Longitudinal Qualitative Case Study of One Engineering Student's Perceptions of Ethics and Social Responsibility: Corvin's Story

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Introduction

Over the past several decades, there has been a growing awareness of the need to develop engineers who can navigate the rapidly changing nature of professional engineering work, in general, and the ethical and social aspects of such practice, more specifically. Furthermore, various stakeholders have increasingly identified the role of engineering degree programs as critical in preparing graduates for these realities. For example, the National Academy of Engineering (NAE) in their *Educating the Engineer of 2020* report called on engineering programs to "educate technically proficient engineers who are broadly educated, see themselves as global citizens, can be leaders in business and public service, and who are ethically grounded" [1, p. 51]. Other reports have likewise called on engineering programs to intensify their focus on ethics, professional responsibility, engaged citizenship, and allied themes (e.g., see [2-3]). In addition, ABET accreditation standards now require programs to demonstrate that students have achieved outcomes related to professional and ethical responsibility, as well as the ability to consider the impact of engineering solutions in global, economic, environmental, and societal contexts [4].

To address these calls and mandates, universities across the US have tried to integrate ethics into their courses and curricula. However, longstanding debates persist on not only how to develop ethically and socially responsible engineers, but also what falls within the scope of social and ethical responsibilities. For example, what roles do professional codes of conduct play in engineering practice [5]? To what extent should engineers concern themselves with micro-ethical vs. macro-ethical issues [6]? How might engineers negotiate cross-national/cultural differences in professional ethics and integrity [7-8]? And how should engineers navigate emerging ethical issues related to bioengineering, robotics and artificial intelligence, privacy and security, defense and surveillance technologies, etc. [9-10]?

Many models and strategies have been proposed to bring such themes into engineering curricula, such as coursework, seminars, project-based learning, service learning, and various other types of experiential learning opportunities [11-12]. Nonetheless, empirical evidence regarding the effectiveness and impacts of such methods have generated mixed results [13-21]. Other research has proposed the existence of a "culture of disengagement" in many engineering degree programs, which can in turn lead to decreased student interest in social welfare, public engagement, and related considerations [22]. Still other studies tentatively suggest that many common approaches to ethics instruction may blind students to the kinds of "everyday" ethical issues that frequently arise in engineering practice [23-25].

Much current commentary and research on engineering ethics also often overlooks the perspectives and capabilities of those who are becoming engineers. We know little about how current engineering students perceive social and ethical responsibility, much less how these perceptions change as they progress toward their degrees and transition into full-time job roles. Without such empirical evidence, faculty and administrators are often left with little more than anecdotal insights to guide the development of curricula and programs. To address this gap, in

2015 we initiated an NSF-sponsored, mixed-methods study that used multiple measures and theoretical frameworks to explore how understandings of social and ethical responsibility change among undergraduate engineering students during a four-year engineering degree program, both in general and in relation to specific learning environments and experiences.

Our study design included interviews and surveys in Year 1, a repeat survey administration in the students' fifth semester (Year 3), and repeat surveys and interviews during their eighth semester (Year 4) [26]. The survey included eight measures which reflect a wide variety of complementary constructs and measurement domains, including both general and engineering-specific measures [26]. The semi-structured interviews are the focus of this paper and thus the interview protocol will be discussed in more depth in the following section. Results from this study have been previously published and include quantitative analysis of the initial and mid-point surveys, thematic qualitative analysis of the initial interviews, and qualitative analysis of a single construct, such as moral disengagement [27-32]. An extensive analysis of our longitudinal quantitative data over the three time periods showed limited changes over time, both across our broad sample and in response to specific experiences while participants were undergraduate students [33, 34]. For example, our results showed that there were not significant differences over time in how the students in our sample responded to measures of social consciousness and moral disengagement. However, they did report decreased perceptions of their respective university's ethical climate over time and showed some improvement in their ability to correctly answer questions requiring ethics knowledge and situational judgment. To better understand changes in students' perceptions over time, we turned to our longitudinal qualitative data in an attempt to illuminate our existing findings from the quantitative data and uncover new insights.

The qualitative data for this project is comprised of pairs of semi-structured interviews from engineering students from four U.S. institutions. The first interview took place approximately mid-way through the interviewees' first year as undergraduate students. The second interview was conducted three years later, by which point most of the participants were seniors. This paper focuses on our analysis of the pairs of interviews, looking for patterns of change or consistency over time as the participants were asked a range of questions related to engineering ethics and social responsibility. To keep the scope of this paper manageable, we report on three themes that have emerged from our initial analysis of one pair of interviews with a single participant, Corvin (pseudonym). Thus, our account uses the case study method [35], and specifically, a single-case approach. The analytical methods used here are similar to those of recent works in engineering education which focus on the experience of single participants or small numbers of participants (for example, see [36-39]).

