WHAT IT MEANS TO BE IN ENGINEERING: MORAL, RELATIONAL, AND PERCEPTUAL TENSIONS

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Abstract – An exploratory study on the students’ learning processes in design project settings led to the discovery of important tensions that students experience in their engineering program. Adopting a Critical Discourse Analysis perspective, an we conducted an analysis of dominant images and discourses in engineering student interviews. The results highlighted key conflicting messages about what it means to succeed in engineering education, what engineering means, and who the engineering student is. Certain ideological beliefs posed as serious barriers and threats to mutually respectful and healthy peer relations, resulting in important tensions that students experience. Critical Discourse Analysis perspective, an we conducted an analysis of dominant images and discourses in engineering student interviews. The results highlighted key conflicting messages about what it means to succeed in engineering education, what engineering means, and who the engineering student is. Certain ideological beliefs posed as serious barriers and threats to mutually respectful and healthy peer relations, resulting in important tensions that students experience. Simultaneously, students demonstrated abilities to critique existing narratives and offer alternative meanings. It is critical, in this paper, we ask the following questions:

1. What kinds of problematic tensions do students face during their engineering education experience?
2. What are the taken-for-granted biases and assumptions, and ways of representation that come into play?

1. INTRODUCTION

An exploratory study on the students’ learning processes in design project settings [1] led to the discovery of important tensions that students experience in their engineering program. By tension we mean the dissonance that students recognize and attempt to reconcile, between their personal meanings and the messages they receive from their educational experience. We identified three locations for such tensions: (a) Personal morality, where the values espoused in the curricular experience that either enhance or inhibit students’ personal meanings attributed to engineering; (b) Peer interactions, especially within design project teams; and (c) Perception of the nature of engineering (e.g. mental model [2]). All three types reveal conflicting narratives or messages about what engineering is, and who the engineer is. Students’ responses to these tensions may have an important effect on the way students ‘see themselves in the field’ of engineering [3].

There are multiple, competing if not contradictory, narratives about what engineering is, and who the engineer is. Gary Lee Downey coined the term, ‘dominant images,’ to explain how particular engineering narratives are sustained long-term and pervasive, even as demographics and localized cultural norms shift over time [4]. These dominant images of engineers represent implicit beliefs about who or what becomes included/excluded as ‘normal engineering.’ These implicit beliefs justify explicit attitudes and behaviours, not in the least affecting the quality of the human relations and member well-being within the field of engineering. The espoused values, worldviews, and norms could arguably shape the very nature of the engineering academe, profession, or discipline, which would have broader and long-term social impact.

Therefore, in this paper, we ask the following questions:

1. What kinds of problematic tensions do students face during their engineering education experience?
2. What are the taken-for-granted biases and assumptions, and ways of representation that come into play?

In this paper we show how students bring in their own vision and interpretation of what engineering is, and who the engineer is. The conflicting messages they encounter, through lived experiences in the academic setting, challenges the educators to critically examine the coherence of the narrative we create by our own instructional design and educational practice.

We also begin to see the push out effect of the cultural layer of the educational experience. Ignorance in this area is costly: some students see themselves less and less in the field of engineering; some students simply accept the moral disconnect between who they are and what the work requires of them. The ‘moral deskilling’ [5] of engineering students would seriously undermine their innovative ability to address 21st century challenges, let alone their ability to lead an equitable,
2. METHODOLOGY

Because the overall larger study aims to build new explanatory understanding of design learning processes, and to allow emergence of unexpected themes, grounded theory methodology has been adopted [6]. Specific to the aims of this paper, there is an extra step of identifying and to allow emergence of unexpected themes, grounded in Foucault’s discourse theory [10]. CDA is rooted in Foucault’s discourse theory, which enabled a rich analyses of text data with explanatory power, “to understand the history and evolution of constructs that were considered natural (normality, justice, intellect, and so forth) and how such constructs are a product of power/knowledge relationships” [11]. Rogers and colleagues [11] succinctly capture the purpose and nature of CDA:

Critical Discourse Analysis was an attempt to bring social theory and discourse analysis together to describe, interpret, and explain the ways in which discourse constructs, becomes constructed by, represents, and becomes represented by the social world...

