Crushed Dreams: Faculty Perceptions of Discrepancies Between Engineering Academics and Students’ Future Careers

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Abstract: This paper summarizes the findings from a qualitative analysis of how faculty view gaps between the curriculum in which they teach and the profession in which their students are likely to be employed. The data – a set of transcribed, anonymized interview responses – was collected in Fall 2021 at a public university in Western Canada as part of a larger study on macroethics and social justice. Eight faculty affiliated with engineering departments consented to be interviewed for the study. Coding and analysis performed by this paper's three authors resulted in six relevant categories to help us understand the data, which might help to improve the curriculum in the future. The six categories that the authors discovered through the qualitative research process are outdated academics, cheating, non-technical skills, innovation, ethical responsibility, and greater purpose. We observed that ethical responsibility and greater purpose were more often described as fostered in the context of the post-university career, while outdated academics, cheating, and innovation were more often described as fostered within academia. The final category, non-technical skills, was relevant to both settings.

INTRODUCTION

Engineering is one of the fastest growing fields with a thriving job market. A staggering 140,000 new jobs have been created over the past decade with a median wage of $91,010 in the U.S. [1]. With an exploding job market and high compensation rates, it is no surprise that the rate of engineering undergraduate enrollment has increased by 63% between 2006 and 2015 [2]. Despite this increase in interest in the field, there has also been a high rate of students dropping out or early-career professionals leaving the engineering field after graduation. This is concerning since the demand for engineers continues to rise as the baby boomer generation retires, and with students leaving engineering some companies struggle to fill the positions left behind [3].

In this paper, we seek to understand one aspect of how an academic engineering program prepares students for their careers. We do so by analyzing responses to one question from a set of interviews conducted with faculty from the School of Education and School of Engineering at a public university in Western Canada. Broadly, the interviews were conducted to learn more about perceptions of macroethics and social justice among faculty and postdocs at this university. Macroethics has been defined by Joseph Herkert in the engineering context as applying to the "collective social responsibility of the [engineering] profession and to societal decisions about technology [4, p. 373]". Prior work suggests a disconnect between the reductionist perspectives often utilized in engineering education [5], [6], [7] and the sociotechnical nature of engineering professional work [8], [9], and we wanted to see whether a similar disconnect could be observed in the data analyzed in this paper.

In 2021, one of this paper's authors asked a group of engineering professors about the gaps they observed between academia and the engineering profession as part of the broader research project [10]. This paper is partially motivated by the idea that if those gaps can be identified and mitigated it could help to increase the retention of students in engineering and ensure a strong future for the profession. The data from the specific interview question analyzed for this paper does not explicitly ask about macroethics or social justice. However, since it was the 10th question in the semi-structured interview protocol, with some of the first nine addressing these topics, it is reasonable to assume that macroethics and social justice might be on the minds of the interviewees when responding.

The specific research question that we seek to answer in this paper is:

RQ: What, if any, gaps exist between the engineering curricula (at their university or more broadly) and the engineering profession in which the students at their university are likely to be employed?

The contribution of this paper lies in a case-study-like description of the gaps between the engineering curriculum and likely professional careers for students at a public university in Canada, as perceived by faculty. Although case study research is not inherently generalizable, each individual case contributes to a broader body of understanding that can be connected to the literature and thus used to further develop categories, themes, and concepts.

This paper is organized as follows. In the next section, we describe our methods for both collecting the data and analyzing it. The Findings section describes the categories we found in the data based on the analysis process. It is followed by the Discussion and Conclusions, in which we comment on the categories and synthesize our big-picture takeaways, as well as remarking on possible future work.

METHODS

In this section, we briefly discuss our subject recruitment, data collection, and analysis methods.

Subject Recruitment and Data Collection

The third author collected the data used for this analysis in Fall 2021 while on sabbatical at a public university in Western Canada. A human subjects research ethics review was conducted, and all approved processes were followed, including anonymizing the data immediately after transcription and before any analysis was performed. All interviewee names used in this paper are pseudonyms.