From the analysis of this case, three themes emerged: a shift in the student's attitudes from idealism to pragmatism; an adjustment in how he thinks engineers should balance their responsibilities to the public and to their employers; and the characteristics he associates with ethical engineers. This data analysis is ongoing, and in future publications we will report results from additional cases. While case study analysis is usually not intended to provide generalizable results, we believe that expanding our analysis to include additional cases will allow us to more readily see the similarities and differences of the evolving perspectives of a small number of engineering students as they wrestle with questions of ethics and social responsibility.

Our objective for this paper is to explore how one student's views of ethics and social responsibility changed (or failed to change) over time. Our findings provide valuable insight beyond what emerged from our longitudinal quantitative data. We expect that this paper will appeal to engineering educators and researchers with interests in qualitative longitudinal analysis and studies of engineering ethics and social responsibility.

Methods

Data Collection and Analysis

The data for this paper comes from the qualitative phase of our larger project that included pairs of longitudinal interviews with 33 students. The first interviews took place during the students' first year of their undergraduate programs and were followed by a second interview during their fourth year of study. The participants were selected for interviews based on their responses to surveys which were administered earlier in the first year of the study. Interviewees were purposefully sampled based on demographic characteristics such as gender, age, international status, participation in certain activities (i.e., service-learning programs or a religious mission), engineering major, and responses to various survey measures [26].

All data collection efforts, including the interviews, were carried out with appropriate IRB approvals for human subjects research at each of the four participating universities. The protocol for the first interview was semi-structured and had four sections: questions about general definitions of ethics, experiences that shaped how students thought about ethics and social responsibility, ethical climate, and questions referencing specific items from the survey. The interview protocol for the second interview included the same four sections and an additional section asking specifically about students' experiences in ethical situations. The interviews each lasted approximately 45-60 minutes. All interviews (first and second) were recorded, transcribed, and analyzed using a codebook developed by the research team [26]. Preliminary results from thematic analysis of select interviews from the first round of data collection can be found in prior published work [27].

To understand specifically how students' perceptions of ethics and social responsibility changed over time, we initially divided up the 33 pairs of transcripts among the members of the research team so that the unit of analysis was the pair of transcripts. We each read through the pairs of transcripts that we had been assigned and then discussed our finding as a larger research team. However, identifying any common patterns in this cross-case analysis proved to be challenging. This was in part due to the significant variations in the breadth, context, and focus of each student's responses to the given prompts.

To address this issue, we next developed a comparison template to help us better visualize and conceptualize the longitudinal changes (or the lack thereof) for each of the 33 individuals in specific areas of interest and related to specific constructs. The template included nine broader categories: personal information, engineering identity, definitions (general), definitions (specific to engineering), influences on perceptions, justice beliefs, ethical climate, moral disengagement, ethical scenarios (selected from the survey), and other. The researchers then went back to their assigned interview pairs to map relevant insights from the interviews onto these nine constructs.

The template also included a place for the researchers to identify and note any preliminary themes emerging from the longitudinal interview data for each individual. Once all the templates were drafted, the researchers regrouped again to identify cross-cutting themes across the 33 pairs of interviews. While there were congruencies evident in some aspects of the findings across the interviews, it was also interesting to note that each individual participant seemed to have unique contextual experiences and observations relevant to the themes.

To allow us to thoroughly explore and contextualize the changes to one student's views over time, we decided to use single-case analysis [35]. In using single-case analysis, our aim is not to create generalizable results, but rather to highlight the uniqueness in one participant and, in the process, underline some of the challenges and opportunities afforded by qualitative, longitudinal analysis focused on ethics, social responsibility, and related concepts. We used purposeful sampling to select one participant who provided an "information-rich case… from which one can learn a great deal about issues of central importance" to the research questions at hand [40, p. 273].

To identify a student to focus on for this single-case analysis, we read through the comparison documents for each of the 33 students. Two aspects of one participant, Corvin, differentiated him from the other students and were the reasons we ultimately selected him for this analysis. First, as a first-year student, he showed a sophisticated understanding of engineering ethics which was unusual among the interviewees. For example, as a first-year, he described engineering ethics in the following way:

> Engineers, they have the same obligations as the rest of society. It's just that as engineers they have a more technical and specific skill set which could lead to the ability to make a change or make a difference if there is an ethical standoff of sorts. Engineers are people who have the skill set to be able to make a breakthrough in that and either find a compromise or determine a better way or determine that okay, there really isn't anything we can do here...

We also hoped that this sophisticated understanding which Corvin displayed as a first-year student might aid us in establishing a baseline for analysis and comparisons to other participants in the future.

