; instructor rank, gender, and race/ethnicity; and institutional characteristics. These demographics in combination with the earlier survey responses were used to explore potential differences in the use of reflection associated with ESI education. Statistical comparisons between two groups (e.g. male vs. female in the use or non-use of reflection) were conducted using Fisher's exact tests, with differences inferred when the two-tailed p value was below .05. Statistical comparisons among three or more groups (e.g. race/ethnicity, rank) were conducted using chi square tests, inferring differences for two-tailed p values below .05.

A second phase of the research interviewed 35 ESI educators in the U.S. and received written responses to the interview questions from 1 international educator. These individuals were intentionally selected from among the survey respondents who indicated an interest in participating in an interview and appeared to represent potentially exemplary ESI education from a diversity of settings (more information in [45]). The use or integration of reflection was not a criterion for selecting interviewees from among the survey respondents. The goal of the interviews was to gain a more detailed understanding of the teaching practices and motivations of the instructors; there was not an explicit question during the interview about the use of reflection. Course materials (such as a syllabus) were requested and provided by 27 instructors, and in 11 settings examples of assignments were collected. This more detailed information was used to answer RQ3 about how reflection is used to teach engineering ethics and the types of reflection used (based on the categories of cognitive, affective, or process [23] and descriptive, dialogic, or critical [24]).

Results and Discussion

RQ1. Overview of Reflection Integration

Within the survey, reflection was used for teaching and/or assessment of ESI in one or more courses by 537 people (48%). It appears that reflection was associated with deeper levels of ESI integration into teaching, as compared to instructors who did not use reflection. For example, individuals who used reflection taught an average of 7.7 ESI topics among their courses, compared to only 5.2 ESI topics among those who did not use reflection among their ESI teaching or assessment practices ($p<.001$). Among the "most effective ESI education" courses that included reflection ($n=522$), an average of 6.5 different ESI teaching methods and 2.7 different ESI assessment methods were used, compared to 4.0 ESI teaching methods and 1.6 ESI assessment methods among those not using reflection ($p<.001$, $p<.001$, respectively). There were an additional 15 individuals who integrated reflection into a "second" course with ESI but did not include reflection in the course they perceived as most effective for ESI education. The ESI teaching methods most commonly used in the courses that included reflection were: in-class discussion (80%), case studies (77%), examples of professional scenarios (68%), and lectures (68%). Note that discussion may be a form of dialogic reflection. Case studies and professional scenarios may form the basis for students to practice reflection. It was found that 89% of the courses that integrated humanitarian readings also used reflection; reflection also co-occurred with 74-75% of the courses including moral exemplars, think-pair-share, and in-class debates/role plays for ESI instruction. Surprisingly, among the 147 courses on the survey that included service-learning (SL) only 68% also included reflection; this contrasts with the

literature and best practices that consider reflection a critical component of SL. Overall, many instructors used reflection concurrently with many other pedagogies to educate engineering students about ESI in their courses.

In terms of methods used to assess students' knowledge of the societal impacts of technology and/or ethics, individual reflective essays were used in 40% of the courses described on the survey as "most effective for ESI education". There were 78 courses where reflection was identified as a teaching pedagogy without identifying individual reflective essays as an assessment method. This implies other forms of reflection (such as discussion-based or case-study analysis written up by a group) and/or not using reflection to formally assess students (perhaps interpreted as grades). In addition, 3% of those who reportedly used reflection among their ESI teaching practices indicated that they do not assess these learning outcomes.

All 19 ESI topics listed on the survey were more frequently taught by those using reflection (all p values <.02). However, based on the survey structure, it cannot be assumed that the instructor intended the specific ESI topic to be learned or assessed via the reflection activity. The ESI topics that were much more frequently taught by those using reflection versus those that did not use reflection (15% or more) are shown in Table 1. This spans topics taught by many ESI educators (e.g. societal impact) down to topics fairly rarely taught among ESI educators (e.g. social justice). Looking at the data another way, 73% of those who taught social justice also used reflection; 70% of those teaching engineering and poverty and ethical theories taught ESI using reflection (additional data for selected topics in Table 1).