Critical Discourse Analysis focuses on how language as a cultural tool mediates relationships of power and privilege in social interactions, institutions, and bodies of knowledge...

Within a CDA tradition, discourse has been defined as language use as social practice. That is, discourse moves back and forth between reflecting and constructing the social world. Seen in this way, language cannot be considered neutral, because it is caught up in political, social, racial, economic, religious, and cultural formations.

This paper adapts a small number of analytic strategies of CDA perspective to examine the content and impact of dominant image or representations in engineering students’ experiences [10]: Which views are perpetuated? What do they include and exclude? How are words used to assert particular meanings and definitions? Of particular interest is the interdiscursive analysis as described by Taylor [9], which identifies which discourses are drawn on in the talk. Uniquely, the students are trying to make sense of the representations they did not choose, but were formidably introduced through various experiences in school. Students notice the inconsistencies and tensions between their (initial) views and the views presented by others, and between multiple discourses existing within their curricular environment.

2.1. Participant Recruitment

Interview participants were recruited by in-person visit to Mechanical Engineering design courses in Winter 2016 and Winter 2017 semesters. Most participants were interviewed once in the winter semester, and a second time in the summer. As part of a larger longitudinal study, survey participants who indicated interest in interviews were also contacted via email or phone. In Winter 2018, the main method of recruitment has been through the survey question. 2018 interviews are still ongoing. Included data for this paper come from 11 unique students contributing 13 interview sets (1-2 interviews per set for one person) in total (Table 1).

The larger study has recruited focus group and interview participants since Winter 2015. It is important to note that female student participation in the interviews (and expressed interest for interviews in 2018) has dramatically increased after female research staff began visiting the classes in 2017.

### Table 1: Interview Participants

<table>
<thead>
<tr>
<th>Interview Dates</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter – Summer 2016</td>
<td>3 male students in second year (UG 2)</td>
</tr>
<tr>
<td>Winter – Summer 2017</td>
<td>4 male students, UG 2</td>
</tr>
<tr>
<td></td>
<td>2 female students, UG 2</td>
</tr>
<tr>
<td></td>
<td>2 male students, UG 3</td>
</tr>
<tr>
<td>Winter – Summer 2018</td>
<td>2 male students, UG 4</td>
</tr>
</tbody>
</table>

Student quotes are referenced by [Code #]. [Sex: m/f], and [Paragraph # in Transcript]. Interviewees in 2016, 2017, and 2018 are coded A1-A3, S1-S9 (skipped S2), and B1-2, respectively.

2.2. Data Collection

As part of a larger study, the interviews included questions main about design education in engineering. Questions included topics such as: design project experience, key learning outcomes, success factors,

diverse and inclusive workplace environment for themselves.

On a positive note, we find students’ resilience and agency to be truly inspiring. They bring purposeful meaning to their choice to pursue engineering, and envision how engineering could indeed be contributing to enhance social justice and people’s lives. Engineering educators can learn much from inviting each cohort to co-construct the vision for engineering, which would include meaningful challenges, shared values, and meaningful identities. Even more, engineering educators can play a critical role in facilitating intergenerational learning between industry professionals and cohorts of students. A collective vision benefits as much from understanding the historical developments and the current context, as from building authentic relationships that empower one another.

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motivation, school culture, and the meaning of design in the engineering education context.