The second reason we selected Corvin was that he expressed an interest in activities (and had already joined such activities during his first few months in college) and experiences that "will allow me to express what I already believe." This expression of self-selecting into certain experiences was reflected in our earlier quantitative analysis [34], and we were interested to see how it manifested the qualitative data from one of our participants.

To highlight Corvin's unique journey and changes in his perceptions of ethics and social responsibilities over time, we decided to present our findings using narrative techniques as described by Kellam et al. [39]. In particular, the thematic analysis within the narrative approach prescribed by Kellam et al. is used as an inspiration to draft the case narratives which include the researcher's analysis of the students' experiences interjected with direct quotations from their interviews [39]. This narrative is presented in a third person point of view and is high in both authorial distance and narrator reliability. Essentially, this approach helps us delve into the

thematic findings emerging from the data set while also keeping the context for Corvin intact to convey richer insights about the complexity of the changes (or the lack thereof) in perceptions specific to his experiences. The results from this analysis are presented below.

About the participant, Corvin

Corvin was a male student from the Pacific Northwest who was enrolled in a mechanical engineering program at the Colorado School of Mines (Mines), a small public university in Golden, Colorado with a focus on undergraduate students and engineering disciplines. Prior to college, Corvin had volunteered, participated in a mission trip, visited a developing country, and participated in an honors program. In his first interview, Corvin admitted that Mines was not his first choice of college but that he generally was happy to be there. He was already involved in several co-curricular activities at the university by the time of the first interview, including an innovation-focused fellowship program and Engineers Without Borders, and he reported that he enjoyed the cooperative nature of the students at the university. By his senior year, he was still majoring in mechanical engineering, had completed an internship with an oil and gas company, had performed undergraduate research, and had secured a job in manufacturing that he would start after graduation. Corvin was one of only two students in the final survey (n = 286) who participated in a Grand Challenges Scholars Program throughout their entire undergraduate career.

To contextualize the findings presented in the next section from Corvin's qualitative interview responses, we first highlight here his responses to two quantitative measures from our survey where we saw a notable shift in his responses over time [33]. The first of these measures, the Political and Social Involvement Scale (PSIS), asked students to rank the importance of twelve different activities (e.g., volunteering in my community, helping to promote racial understanding, etc.). As a first-year student, Corvin ranked 11 of the 12 activities as "very" or "extremely important" which placed him in the 90th percentile of our sample for that year (n = 757). In his senior year, he only selected 7 of the 12 statements as being "very" or "extremely important." This placed him in the 50th percentile of respondents (n = 286). The second measure where we saw a substantial change in Corvin's responses over time was the Moral Disengagement scale, which measures a person's propensity to engage in unethical behaviors. On this scale, Corvin went from being in the 10th percentile on the first survey (indicating low levels of moral disengagement) to the 40th percentile on the final survey (indicating nearly median levels of moral disengagement). In summary, Corvin's survey results show that his commitment to public welfare shifted from being very high in his first year to average by the time he graduated, and that he evolved from having a very low level of moral disengagement as a first-year student to a near-average one as a senior.

Findings

From the two interviews with Corvin, we were able to observe some changes in his perspectives over time and how those changes were shaped by various experiences. Specifically, three themes emerged from our analysis of the interviews with him: his evolution from idealism to pragmatism; a refinement of his views about how engineers should balance their responsibilities to society with their responsibilities to their employers; and both consistencies and nuanced

changes in how he described the characteristics of an ethical engineer. In the sections that follow we delve into each of these themes in turn.

Evolution from idealism to pragmatism

One of the most evident changes in Corvin over time was the evolution of his initial "change the world" idealism to a more pragmatic perspective. Reflecting on how his perceptions changed in the second interview, Corvin alludes to how his experiences have taken him from an idealistic first-year student to a more realistic senior, stating:

> It's kind of realizing that not everything is exactly as it seems, or not everything is as easy as it seems. Sometimes you're going to apply for jobs you're not going to get them. You're going to dream about things and they're not going to happen. It's kind of influenced my mindset when I'm looking at things. I think that's probably one of the biggest ways I've been influenced here at Mines. Also realizing there's just a lot more out there than you know of when you're younger. Coming out of high school, I was like, "I know how the world works," but you just gain a lot more experience. I'm sure that's something that continues to grow as you age more and more.

For Corvin, the shift from idealism to pragmatism is reflected in several aspects of his engineering journey. The three most notable areas that we see this change are: 1) his stated goals for himself and his motivation to achieve those goals, 2) his perceptions of how these goals can be achieved within a corporate setting, and 3) the industry he hopes to work in. Across each of these three areas, there was an evolution in his views, where he was initially very idealistic as a first-year student, then much more pragmatic as a senior. Furthermore, there were multiple instances where he gave a *retrospective* reporting of his prior self, often revising his past goals and motivations to be less idealistic than they actually were at the time. We point out these instances below.