Potential interviewees were identified using publicly available information such as faculty web sites, news articles, and similar sources to identify people who may be interested in the topics being studied. Additional potential interviewees were identified via snowball sampling of people who agreed to be interviewed. Participants were recruited by email using language approved by the human subjects research ethics review process. The third author conducted the semi-structured interviews either in-person or virtually based on the interviewee's preference while following COVID-related protocols.

The specific wording of the interview question relevant to this paper, which was asked of interviewees who had experience in engineering, is "Do you observe any gaps between the engineering curricula (at the University of Calgary or more broadly in Alberta or Canada) and the engineering profession in which your students are likely to be employed? If so, please describe or give some examples."

Analysis Process

After all the data was collected, transcribed, and anonymized, the three authors of this paper held weekly meetings to discuss the data and synthesize our findings. The first two authors of the paper are students, who were working to learn qualitative research methods as part of the process. We consider our fresh perspective on qualitative research methods to be a benefit to the analysis, since our questions about processes, methods, and interpretations led us back to source material on qualitative research methods throughout the process.

The particular interview question under study was selected because it was of most interest to the student researchers of all of the questions in the interview protocol. Using the qualitative research analysis software NVivo, the two student researchers independently read through each response to the question and created short codes to summarize the information. The first coding practice the students used was eclectic coding [11], which involves highlighting key details based on first impressions. This first round of coding provided a basic understanding of what the codes might look like before fully analyzing each response.

Our next step was to discuss progress among the three researchers at weekly meetings, then use descriptive coding to summarize our data into primary topics discussed. After further discussion, the students grouped the codes into categories as a step toward synthesizing the information. Next, we again compared our code groupings with each other to find similarities and differences within our codes and begin to identify our combined categories. The two student researchers then re-coded our data to find items that may have been missing. We also looked for opposing views that might challenge the proposed categories, continuing to discuss among the three authors. Finally, we synthesized the categories to obtain those most relevant to the data. In the end we found a total of six categories that we describe in Findings.

FINDINGS

Following the analysis process described in the Methods section, we found six categories to describe the data related to our research question. These are summarized in Table 1, which also includes illustrative quotes from the data. The subsections following Table 1 further describe each category.

Table 1: Categories, descriptions, and illustrative quotes resulting from the analysis process. The table continues on the following page.

Category	**Description**	**Illustrative Quote(s)**
Outdated Academics	Old material and outdated teaching practices can impact a student's transition into industry.	"We still, having a conversation the other day where it's like the students, well, what do we teach them in mass transfer? Well, it's distillation and I'm kind of like why do we teach them? I guess I understand why we teach them distillation and yes, we use a lot of distillation in industry, but geez, that's not the most efficient way to do things and certainly not necessarily the way you want. You don't want it to make it their go-to thing like, 'Oh, I need to separate this. Well, we should use distillation.' No, no, no, no, not necessarily. Right. So, we don't exactly teach them in a way, which is sort of integrative and getting them to understand why you might do one thing over another, that's still grad level here." (Zachary)
Cheating	Cheating affects a student's academic experience, which can have different consequences in industry.	"But it could be as simple as maybe copying the assignment, going from should I attend lectures? Seeing this as kind of the duty for the student rather than, 'I can skip class because it's not convenient to me.'" (Christina)