Most interviews were conducted individually with one researcher. One interview session in 2016 (2 male students) and one session in 2017 (3 male students) were conducted as group interviews. Group interviews, when the interest and scheduling align, allow multiple views to be expressed on a topic. Students comfortable with a group interview were comfortable disagreeing or elaborating on other participants’ responses, bringing increased clarity and plurality of meanings. However, individual interviews created a much more confidential space for speaking about contentious issues that were troubling to the participants. Each main data for this paper). Individuals who initially spoke only on positive aspects of their learning experience were able to offer insights on troubling aspects in ways that helped fully address the research questions. We also saw a stark contrast between two students’ interpretations of the same incident (i.e., regarding underrepresentation of minority groups) that signaled a real gap in understanding among the same student cohort. Such discoveries were possible because of the strength of individual interviews.

2.3. Data Analysis

Interview transcripts were read and discussed among the research staff to identify key themes that emerged, key connections across separate interviews, and interesting observations that deserved further investigation. Each transcript was also coded with in vivo concepts to make connections between different sections of the interview. Category labels were assigned by paragraphs to maintain the context of particular statements, and key concepts from individual sentences were organized into concept categories. The interview responses were then organized by the categories: Personal moral tensions, relational tensions, and novice-expert transition. This enabled integration of all interview participants’ voices, and comparison between participants. These excerpts were coded to develop categories (Fig. 1) according to the grounded theory framework [12].

Representation of engineer identities and the engineering norm were interpreted and made explicit (Tables 2-3). These descriptive representations were also coded in similar fashion as the original interview data, to further develop concept categories (Fig. 1) that would help explain the ‘tension’ experiences. Analytic memos were written throughout the coding stages, and integrated into the discussion of findings.

3. RESULTS AND DISCUSSION

‘Moral tensions’ included student experiences where their values or ethical ideals conflicted with what they observed in their peers or in the curriculum. ‘Relational tensions’ included interpersonal experiences that appeared problematic at a deeper level than the negative emotions of a conflict. ‘Perceptual tensions’ included areas of transition from a novice towards an expert, in which the perceived nature of engineering simultaneously held two polar opposites in qualitative characteristics. All three types of tensions implicitly dealt with the questions of: What is engineering? Who is an engineering student? What does it take to succeed in engineering education? Several engineer images and discourses were identified (Tables 2-3). One particular issue of privilege is discussed below.

3.1. Merit vs. Privilege in Peer Interactions

‘Privilege’ was not part of students’ vocabulary, not surprisingly given that the dominant rationalistic view does not accommodate an awareness of the issues of privilege. However, S1 (m, UG3), S7 (f, UG2), and B1 (m, UG4) described three distinct forms of privilege, even as they wrestled with the lack of adequate terminology.

I got a weird vibe of them trying to pick fights with me, then he would start spewing facts, not answering my question. He maybe tried to intimidate, it was a power play, I wasn’t a fan of it [...] not accepting the random bits of shutdown, saying hey you’re acting like a jerk [...] criticism for no reason isn’t acceptable. Sometimes he thought I was challenging him just because I was clarifying. Unnecessary animosity. (S7, f, 56, 59)

The assertion that female peers ought not to challenge their male peers, immediately places the men and women in a hierarchy, with the only possible personas being: the dominant, and the submissive. The duality affects male peers as well (as passive bystanders or as the target of control).

There can be subtle and overt ways of assuming and treating someone as less competent, unqualified, or unacceptable in an environment purely on their background characteristics. In a male-dominated environment, a majority of bystanders can amplify the impact of the biases by only a few overtly condescending male peers. Training for unconscious biases against women, as well as bystander training, may be essential.