First, one of the most striking changes about Corvin was in his goals and motivations for studying engineering and aspiring to become an engineer. Initially, he joined Mines to pursue a mechanical engineering major with a stated desire "to change the world." Elsewhere, he also explained that he wanted to be at Mines "to work towards doing something great." However, as he progressed in his degree program, his goals became much more practical. As a senior, for instance, he talked about "taking practice out into the real world" as the motivation driving him towards engineering.

We also see here an example of Corvin engaging in revising his descriptions of his past self. As a senior, he reflected on his choice to major in engineering and said he initially chose to study mechanical engineering because, "I kind of came in and I felt like, 'I'm an engineer because I like to make things, and I like to work with my hands, and I know it pays well.' Now it's more so, 'I'm an engineer because I can do something that matters, and I have the skills and abilities to be able to do that.'" This very non-idealistic approach was very different from how he actually described his view when he was a first-year student. He further differentiates himself as a senior from other students at Mines by stating: "You talk to a lot of people and they're in engineering because they want to make a difference, they want to do something to leave the world a better

place. I didn't think that that was my intent on becoming an engineer. I just like to make things." Thus, we can see how Corvin retrospectively reconstructs how he came to study engineering and explicitly says that though he sees others at Mines who want to improve the world, that was never his primary intent. Though he stated as a first-year student that he did want to change the world, three years later he rejected that idea in favor of believing that engineering is a choice aligned with his interests and which will allow him to provide for himself.

The second shift from idealism to pragmatism was tied to the path Corvin saw to achieving his goals. As a senior, he stated that he wanted to use his skills to do something that matters and to work for a company that strives to "do something good." Here we see that rather than focusing on how he, personally, can change the world, he wants to be a part of a company that is doing good in the world. When he was specifically asked about his goals, he said that his goal was "to enjoy what he does" and though he would "like to make money, the more the better, but I don't think that … is my primary goal." He also spoke of a desire to have "a good work/life balance," with "life" being defined as his passions and hobbies. One possible interpretation of these comments is that he made changing the world a quality of his company rather than an aspect of his individual work because he realized he also had the goal of finding a balance between his work and his life outside of work. By letting the desire to "do something good" be ascribed to his company rather than himself, he frees himself to pursue interests outside of work without sacrificing his ideals. An alternative interpretation is that Corvin realized that changing the world can be done through his work in a company, and not necessarily independent of that work.

Third and finally, Corvin's views on work also changed, in part due to the internship he completed. One stated goal he had as a first-year student was to eventually design clean energy vehicles. During that same year, he championed a university initiative to "bring clean energy to the Mines campus." By his senior year, he had completed an internship with an oil and gas company. In that interview, he said that prior to his internship he thought that "I'll be able to work in any industry, as long as I'm able to make money and I'm enjoying the work I'm doing. The industry won't matter to me." However, his time at the oil and gas company changed his view. He realized that this particular work experience "didn't feel super fulfilling" and he "felt a sense of responsibility for basically climate change." In this second interview, he reported this as a change in his views. He recognized that his stated previous view (i.e., industry does not matter) was wrong. Comparing the first and second interviews, we see that it may be that his views on work are actually more consistent over time than he realizes, and that Corvin was again possibly revising his narrative of his past self when he said that he previously did not care about the industry in which he worked. It seems that he valued clean energy and was concerned about climate change all along, and that his belief that industry does not matter was temporary (or not actually ever present), and may have served as a justification for choosing to participate in that particular internship which actually ran counter to his deeper values.

Shift in the balance of responsibilities to the public and to one's employer

Over time, Corvin's views on the relationship between his employer and the public were also refined. As a first-year student, Corvin believed that as an engineer "your duty is to do the best for the general public. Sometimes that will come at your own expense but you can put that aside. If you lose your job you know there's another engineering job that will come open." As a senior,

Corvin had somewhat more nuanced views. He discussed the responsibility that engineers have to their company and that there are instances where engineers' loyalty to the company supersedes their loyalty to the public. When discussing how an engineer should act toward their employer, Corvin said that an engineer should be honest and take responsibility for mistakes: "That allows you to not cost your company any more time trying to figure out who did it, and just allows you to rectify it right away, instead of it potentially building on itself and continuing to manifest and grow." His focus on conserving the resources of the company imply that he saw himself as part of the company and wanted to serve it well. This is a clear shift from believing that he would be able to take a principled stance against wrongdoing by a company (because he can always find another job) to concluding that he feels some loyalty to his company in addition to wanting to serve the public's best interest.