Non-Technical Skills	As you transition to the workforce, non-technical skills play a much larger role in many aspects. Teaching this can be difficult and is often not a priority in a college setting, which can leave students without practice or experience in these areas.	"All they [interviewers] ask is what would you say or do in the following situation? So behavioral questions, and this is not something that you are teaching us and whatever you're teaching us as a result. They're implying is not really important because companies are not asking of us, about our understanding of the fundamental science." (Alex) "… one of the new pieces of curriculum is we invite speakers from creative writing who teach students about empathy and how to build empathy. So those are things we are adding to our curriculum" (Tara)
Innovation	Most students want a chance to change the world once they are in their professions. They are naturally looking to innovate in the future, but not every workplace allows young minds this opportunity.	"Once you've been there 20 years you might get to be one of the people who gets to scout for technology to bring in, but you never get the chance to do it yourself." (Leo) "We don't need an intern that will come up with a new design because we're not going to redesign a unit, right? We already have engineers to do that. We already have smart people to do that. And that intern is going to be there just to make sure that he's running the unit and the unit is running smoothly and it's not going to cause us problems. The unit, but also the intern is not going to cause us problems because they are behaviorally okay." (Alex)
Greater Purpose	A good engineer isn't just an engineer for engineering's sake. There must be a greater understanding of their roles and responsibilities to the greater public.	"There might not be a technological answer to this particular problem when it's framed with the folks that care about the solution. And that's a really profound thing to ask an engineer to accept." (Leo)
Ethical Responsibility	As you enter the workforce you must not only consider the implications of your individual actions, but also work to drive the profession towards a more ethical future.	"And your work makes a change, but you need to also be part of the people who lead the change." (Tara)

In this section, we briefly explain each of the categories we found that we have summarized in Table 1 and connect them to the literature.

Outdated Academics

Over the decades, the general structure of college education has remained rather rigid. The content of some college courses can also remain quite similar throughout the decades, even while technological advances in the field are occurring. Concern about outdated academics was voiced by about half of the engineering professors interviewed and the impacts are exemplified by Zachary's quote in Table 1. The gap identified by the interviewees involved an incorrect understanding of key concepts being fostered in an academic setting, leaving students lost and confused when the solutions learned in the classroom were not the best solutions to apply in the workplace. The reason identified by the professors stemmed from the content of the course being outdated compared to industry standard. When the students lack a clear understanding of the "why" behind the concepts learned in the classroom, there is a much larger gap to overcome when adjusting to the profession. An example of this problem and a solution is described in the paper by Heckman et al. [12], where students were tasked to work on a software project that was over ten years old. The technology was outdated and had many bugs and complications that were preventing the students from having a productive learning experience. By completely overhauling the software and beginning routine updates to the program, the teachers were able to remedy the issue. [12] This is an example of adjusting the course material to reflect a professional environment and better prepare students for the transition into their career.

Cheating

With the advent of substantial new technology in the classroom comes a great opportunity to offer new and innovative ways to deliver content to students. From a student perspective, however, technology can also pose an opportunity to subvert the expectations of the classroom. In a study from the University of Michigan it was reported that around 74% of the engineering students surveyed had participated in some form of cheating during their time at university [13]. With such high rates of academic dishonesty, in some cases students may be finishing their degree with critical gaps in their foundational knowledge. As expressed by Christina in Table 1, students who over-rely on technological tools (especially in an unethical manner) to reduce the time devoted to their courses may thus have a lack of understanding of the fundamentals. This lack of understanding can lead to problems when entering the workforce, as there are far less resources to lean on and the student becomes responsible for critical problem solving on their own. Concerns related to cheating were expressed by three of the engineering professors during their responses to this question.

Non-Technical Skills

When transitioning to a professional career from education, non-technical skills are just as important – if not more so – as technical skills [8], [9]. However, many professors find it difficult to teach these non-technical skills or consider them a low priority. These skills are necessary for engineering students to be successful since if a student only has technical skills, then they might not be prepared to work with clients or communities or operate in team-based environments once they enter the workforce. They also might not be able to communicate well on the projects they're working on, which could damage or halt progress on it. Engineering students need to be able to have technical and professional skills to be successful [14], which suggests that teaching these skills should be an element of the academic program for engineering students.

Innovation

As new technologies start to develop, engineering students look to innovate them and strive to make a difference in the world. Even if the students don't naturally have this drive to innovate, they may pick it up from their engineering coursework, whether it's intended or not intended [15]. Even with all these students wanting to contribute, not many are given a chance to innovate once they graduate. Most new graduates and interns would start off performing supporting work to show that they understand what they have learned from their schooling. A lot of engineering workplaces only have a few senior engineers work on innovating the technology, leaving out all the young professionals who are striving to change the world, as expressed by Leo in Table 1.