TABLE 1. Ratios of individuals using reflection or not in their teaching practices with respect to teaching specific ESI topics

ESI Topic	Used reflection and taught topic (n=537), %	Did not use reflection and taught topic (n=585), %	% more frequent by those using reflection	% among those teaching topic who used reflection
Societal impact	72	51	21	58
Ethical theories	36	16	21	70
Social justice	30	11	19	73
Ethical failures	59	41	18	59
Ethics in design	53	36	17	60
Code of ethics	60	44	16	58
Engrg & poverty	25	11	15	70
Bioethics	12	6	6	67

The course types that included reflection for ESI teaching and/or assessment included required undergraduate courses (64%), elective undergraduate courses (30%), required graduate courses (7%), and elective graduate courses (14%), where the same course could be identified in multiple categories. The courses with reflection also spanned all different types of undergraduate courses. Reflection was most commonly used among full ethics courses (88%), humanities/social science courses (80%), and professional issues courses (60%); the least common use of reflection was in sophomore/ junior level engineering / engineering science courses with ethics integration (35%). These differences in using reflection for ESI education in different course types seem largely due to instructor preferences, since reflection was used in all course types by 25 or more faculty among the survey respondents.

RQ2. Differences in the Use of Reflection Among Demographic Groups

The survey responses were used to explore whether the use of reflection in teaching and/or assessing ESI education in engineering differed among demographic groups. Among all survey respondents, 48% used reflection in ESI education. (Note: some survey respondents skipped one of more of the demographic items or selected the "prefer not to say" option.)

Among faculty at different institution types the use of reflection varied. The percentage of faculty teaching at doctoral, master's, and bachelor's level institutions who used reflection was 46%, 55%, and 56%, respectively (among 886, 149, and 79 faculty, respectively); thus lower use of reflection at PhD institutions compared to Master's/Bachelor's level ($p=0.014$ in Fisher's exact test when Master's combined with Bachelor's into a single group for analysis). The use of reflection did not differ significantly among faculty teaching at private institutions (51% of 314) compared to public institution (47% of 806); Fisher's exact test $p=0.23$.

The disciplines with the highest percentage of respondents indicating the use of reflection for ESI education were: humanities and/or social science for engineers (82% of n=65), general engineering (80% of n=69), first-year engineering (63% of n=156), engineering management (60% of n=48), and biomedical engineering (57% of n=108). Among more traditional engineering disciplines there was minimal variation among the use of reflection: 49% civil, environmental, mechanical; 52% computer, 53% electrical, 54% chemical. (Note that respondents indicated the engineering discipline(s) where they taught societal context and/or ethics among 27 options. While the majority (n=670, 60%) indicated a single discipline, a high percentage indicated 2 disciplines (n=267, 24%; typically those co-located in the same department), a few three disciplines (n=79, 7%), and others four or more.)

Female instructors used reflection in association with ESI education more than male faculty (55% of n=355 vs. 45% of n=730; $p=.0035$). The use of reflection did not differ significantly among racial/ethnic groups, but there were low numbers of some groups represented among the respondents; reflection was used by 50% white non-Hispanic, 53% Asian, 43% Hispanic/Latinx, 33% Black or African American instructors; n 7= 68, 89, 60, 33, respectively (chi test $p=.177$). There were not large differences by rank in the use of reflection (48% full professors, 42% associate professors, 50% assistant professors, 54% non-tenure track; chi test $p=.055$).

The findings here generally align with previous results for higher education faculty (not specific to engineering) which found a higher percentage of women versus men faculty giving ethics-related assignments and requiring reflection in courses [31].

RQ3. More Detail on How Reflection Was Enacted

More specific information on how reflection was integrated into their ESI teaching practices was described in the interview phase of the research. Some of those faculty also supplied course artifacts (e.g. syllabus, assignments). Table 2 summarizes this information related to reflection. These reflection activities have been characterized into different types based on the major groupings from the literature: cognitive, affective, process [23]; descriptive, dialogic, critical [24]. These types were only roughly assigned, based on the information available.