There is also room for proactive training in interaction behaviours. Given adequate language and protocols peer accountability, there may be enhancement in the individuals’ and collective ability to call out toxic behaviour and establish mutually empowering ones. S7’s example of a highly effective team provides ample list of factors: e.g. established trust and mutual respect; shared value for honesty; separation between personal self-esteem and constructive feedback; mutual commitment to peer learning. What students are doing well, creatively
Table 2: Discursive themes and representations experienced as tensions by male students

<table>
<thead>
<tr>
<th>Moral</th>
<th>Relational</th>
<th>Perceptual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Social responsibility and ethics are introduced as important, and revealing of the nature of professional practice. However, these are treated as add-on rather than an integrated core of engineering curriculum, and thus not essential to success.</td>
<td>• Competence is more important than diversity.</td>
<td>• Confidence level in course-specific part knowledge does not equal effectiveness in integration (design projects).</td>
</tr>
<tr>
<td>• Human-centric design and related topics treat the ‘public’, ‘society’, and ‘people’ only as users and consumers. Only includes individual product relations to single users.</td>
<td>• Belief than all team conflicts are idea-based (disagreements) and can be resolved. The responsibility to speak up is on the individual who is not heard.</td>
<td>• Reductionism for practicality, overwhelmed by complexity; but detailed experience in complexity and systems thinking are vital.</td>
</tr>
<tr>
<td>• Engineers are primarily hired by for-profit companies. Companies are perceived as inhospitable to students’ desire to help society. Students feel either confident to create a win-win scenario, or feel powerless but to comply.</td>
<td>• Privilege of socioeconomic status: Treat privilege as merit to status; assign more work to ‘lower status.’ Devalues both the academic work and the less privileged peer.</td>
<td>• Engineering schools train for particular ways of thinking. Learning to think like an expert, but specific to the school. Diverse exposure is lacking.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Learning methodology is extremely helpful; but it is possible to stop thinking and simply rely on the methodology.</td>
</tr>
</tbody>
</table>

Table 3: Discursive themes and representations experienced as tensions by female students

<table>
<thead>
<tr>
<th>Moral</th>
<th>Relational</th>
<th>Perceptual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Engineering discourages creativity and individuality.</td>
<td>• Behavioural maturity adds much to engineering design project success.</td>
<td>• List of activities involved in engineering work does not help define what engineering is.</td>
</tr>
<tr>
<td>• Engineering is a people-oriented field, and thus should care for people even within engineering programs.</td>
<td>• Conversations are vital to team success; a number of male peers devalue conversation and listening.</td>
<td>• A personal sense of ‘fit’ with engineering is reflexively developed with a perception of engineering. Curricular projects need to invoke an internal motivation by empowering ownership and autonomy.</td>
</tr>
<tr>
<td>• Engineering skills should be used to help the world. New programs should allow students to co-develop the program direction.</td>
<td>• Male peers taking personal offense to female peers giving constructive feedback. Power play, belittling, disengaging, and intimidation are some of the ways male peers negate female peers’ efforts for collaboration. There is active shutting down of voices.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• ‘Success’ in engineering promotes selfishness.</td>
<td>• Female students treated by some as less competent than male students.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ‘Mech Eng boys’: immature, overly competitive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ‘Guys in engineering’: cliques, narrow-minded</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Privilege of particular male personas: impose dominant-submissive roles among peers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good team: collaborative, respectful, genuine, hard working, caring, supportive of peer learning</td>
</tr>
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</table>
and effectively, deserve more attention even as project instructors seek training resources for teams.

There was an overwhelming unawareness of male privilege and biases against women. However, a comparable experience in classism and racialized disadvantages may help engage male students in the discussion of privilege.

*They’ll be someone who feels they don’t have to contribute as much to the project, this is from my personal experience, they think they are too good for this, or have more important things to do [...] So how some people think they're too good for the group this is a big problem [...] I don't give them credit for things they didn't do [...] then the people who do the work, I give them the credit and I boost them. Ethics: people who don't follow those will never be successful in engineering. (S1, m, 101, 122)*

It is deeply unsettling for S1 to be treated as less important and ordered to work by someone who has materialistic privilege, that somehow translates into a higher ‘class’ of being. That status was used as if it had been earned, treating privilege as merit. Work was expected from someone of a lower status, as if without material resources, one must work to be treated as equals with those with resources. This not only devalues ‘work’ and the person both, but poses serious questions about our faith in merit-based reward system. If privilege is unseen, and status is set up as a common goal for equal treatment, those with less resources are condemned to more work that is continually becoming devalued. Along with rationalism, meritocratic beliefs [13] need to be challenged before a truly merit-based evaluation system might be effectively developed and fairly applied (e.g. to hiring decisions, promotion, salary negotiation).