Ethical Responsibility

The ethical responsibility category is linked to prior research on macro- and micro-ethics in engineering education [4]. Although many engineering codes of ethics and other engineering ethics documentation focuses on individual ethics, we found data from our interviews that also aligns with Herkert's macroethical concept of "the collective social responsibility of the profession and to societal decisions about technology." [4, p. 373] Tara's example quote in Table 1 nods to this concept by referring to leading broader change, which suggests a commitment to community- or societal-level ethics. Prior work by one of the authors [16] found that engineering students at a different university were more likely to consider micro- than macro-ethics, a difference that could prove fruitful for further study.

Greater Purpose

Analysis of the coded data that eventually formed the "Greater Purpose" category suggested the "Crushed Dreams" title of this paper, and the three authors returned to this category for further discussion several times. As [6] has reported, the engineering curriculum in the U.S. can contribute to a culture of disengagement within engineering students, who may start their programs with idealized senses of a greater purpose and leave disengaged and therefore much less motivated by a sense of greater purpose. By disengaging students from a sense of a greater purpose, the academic curriculum can lead to lack of a sense of belonging and dissatisfaction with engineering, contributing to poor persistence into and through the engineering profession. This category has substantial overlaps with both "Innovation" and "Ethical Responsibility." Engineers who feel that they serve a greater purpose in their work may be more intrinsically motivated to innovate. When compared to "Ethical Responsibility," we see the "Greater Purpose" category as being more aligned with individual-level motivations and decisions (perhaps closer to the idea of microethics). In all cases, we view the intrinsic motivation of feeling a greater purpose as beneficial to students, programs, and the profession, and suggest that it should be supported, not crushed through a disengaging curriculum.

DISCUSSION AND CONCLUSIONS

As described in the Findings section, interviewees did describe gaps between the engineering profession and academic curricula, many of which aligned with the six categories described therein. Table 2 summarizes the interviewees who described gaps that aligned with each of the six categories that emerged from our analysis process. Notable trends in this table include (1) greater purpose and ethical responsibility almost always being mentioned by the same people, and (2) all three of the female-identifying professors (Tara, Barb, and Jane) mentioning both of these categories. While the sample size is small and we therefore do not claim to extrapolate to all engineering faculty, these trends can still give us insight into the culture and ideals of this group of engineering professors and suggest potential future research directions.

Table 2: Interviewees who provided responses aligning with our six categories. While most interviewees made comments that fell into the "Ethical Responsibility" and "Greater Purpose" categories, fewer did so for "Non-Technical Skills" and "Innovation"

	Pronouns	Greater Purpose	Ethical Responsibility	Non-Technical Skills	Innovation	Outdated Academics	Cheating
Tara	She/Her	x	x	x		x	
Barb	She/Her	x	x				
Jane	She/Her	x	x			x	
Alex	He/His		x	x	x		x
Zachary	He/His					x	
Leo	He/His	x	x		x		
Theodore	He/His						x
Christina	He/His	x	x			x	x

The six identified categories can be further understood through the context in which the interviewees discussed them. Figure 1 synthesizes the observed categories in terms of their primary "location" in the engineering academic to career pathway. This trend emerged during the analysis of the transcripts and was not explicitly asked for during the interview stage. These locations were inferred by the research team and agreed upon based on the interviewee's response to the interview question. By examining Figure 1, it can be seen that the majority of the categories were described in the context of either the classroom or the workplace rather than both (with non-technical skills being the exception). Identifying the time during which these categories appear to be fostered is helpful to be able to address the problem at its root. For example, a push for more consistently relevant course material updated frequently would help equip students with useful tools that would help ease the transition into industry by starting in the classroom. On the career side, programs to help place employees in departments where they feel like their work is meaningful and satisfying to them personally could help to foster greater purpose in a young engineer. By understanding what gaps develop at what point in an engineer's education and career more effective practices can be put into place to help increase retention in the field.