Table 2. Summary of examples of reflection integrated into course settings

Course	Reflection [types]	Descriptive information and/or prompts
Software Ethics	Reflection essay at start and end of course [cognitive, descriptive] Case studies with class discussion [dialogic]	Pre essay: Explain why you are here and what you hope to accomplish by being in this course. How is ethics relevant to your life and work? 300-500 words. Due class 2. Post essay: Reflect on what you have learned about engineering ethics, using "vocation" or "calling" (your purpose in life) as an organizing framework. Describe what you think are the most important elements of this class, professionally and/or personally. 300-500 words.
Engineering Ethics	9 weekly reflection papers on assigned readings Final reflection paper to describe what learned in the course [cognitive, descriptive]	Students bring a one-page reflection on one or more of the readings assigned for that week to class. Reflection papers checked and counted but not graded; intent to help student prepare for in-class discussions. Suggestions to students: summarize the main points of an article, identify the author's implicit assumptions and perspectives, assess the strengths and weaknesses of the author's arguments, formulate own Questions (and answers) that the readings suggest, relate to personal experiences and aspirations for the future.
Engineering Ethics	Papers [cognitive, descriptive]	After reading assigned sections/chapter(s) of the book or paper, students are required to write a Q&A or response/reflection paper. Each paper should be 2+ pages. Reflection papers should include critical evaluation of the material, including comments on the viewpoints the student agrees with the author, some push-backs on viewpoints that the student might not agree with, or viewpoints the student has some questions on.
Science, Technology, Society (International)	Discussion [dialogic]	Applies approach of "Teaching the Controversy" in many lectures, by outlining and exposing opposing positions in a controversial topic. Start by studying political ideologies, so students can reflect upon their positions on controversial issues. Thus, foster reflection through discussion.
Engineering Ethics and Professionalism	Reflective papers [cognitive, *affective,* descriptive]	Students have active role as learner. Reflection, reading, case study, group work. Example: reflect on how being an engineer in the workplace integrates with the mission of his or her faith.
Professionalism Seminar	Reflective journals [cognitive, process, critical]	Reflections on: Team experience, including issues related to inclusivity and diversity; Learning about the history of an ethical code Ethical impacts of student's design project Contemporary issues that may result in changes to the ethical code
Sustainable Civil Engineering	Reflection paper [descriptive] In-class discussion [dialogic]	Students read real world case studies to exemplify stories of sustainability, community, and ethics; forms the basis for a written reflection, and then some class discussion.
Capstone Design	Reflection papers [cognitive, descriptive]	Teamwork case studies with ethical issues (deontological frame). Individual written reflections on personal experience with assessment via qualitative analysis. Letters to incoming cohort on ethical issues.
Intercultural Communication	Reflection essays [cognitive, descriptive, dialogic]	Students introduced to process of positioning, dialogue, reflection, and action Reflection is a form of self-critique, but also reflecting on how you could enhance better communication and a better design for a given community.
Service-learning activities and courses		
Materials	Paper to earn extra credit based on K12 outreach activity [critical]	Prompts: List 5 assets about the school that you visited What cultural, racial, gender, or socioeconomic issues prevent children or teachers in seeing engineering as a fun, achievable and exciting career choice? Are there community assets that could be leveraged to change these perceptions and improve diversity in the engineering profession? Why is this important?

Course	Reflection [types]	Descriptive information and/or prompts
Service-learning projects	Weekly written reflections in journals, sometimes including ethical considerations [cognitive]	Prompt such as: What larger need is the project partner addressing? Final reflection prompts: 1. What did you learn about the broader impacts of your work and how you and others can affect change locally and/or globally? 2. What did you learn about the community, the needs, and/or the quality of the service provided? 3. What you have learned about professional ethics, the ethical issues you encountered in your team and your project, and how decisions regarding ethical issues are made individually and as a team?
Real World Design: International Water Project	Written in journal [cognitive, descriptive]	SL project; first semester, weekly assigned reading and reflection prompt (in work journal) 10%; hear from alumni and professionals who have engaged in international service work and then reflect on their own motivations
Humanitarian Engineering	Discussion and written [cognitive, descriptive, dialogic, critical]	After traveling as part of a field experience in humanitarian engineering, students reflected on the experience. They also analyzed case studies. Discussion rich and written reflections. Assessment rubric included identification of ethical issue, identification of stakeholders and their motivations, analyzes alternatives and consequences from social, economic, and environmental aspects and the interrelationships among these.