Characteristics of ethical engineers

In exploring his perceptions of ethics and engineers, Corvin discussed two ideas that relate to the characteristics of ethical engineers. First, he emphasized that engineers should have certain attributes to be considered ethical engineers, including effective communication, honesty, transparency, responsibility, and respect for intellectual property. Second, he stated that engineers must consider not just the intended use of their designs but also potential misuse.

In relating his ideas about the attributes of ethical engineers, Corvin consistently placed importance on engineers communicating effectively, though with additional depth offered in his responses as a senior. He discussed the idea that engineers have a unique role as professionals who possess specialized technical knowledge. This unique role comes with the responsibility to communicate that knowledge effectively. As such, he said as a first-year student that it is unethical for engineers to "tak[e] advantage of your position of understanding." He added that one role of an engineer is to "communicate what you're doing with other people who are non-engineers" and that in doing so, it is "not practical to throw a bunch of extremely technical designs and words at people who don't understand them." He held this same view as a senior when he noted that engineers should be "able to communicate the engineering side of things effectively, without speaking in math, in order so that an employer or someone who isn't an engineer is able to understand what's going on." This consistent belief in the unique responsibility of engineers to communicate with non-specialists is a view that he maintained over time. His additional training and work experience during his years as an undergraduate student, including interactions with people in industry with "business backgrounds," have made him aware "that your employer has a lot more going on than just engineering design" and that an engineer needs to understand this context when communicating with colleagues of varying levels of technical knowledge.

In addition to believing that ethical engineers should communicate clearly to various audiences, by the end of Corvin's time in college he also has a more concrete idea of other characteristics an ethical engineer should possess. When asked specifically about what it means for engineers to be ethical, as a senior he stated that "honesty is one of the biggest attributes" along with "transparency" and "taking responsibility." His lengthiest comments came regarding intellectual property, saying that "in your work, the kind of biggest thing is not stealing from competitors, but then also not taking from your own company, and not taking information for your own gain."

This comment seems related to an experience at his internship which he had described earlier in the interview:

> One of the engineers I was working with had previously worked with a competitor, and had those calculations saved in an Excel sheet, from the competitor. I didn't see any problem with this, given that it was just calculations that were written out from a machine design textbook, and he had just written them out in an Excel sheet, and then carried it with him as he had gone through. To me, that was just saving us work, instead of going back and retyping in anything.

Corvin felt that this could be a "potential dilemma, given that he made it [the Excel sheet] while he was working with a competitor, but I didn't personally see any issue with it." He also noted that though "these [calculations] came from a different place … this is not anything we wouldn't have had access to [otherwise]" because the formulas were readily available in a textbook. Given his comment that the "biggest thing" in work is to not steal from competitors, he had given this "potential dilemma" some consideration before deciding the choice he and his co-workers made was justified. Nonetheless, it is notable that Corvin seemed very attuned to this particular issue.

The second idea he addressed regarding engineers and ethics concerns the use and misuse of technologies. Here, he equivocated between two views - that engineers have a unique role to create and be responsible for technology versus the notion that the misuse of some technology cannot be entirely the engineer's fault. In both interviews, Corvin refered to users "twisting" the intended use of technology to some other, unintended use. As a first-year student, he stated that "engineers in general take a lot of responsibility for what they do" and that "engineers have a responsibility to ensure that what they're delivering isn't just technically sound but also ethically sound." When some design is misused, he felt that is "not entirely on the engineer" and that when "the intended use was twisted … there's also a responsibility on the user of the design." As a senior, he stated that because users are likely to misuse technology (noting that "they'll find ways to twist things for their own benefit and gain"), engineers should seek opinions from numerous others who are working on a project. Doing so will help the engineers "better understand how it could be used, or ways to mitigate risk." His oil industry work seems to have informed this view. While in that role, he said that it was up to everyone on a project "to catch a risk" in order to mitigate the effects their project could have on people or the environment. Corvin's views about the misuse of designs developed from believing that users and engineers have a shared responsibility to a view that engineers should do all they can to prevent misuse. As a senior, this concern about misuse seems to be situated within concerns about liability for the company. This demonstrates a turn from an optimistic conception of responsibility, shared between engineers and users, to a view grounded in practical realities such as risk mitigation.

Discussion

As a first-year student, Corvin's idealism set him apart from the other 32 participants who we interviewed for this study. He started college with a stated desire to "change the world," and described paths toward this goal through his engineering work, his participation in extracurricular activities, and his efforts to improve his university. By his senior year, this idealism had moved toward a more pragmatic worldview. "Doing something that matters" is still

important to him, but he now sees the possibility to do this through his work for a company. We see this evolution in the longitudinal changes to Corvin's quantitative survey results, too. On the surveys, he went from a very high commitment to public engagement and very low level of moral disengagement as a first-year student to average levels of both as a senior. These changes seem to support our finding that Corvin evolved from being extremely idealistic to pragmatic over his years as an engineering student.