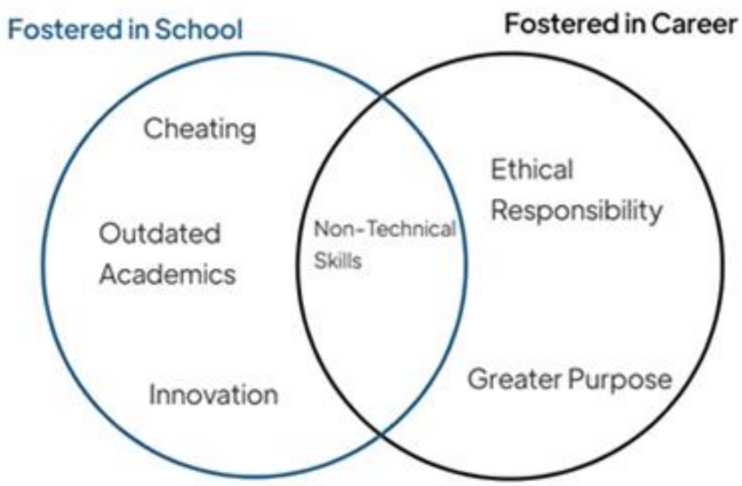

Figure 1: Interviewees described the environment in which each of the six categories appeared the most. While non-technical was seen in both, the other 5 categories were almost exclusively mentioned in the context of either school or career.

In this sample of engineering professors, there was a strong overtone of concern for the future-engineers in their classrooms. Whether it was high levels of cheating preventing students from developing relevant skills or eager students being stifled with little to no opportunity for innovation in the workplace, each professor saw areas where students were being discouraged from the professional engineering environment and expressed a desire to improve the situation. These gaps highlight areas in which academia and professional settings have room to improve in order to increase the retention, happiness, and productivity of young engineers. From Figure 1, there may be an opportunity to shift the cultivation of ethical responsibility from the workplace to the classroom. Supporting the education of confident and ethical young professionals with an understanding of their responsibility to the general populous would help push the profession as a whole to be more ethical. We believe that having the opportunity to develop these skills earlier in a student's education would help to increase their resilience and diminish strain or mistakes in that learning process [17]. Preparation in college is an opportune time to build problem solving skills and understanding of the profession so that the transition to career can be more focused on the day-to-day details of the position. By working to close these identified gaps, students would be more prepared to take on engineering positions after college and find more satisfying careers earlier on.

It is important to note that this discussion only includes the perspective of a small group of engineering professors and lacks input from industry professionals. From a recent study focused on closing the gap between education and the software engineering industry, many industry professionals identified non-technical skills as one of the most valued industry skill sets that is not being taught [18]. These professionals expressed that non-technical skills are difficult to teach, and they often prefer candidates with well-developed non-technical skills that can be brought up to speed on the technical aspects of the team. This study echoes the sentiment expressed by two of the interviewed professors, while providing additional insight into the needs of a professional workplace [18].

Positionality

We recognize that our lived experiences have shaped our understanding of the data and therefore our findings. All three authors are affiliated with a public university in the Western U.S. that has a science and engineering focus. The first two authors are both undergraduate students. One is a Senior studying Electrical Engineering who identifies as a white woman. The second author is a Sophomore studying Electrical Engineering who identifies as a white man. The third author is a Professor in an engineering department who identifies as a white woman and who has conducted research in engineering education since 2015.

Limitations and Future Work

It is important to note that while this research group identified created large scope categories, this does not imply that each category has equal weight for every engineering student or affects every engineering student equally. There are many other factors that may lead to different challenges and gaps depending on your race, gender identity, or other personal factors. For instance, [19] suggests that workplace culture and unfair gender roles within the workplace contribute to women leaving the profession at higher rates than their male counterparts. Such demographic impacts were not part of our analysis of the data, or the resulting categories identified since we did not ask interviewees to distinguish among students from different demographic groups. Further, although we connected each category in some ways to existing engineering education literature, analysis of interview responses from eight faculty at a single university does not result in generalizable information. Instead, our findings should be further connected to research in other cases before any broader conclusions can be drawn.

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