The majority of the courses with reflection had an explicit ethics focus or were service-learning / humanitarian engineering oriented. The majority of the reflection essays appeared cognitive and descriptive in nature. It was assumed that the class discussions were examples of dialogic reflection (among individuals). The instructor could also turn these discussions into additional types by asking students to discuss their feelings (affective), think about the process (process), or consider power differentials/social justice issues (critical).

It is worth noting that none of the syllabi, course assignment documents, or interviews directly used the various classification and typology nomenclature found in the literature. The absence of these terms in the syllabi and assignment documents for students is not surprising, since these terms would not be meaningful to students. In fact, using terms such as “dialogic reflection” might increase their wariness, apprehension, and/or resistance. However, the lack of these terms used by instructors seems to indicate that the engineering educators do not use these categorizations or framing in the context of integrating reflection activities into their teaching.

In a number of the courses, students were assigned readings and then asked to reflect on what they had read. The selection of readings seems important to successfully catalyze student’s ethical development. It can be challenging to find readings that are interesting to students, written in accessible language, discuss issues relevant to the course, and present compelling or controversial viewpoints. Examples of some short case studies are provided in [46]. Some of the reflection prompts in Table 2 are rather “generic” and it isn’t fully clear if these would catalyze deep thinking by the students. Thus, the reflection types appeared largely cognitive. In some courses, the readings and personal reflections were then extended into discussion during class. The instructor would have the ability to facilitate a rich discussion, and the various viewpoints of the students might move into the dialogic reflection typology.

In describing an optional extra credit activity to engage in K12 outreach embedded into a core required engineering science course in materials, the instructor noted:

> "They get a little bit of extra credit for doing this and then they write a reflection paper. And I have - and I have them reflect on what assumptions do they have going into the school. And it depends on where they go up - they go to their home school or if they're going to one of the schools that we arrange for them. What assumptions were correct? What assumptions were not correct? You know. What responsibilities did they have as an engineer to empower them to think about STEM careers? And how do we convey what an engineer does? You know, those types of things."

In describing a humanitarian engineering course, the instructor made clear that student reflections were grounded within case studies. The course uses a series of 10 case studies based directly on or related to situations encountered by the entrepreneurial teams to explore these issues. The case studies cover topics such as negotiating entry into a community, indigenous perspectives, self-determination, international research ethics, and intellectual property. The students read the cases, discuss them as a class, and use ethical reflection and grassroots diplomacy methodologies to evaluate the situations and determine how they would act. Thinking in the course is guided by effectuation, the dominant theory in entrepreneurship in which students consider their values, networks, and resources and make the most with what they have. Students are engaged in the discussions because the cases are real and poignant. It appeared that the range of case studies and engagement led to various type of reflection including cognitive, descriptive, dialogic, and critical.

Reflection has also been used to facilitate ethical development in settings outside of courses, such as via co-curricular groups. One advisor described, "basically, [ ] the students collect bikes in the community. They work to repair these bikes throughout the year. And so we've done a lot of different reflection pieces on that. About things related to privilege and even some ethical considerations." The description alludes to elements associated with critical reflection (e.g. privilege), and provides a model for a prompt the could be used in service-learning courses.

One instructor of a course on professionalism and ethics who tried to foster rich reflective discussions in the classroom, along the lines of dialogic reflection, noted:

> I've had resistant students…. They just don't want to reflect…. I'll always have some sort of pushback on just reflecting in general in any given class. And like sometimes it's cool to see it, like it will happen in a way that transforms in the midst of the reflection. That the student will say "I was going to sit down and say I have nothing to say but now I do." And they actually reflect and it's wonderful and they see it. But some resist all the way through.