As a senior, Corvin offers some additional details on the experiences which influenced these changes in his perception. These experiences include his overall time at Mines, his general work experience, and his specific internship in oil and gas. He says that his years at Mines strongly influenced his future goals, realizing during that time "that not everything is exactly as it seems, or not everything is as easy as it seems. Sometimes you're going to apply for jobs you're not going to get them. You're going to dream about things and they're not going to happen." His work experiences showed him what engineering is "really" like – namely, "that the majority of what you learn [as an engineering student] isn't directly applicable [to engineering work]." His internship in the oil and gas industry served to stem his increasing moral disengagement. After that internship, he decided he did not want to pursue further work in that industry because of his sense of responsibility for climate change and other societal concerns. As part of our larger study, we have further explored such influences on students' learned outcomes, both broadly and with a specific focus on workplace influences [27, 32].

In addition to Corvin's initial idealism, another thing that set him apart from the other participants in our study was how, as a senior, he reconstructed the goals and motivations he had when he first entered Mines. Looking back, he claimed that he decided to study mechanical engineering because "I like to make things, and I like to work with my hands, and I know it pays well." In reality, we know that as a first-year student, he had the lofty ambitions of "changing the world." We propose that Corvin's engagement in this revisionist history actually sheds more light on who he is as a senior than who he tells us he was as a first year. In their book chapter on the use of personal narratives as an analytical research tool, Tedder and Biesta write: "Narratives thus reveal why it was necessary [...] the life had gone in a particular way. This means that narration is not only about the construction of a particular 'version' of one's life; it is at the same time a construction of a particular 'version' of the self" [41]. In rewriting his prior idealistic self, Corvin may be revealing a discomfort he currently feels about the changes he has undergone during his four years of college. As a senior, he has a good job lined up with a company and is excited about doing work that he feels is important and interesting. Yet he is not directly changing the world by working in clean energy, as he aspired to do as a first-year. We wonder if he is trying to make sense of this change by telling the interviewer (and himself) that he has actually changed in an altogether different way from the change evident in our data. By Corvin's account as a senior, he has gone from being money-focused to prioritizing working for a company that is "going to do something good."

The emergence of this last finding – Corvin's reconstruction of his past self – provides an example of both the challenges of analyzing the qualitative longitudinal data from this study and the opportunities such analysis allows. We believe that the difficulties we faced in settling on a suitable research method may have stemmed from our initial drive to look for greater coherence and clear trends across the 33 interview pairs. In reality, there was not a single ethics research

framework that could be applied to understand this large body of diverse qualitative data. Ethics and social responsibility can be understood through multiple lenses – e.g., moral judgment, ethical climate, justice beliefs, engineering identity, etc. – and a goal of our broader study was to reconcile these multiple frameworks. However, our analysis has shown that students are complex and humans are often inconsistent, especially with regards to their views on something as multi-faceted as ethics. Responding one way in one section of the interview does not always mean a participant will respond consistently in a different part of the interview and/or at a different point in time. We surmise that research on engineering ethics and social responsibility may never result in a single unifying theory due to the complexity of the questions being asked and of the participants being studied.

Conclusion

This paper uses single-case analysis to understand one student's experiences and perspectives, including when those perspectives (and the student's corresponding description of them) follow a path that is difficult to characterize. In future work, we plan to expand this analysis to include additional cases. While we are not aiming for generalizable results (which the case study method is not intended to provide), we hope that adding additional cases to our findings will allow us to compare across cases and better illuminate the uniqueness of each. In addition, we have also begun to use phenomenography to characterize how students experience engineering ethics. The results from this analysis will be presented in a future publication.

Though we believe that these future directions will yield important contributions to the field, we acknowledge that a single unifying framework to account for the unique narratives of our 33 different engineering student participants may be difficult to develop. Creating such a framework was one of the desired outcomes of this work, since there is not an existing framework that we are aware of that applies to our data in full. We speculate that the challenges we have encountered in creating such a framework may be due to the complexity of exploring changes over time related to something as fundamental as questions about ethics, morality, social responsibility, and related concepts. This only serves to underline the difficulty of doing this research and the importance of pursuing it nonetheless.

By using approaches like the single-case analysis presented in this paper to develop richer and more nuanced understandings of how engineering students and professionals perceive ethics, social responsibility, and related concerns, we hope that our findings will challenge educators to grapple with the complex and formidable challenge of cultivating ethical commitments among current and future engineers.

Acknowledgments

References

[1] National Academy of Engineering, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, Washington, DC: The National Academies Press, 2005.