The issue of class is not readily discussed in the engineering context, given the strong preference for middle-class norms and conservativism in a neoliberal context [14]. B1 also commented on the experience of having financial need (unexpected damage to laptop), and having to rely on school resources to complete his work. Coming from a well-educated and employed family, it was his first experience of ‘lack.’ The assumption that everyone owns a laptop to class, can create a less inclusive environment for those without. Many engineering students at this institution work to contribute to their family income, all the while enrolled in full-time studies.

A fourth year student had identified a consistent lack of representation from the black youth in his engineering program, his peers had very different understanding of the issue. B1 was passionate about outreach to local racialized minority youths; B2 dismissed the whole discussion as a non-issue. B2, even though a visible minority in Canada, is an ethnic majority at this institution and well-supported by his family. The experience of systemic barriers was hard to find.

More importantly, the lack of self-awareness on the issues of privilege (financial resources) can translate into resistance towards critical perspectives, resistance towards social justice discourses, resistance towards acknowledging the equity issues that exist in engineering schools and workplace.

### 3.2. Process Framework

One of the key aims in grounded theory analyses is to define relationships between the main phenomenon, its context, participants’ action/interaction strategies, and the outcome (main categories in the ‘process framework’) [12]. The following three were determined as potential categories (Fig. 1):

- **Phenomenon:** Conflicting messages about ‘success’ as engineering students
- Action/Interaction Strategies: Students’ own internalization, negotiation, and/or construction of the dominant images and engineering discourses
- Outcomes: Moral up/deskill; Interaction and personal character qualities; Agency and critical thinking; Engineering identities; Perceived ‘fit’ and persistence in engineering

The analytic task of defining category relationships has identified a new focus for further data collection: How students develop their own engineering identities, interact with the existing discursive resources, and perhaps create alternative discourses in their localized contexts. Factors

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**Conflicting Messages: “Success”**

- Purpose and nature of engineering
- Who is included/excluded from engineering

**Engineering curriculum:**
- What is made relevant
- How academic performance is evaluated and defined
- Conformity-Agency
- Rewarded methods of success
- Meanings of success

**Students’ Response to the Conflicting Messages**

- Perpetuation–Resistance
- Integration of discursive resources
- Alternative narratives
- Personalized and contextualized meanings

**Mediating Factors**

- Abilities and attributes
- Relationship to engineering
- Quality of experience

**Impact on Student Outcome**

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Fig. 1. Preliminary Categories in Grounded Theory Analysis.
that enable or inhibit such activities will need to be identified; The role of engineering educators will be of crucial interest.

4. CONCLUSIONS

Persistent images of engineers and ideological discourses about engineering provided a deeper understanding of equity and inclusivity issues experienced by engineering students. Rationalistic view of team success and relations was inadequate to address disrespectful, maladaptive and/or toxic behaviours among peers; Meritocratic language masked the role of privilege in belittling and devaluing disadvantaged group members. Unaddressed issues had impact on design project outcome and satisfaction level in the schooling experience. Furthermore, the issues were also linked to a sense of dissonance in students’ relationship to engineering, or self-identification as future engineers.

Engineering educators’ curricular decisions send powerful messages about what is relevant and valued in engineering. We should be inspired to critical self-reflection, by S7’s keen observation: the nature of engineering should be reflected in how we treat one another, and what we care about in academic and extracurricular activities. Our own self-awareness and development can extend to practical training and support strategies for engineering students. We invite colleagues’ feedback and engagement.

Acknowledgements

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References