This acknowledges that ethics topics can be uncomfortable, and students may not always recognize the value in having their beliefs challenged (either by a perspective in a reading or by fellow students). Some students may be particularly reluctant to engage in verbal discussion, and may prefer to engage in written reflection. However, another professor noted that students are sometimes apprehensive about how their written reflection will be graded, and that being clear on expectations can reduce this anxiety and engage more fully and genuinely in the reflection.

Implications

There is a wide range of teaching practices that fall under the broad umbrella of reflection. Using the typologies and descriptors from the literature may help others to recognize distinctions

among types of reflection. This framing may also help instructors to more explicitly acknowledge their goals for reflection in the course, which would result in more accurately selecting and framing student activities and assignments that involve reflection. The most effective types of reflection activities, assignments, and/or prompts among those summarized in Table 2 were not determined, but in many cases represent those iteratively developed by faculty over time to best meet their specific goals.

If you have tried integrating reflection into your teaching practices with the goal to contribute to reaching learning objectives related to ethical reasoning and/or students' ability to analyze complexities around social, cultural, environmental, and global contexts and felt it was unsuccessful, we encourage you to revisit the idea. A different reflection activity or type may be better suited to achieving your goals. Small modifications in your reflective prompts associated with written student reflections might be impactful; examples of these prompts are provided in Table 2. Courses that include a number of reflective activities (such as weekly journaling) may want to explicitly design the prompts toward different types of reflection, extending beyond the typical cognitive and descriptive reflections into affective reflection, reflection on process, and critical reflection. For example, to spur a dialogic reflection the instruction could directly ask the students to engage in inner dialogue with their past or future selves. Peer discussion, either as a class or in small groups, might also be a great step to build to deeper critical reflective abilities among students. We encourage others to share the specific wording of written reflection or oral discussion prompts that they have found to be effective.

More broadly, engineering educators may wish to engage in purposeful reflection on their teaching practices, particularly when striving to meet learning goals related to ethics and societal impacts. Literature from teacher education may prove helpful in this regard. As ethics educators describe and share their practices, we encourage others to more accurately analyze their own practices and goals associated with the integration of reflection. Explicitly using the terminology associated with different types of reflection would be a helpful practice when educators disseminate their experiences via papers and presentations.

Conclusions

In this study that explored the ESI education practices among a large number of faculty who teach engineering students (n=1122), reflection was used for ESI education by 48%. Reflection was used by instructors in association with the ESI education of engineering students in all types of courses, and was particularly prevalent in ethics-focused courses, humanities/social science courses, and professional issues courses (88%, 80%, 60%, respectively). Reflection was not used in isolation as the sole pedagogy for ESI instruction; on average, 6.5 different teaching methods were used. These co-occurring pedagogies were most commonly in-class discussion and case studies. Individual reflective essays were not always used to assess students' ESI learning in courses that used reflection as a pedagogy, implying that reflection was oral discussion oriented, embedded in a group written assignment, or not graded.

There were some differences found in the use of reflection associated with ESI education at different types of institutions, among different types of instructors, and among disciplines. Reflection was less common at PhD institutions compared to Bachelor's/Master's institutions.

Fewer male instructors used reflection in association with teaching ESI. A higher percentage of instructors teaching humanities/social science courses for engineers, general engineering, first-year engineering, biomedical engineering, and engineering management included reflection among their ESI teaching/assessment methods in comparison to faculty teaching 'traditional' engineering disciplines.

Upon deeper exploration, reflection used to teach and/or assess ESI took a variety of forms in different courses. This included both individual written reflections and class-wide discussions. The different courses also included reflection on personal action (e.g. in service-learning settings), as well as reflection on others actions (such as through case studies). While these reflections appeared to fall into different categories that have been described in the literature (e.g. descriptive, dialogic, critical), the instructors did not themselves use these labels to characterize the use of reflection in their courses. An effective implementation for achieving ESI learning outcomes among students may intentionally use multiple types of different reflection. The theoretical framing of reflection in the literature could provide a helpful organizational schema that could improve the transfer of effective practices for ethics education in engineering. Sharing the specific language of reflective prompts may also help others integrate reflection into their ESI teaching practices.