[2] J. J. Duderstadt, *Engineering for a Changing World A Roadmap to the Future of Engineering Practice, Research, and Education*, Ann Arbor, MI: The Millennium Project, 2008.

[3] S. Sheppard, K. Macatangay, A. Colby, and W. M. Sullivan, *Educating Engineers Designing for the Future of the Field*, Indianapolis, IN: Jossey-Bass, 2008.

[4] ABET, https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/

[5] M. Davis, "Thinking like an engineer: The place of a code of ethics," *Philosophy and Public Affairs*, vol. 20, no. 2, pp. 150-167, 1991.

[6] J. R. Herkert, *Microethics, macroethics, and professional engineering societies. Emerging technologies and ethical issues in engineering,* Washington DC: National Academy of Engineering, 2004, pp. 107-114.

[7] C. E. Harris, M. S. Pritchard, and M. J. Rabins, *Engineering Ethics: Concepts and Cases*, Belmont, CA: Wadsworth, 2013.

[8] B.K. Jesiek, Q. Zhu, A. E. Woo, J. Thompson, and A. Mazzurco, "Global Engineering Competency in Context: Situations and Behaviors*," Online Journal for Global Engineering Education*, vol. 8, no. 1, pp. 1-14, 2014.

[9] B. Barry and J. Herkert, "Engineering Ethics" in *Cambridge Handbook of Engineering Education Research*. Eds. A. Johri and B.M. Olds. Cambridge Press, 2014, pp. 673-692.

[10] J. R. Herkert, "Ethical challenges of emerging technologies," in *The Growing Gap Between Emerging Technologies and Legal-Ethical Oversight*, G. E. Marchant, B. R. Allenby, and J. R. Herkert, Eds., Dordecht, Germany: Springer, 2011, pp. 35-44.

[11] J. R. Herkert, "Continuing and Emerging Issues in Engineering Ethics Education," *The Bridge*, vol. 32, no. 3, pp. 8-13, 2002.

[12] J. L. Hess and G. A. Fore, "A systematic literature review of US engineering ethics interventions," *Science and Engineering Ethics*, vol. 24, no. 2, pp. 551-583, 2018.

[13] M. C. Loui, "Ethics and Development of Professional Identities of Engineering Students" *Journal of Engineering Education*, vol. 94, no. 4, pp. 383-390, 2005.

[14] E. A. Clancy, Quinn, P., and Miller, J. E., "Assessment of a case study laboratory to increase awareness of ethical issues in engineering," *IEEE Transactions on Education*, vol. 48, pp. 313-317, 2005.

[15] L. J. Shuman., M. F. Sindelar, M. Besterfield-Sacre, H. Wolfe, R. L. Pinkus, R. L. Miller, B. M. Olds, and C. Mitcham, "Can our Students Recognize and Resolve Ethical Dilemmas?" *Proceedings of the 2004 ASEE Annual Conference and Exposition, Salt Lake City, UT, June 20-23, 2004.*

[16] M. C. Loui, "Assessment of an Engineering Ethics Video: Incident at Morales," *Journal of Engineering Education*, vol. 95, no. 1, pp. 85-91, 2006.

[17] C.-H. Wu, K. Troboy, T. Cole, L. Cochran, and D. Roach, "Does Education Have an Impact on Student Ethical Reasoning? Developing an Assessment of Ethical Reasoning for Engineering and Business Students." *Proceedings of the 39th ASEE Midwest Section Meeting,* Kansas Technology Center, September 20-October 1, 2004.

[18] M. Drake, P. M. Griffin, R. Kirkman, and J. L. Swann, "Engineering Ethical Curricula: Assessment and Comparison of Two Approaches" *Journal of Engineering Education*, vol. 94, no. 2, pp. 223-231, 2005.

[19] C. J. Finelli, M. A. Holsapple, E. Ra., R. M. Bielby, B. A. Burt, D. D. Carpenter, T. S. Harding, and J. A. Sutkus, "An Assessment of Engineering Students' Curricular and Co-Curricular Experiences and Their Ethical Development," *Journal of Engineering Education*, vol. 101, no. 3, pp. 469–494, 2012.

[20] J. L. Hess, J. Beever, C. B. Zoltowski, L. Kisselburgh, L., and A. O. Brightman, A. "Enhancing engineering students' ethical reasoning: Situating reflexive principlism within the SIRA framework," *Journal of Engineering Education*, vol. 108, no. 1, pp. 82-102, 2019.

[21] N. Canney and A. Bielefeldt, "Differences in Engineering Students' Views of Social Responsibility between Disciplines," *Journal of Professional Issues in Engineering Education and Practice,* vol. 141, no. 4, 2015

[22] E. A. Cech, "Culture of disengagement in engineering education?" *Science, Technology and Human Values*, vol. 39, no. 1, pp. 42–72, 2014.