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Appendix. Curricular survey questions (cocurricular survey question number)

Q1. (Q1) Informed consent to participate in research

Q2. (Q11) Do you teach engineering and/or computing students about any of the following topics in any of your undergraduate and/or graduate courses? (check all that apply)

- Bioethics
- Engineering code of ethics (e.g. NSPE)
- Engineering decisions in the face of uncertainty
- Engineering and poverty
- Environmental protection issues
- Ethical failures / disasters
- Ethical theories
- Ethics in design projects
- Nanotechnology ethics
- Privacy and civil liberties
- Professional practice issues
- Responsible conduct of research
- Risk and liabilities
- Safety
- Social justice
- Societal impacts of engineering and technology
- Sustainability and/or sustainable development
- War, peace, and/or military applications of engineering
- Other topic(s) related to social and ethical issues (identify)
- No topics related to the societal impacts of technology or ethics

Q3. (Q12) In what type of courses do you teach students about the societal impacts of engineering and/or ethics? (check all that apply)

- First year introductory course
- First year design-focused course
- Sophomore or junior level core engineering science or engineering courses
- Humanities and/or social science course
- Design-focused course in sophomore, junior or senior year
- Senior capstone design
- Professional issues course (at any level, e.g. project management, communications)
- Full course on engineering ethics (any level)
- Graduate-level course (any type)
- Other (identify) _____

Think about the ONE course in which you believe you most effectively teach engineering and/or computing students about the societal impacts of technology and/or ethics. [A future section of the survey will give you the option to discuss a second course.]

Q4. (Q13) The title of this course is: _____

Q5. (Q14) This course would best be characterized as (check all that apply):

- Required for undergraduate students in one or more engineering/computing majors
- An elective for undergraduate students in one or more engineering/computing majors
- Required for graduate students in one or more engineering/computing majors
- An elective for graduate students in one or more engineering/computing majors

Q6. (Q14b) {*if one of ugrad course types in Q5, asked*} The course type is also (check single most descriptive):

- A first year introductory course
- A first year design-focused course
- A sophomore or junior level core engineering science or engineering course
- A humanities and/or social science course
- Design-focused course in sophomore, junior or senior year
- Senior capstone design
- Professional issues course (at any level)
- Full course on engineering ethics (any level)
- Other (please explain below) _____

Q7. (Q15) What methods do you use in this course to teach students about societal issues and/or ethics? (check all that apply)

- Case studies
- Engineering design
- Examples of professional scenarios
- Guest lectures (e.g. philosophers, social scientists)
- Humanist readings
- In-class debates and/or role plays
- In-class discussions
- Lectures
- Moral exemplars
- Problem solving heuristics
- Project based learning
- Reflections
- Service-learning, community engagement, and/or learning through service
- Think-pair-share
- Videos, movie clips
- Other(s) [fill in] _____

Q8. (Q16) How do you assess students' knowledge of the societal impacts of technology and/or ethics in this course? (check all that apply)

- Group-based written assignment
- Individual critical and/or personal reflective essays
- Individual homework assignments where questions have fairly straight forward right and wrong answers
- Individual homework assignment, essay, and/or papers that are graded with a rubric
- Individual standardized assessment method (DIT, EERI, ESIT, or similar)
- Surveys
- Team ratings
- Test and/or quiz questions
- Other (describe): _____
- Do not assess these learning outcomes

Q9. (Q17) In general, how satisfied are you with your ability to assess the outcomes of societal context and/or ethics instruction in this course?

[Very dissatisfied – Dissatisfied – Somewhat dissatisfied – Neutral – Somewhat satisfied – Satisfied – Very satisfied]

Q10. (Q18) Would you like to tell us about another course where you teach students about societal and/or ethical issues related to engineering/computing? Yes {then ask Q4-Q9 again} - No

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