[23] M. Davis and K. Riley, "Ethics Across the Graduate Engineering Curriculum: An Experiment in Teaching and Assessment," *Teaching Ethics*, vol. 9, no. 1, pp. 25-42, 2008;

[24] P. Lloyd and J. Busby, "'Things That Went Well - No Serious Injuries or Deaths': Ethical Reasoning in a Normal Engineering Design Process," *Journal of Engineering Education*, vol. 9, no. 4, pp. 503-516, 2003.

[25] M. W. K. Feister, C. B. Zoltowski, P. M. Buzzanell, W. C. Oakes, and Q. Zhu. "Understanding Team Ethical Climate Through Interview Data," *Proceedings of the 2014 ASEE Annual Conference and Exposition, Indianapolis, IN, June 15-18, 2014.*

[26] C. B. Zoltowski, B. K. Jesiek, S. A. Claussen, and D. H. Torres, "Foundations of social and ethical responsibility among undergraduate engineering students: Project overview," *Proceedings of the 2016 ASEE Annual Conference and Exposition,* New Orleans, LA, June 26-29, 2016.

[27] B. K. Jesiek, C. B. Zoltowski, D. S. Fuentes, S. Claussen, and G. M. Warnick, "Investigating engineering students' understandings of social and ethical responsibility: Coding framework and initial findings," *Proceedings of the 2017 ASEE Annual Conference and Exposition,* Columbus, OH, June 25-28, 2017.

[28] S. M. J. Howland, G. M. Warnick, C. B. Zoltowski, B. K. Jesiek, and R. Davies, "A longitudinal study of social and ethical responsibility among undergraduate engineering students: Comparing baseline and midpoint survey results," *Proceedings of the 2018 ASEE Annual Conference and Exposition,* Salt Lake City, UT, June 23-27, 2018.

[29] S. Nittala, S. Howland, and B. Jesiek, "Changes in perceptions of ethical climate among undergraduate engineering students," *Annual Meeting of European Society for Engineering Education (SEFI),* Budapest, Hungary, September 16-19, 2019.

[30] C. B. Zoltowski, B. K. Jesiek, S. Claussen, S. J. Howland, D. Kim, and S. Nittala, "Foundations of Social and Ethical Responsibility Among Undergraduate Engineering Students: Overview of Results," *Proceedings of the 2020 ASEE Annual Conference and Exposition,* Virtual, June 22-26, 2020.

[31] D. Kim, B. K. Jesiek, and S. J. Howland, "Longitudinal investigation of moral disengagement among undergraduate engineering students: Findings from a mixed-methods study," under review.

[32] D. Kim, S. J. Howland, and B. K. Jesiek, "Engineering students' learning of ethics: Influences and lessons," under review.

[33] S. J. Howland, B. K. Jesiek, S. A. Claussen, and C. B. Zoltowski, "Measures of ethics and social responsibility among undergraduate engineering students: Findings from a longitudinal study," under review.

[34] S. J. Howland, B. K. Jesiek, S. A. Claussen, and C. B. Zoltowski, "Measures of ethics and social responsibility among undergraduate engineering students: Findings from a longitudinal study," under review.

[35] R. Stake, *The art of case study research*. Thousand Oaks, CA: Sage Publications, 1995.

[36] B. K. Jesiek, N. M. Trellinger, and A. Mazzurco, "Becoming boundary spanning engineers: Research methods and preliminary findings," *Proceedings of the 2016 ASEE Annual Conference and Exposition,* New Orleans, LA, June 26-29, 2016.

[37] C. E. Foor, S. E. Walden, and D. A. Trytten, "'I wish that I belonged more in this whole engineering group:' Achieving individual diversity," *Journal of Engineering Education*, vol. 96, no. 2, pp. 103–115, 2007.

[38] A. L. Pawley, "Learning from small numbers: Studying ruling relations that gender and race the structure of US engineering education*," Journal of Engineering Education*, vol. 108, no. 1, pp. 13-31, 2019.

[39] N. A. Kellam, K. S. Gerow, and J. Walther, "Narrative analysis in engineering education research: Exploring ways of constructing narratives to have resonance with the reader and critical research implications," *Proceedings of the 2015 ASEE Annual Conference and Exposition,* Seattle, WA, June 14-17, 2015.

[40] M. Q. Patton, "Two decades of developments in qualitative inquiry: A personal, experiential perspective," *Qualitative social work*, vol. 1, no. 3, pp. 261-283, 2002.

[41] M. Tedder and G. Biesta, "Biography, transition and learning in the lifecourse: The role of narrative," in *Researching Transitions in Lifelong Learning,* London, UK: Routledge, 2009.