

## **Connected Ways of Knowing: Uncovering the Role of Emotion in Engineering Student Learning**

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“Connected Ways of Knowing” was a National Science Foundation (NSF) funded, Research on the Formation of Engineering grant that concluded in Fall 2016 (Grant #: 1160350 and 1541358). The broad purpose of this narrative research project was to explore the role of emotion as a core aspect of connected ways of knowing in engineering student learning and professional formation. There were 21 participants in this project who were undergraduate engineering students in a small engineering program at a large Research 1 university. The students were diverse in their engineering disciplines, years in the program, gender, and race/ethnicity. In this paper, we will provide an introduction to the importance of studying emotions in engineering student learning, an overview of this research project focusing on key works that emerged from the study, and implications that emerged for practice.

## Introduction

In the concluding chapter of the influential research compendium *How People Learn*,<sup>1</sup> the editors recommend increased focus on research that elucidates “how student interests, identities, self-knowledge, self-regulation, and emotion interact with cognitive competence” (p. 280). In engineering education, we have often considered emotion as a by-product of learning, but recent developments demonstrate that emotion is an integral and central part of learning.<sup>2</sup> This research builds on the developments in neuroscience that point to the critical role of emotion in learning and decision-making.<sup>3,4</sup>

In engineering education there has been very little discussion about the role of emotion in engineering student learning.<sup>5-7</sup> However, most of these discussions consider emotion as separate from learning, not as an integral part of learning as the educational psychologists and neurologists are establishing.<sup>2,8-12</sup> This recent research on the integral role of emotion in cognition is very relevant to engineering educators as we are preparing engineering graduates to make decisions within the increasingly global society regarding multi-dimensional problems situated in increasingly complex socio-political contexts.

This paper is an overview of multiple research projects associated with this broader research project. The following sections will include a brief discussion of the overall research design, findings from each of the studies that emerged from this broader project, and implications that emerged from this work.

## Research Design

In this project we used a narrative research approach that, in combination with the multi-dimensional model of emotions (activation and valence), enabled us to understand the emotions that students experience throughout their undergraduate engineering program. This led us to a development of trajectories of students’ emotions, thus helping us develop a broader understanding of the role of emotions in student learning.

We conducted 21 narrative interviews with engineering students that ranged from first year to fifth year students and were in a diverse set of engineering majors (including agricultural, environmental, civil, mechanical, and electrical engineering). There were a few different analysis methods taken for this project—one involved a structural narrative analysis method<sup>13</sup> and another involved identifying critical events in students' experiences and categorizing them using the multi-dimensional model of emotions.<sup>14,15</sup>

## Research Findings

This research project explored the role of emotion in engineering student learning with a focus on professional/connected knowing. The hypothesis of this research is that emotions are a facilitator of and essential mechanism in the acquisition of professional and connected ways of knowing. The project has resulted in five journal articles—the following sections state the primary research question and highlight some significant results for each study:

*How might we find a reliable way to construct stories from narrative interviews (with attention to the structures of stories) so that we might compare trajectories of student experiences<sup>13,16,17?</sup>*

In our methodology paper, we developed a process for performing structural narrative analysis<sup>18</sup> that draws on narratology and literary studies. Our structural narrative methodology involves understanding underlying structures within stories using Joseph Campbell's monomyth,<sup>19</sup> constructing narratives according to those structures,<sup>20</sup> and then a paradigmatic analysis of the narratives to allow for a cross-case analysis of the constructed narratives. Joseph Campbell's monomyth created a simple-to-follow structure with which to reconstruct student stories, and once coded, it was easy to follow the course of the monomyth structure to construct coherent and meaningful narratives for cross-case analysis.

We are also completing a second research paper that uses this methodology to understand the beginning of students' journey: 1) call to adventure, 2) refusal of the call, 3) supernatural aid, and 4) the first threshold. In the paradigmatic analysis of the constructed narratives, we found that despite indicating an initial interest in engineering, three quarters of the participants initially chose majors other than engineering when entering college. A lack of information or pre-conceived and oversimplified understandings about engineering (such as engineering being reductive, difficult, and math-intensive) resulted in potentially interested students from our sample opting out of engineering education programs. Seven students described 'competing interests' as being reasons that they did not initially pursue engineering as a major—examples of this include a participant pursuing journalism because she wanted a creative major. These students then received a form of aid along their journey that brought them back to engineering as a major. This aid took the form of family, friends, teachers, advisors, or professors. After returning to engineering, many students describe that they had 're-found' their calling. The themes of comfort, relief, and belonging continued into the first-threshold experiences for many of the students in this study. While a number of students indicated that they felt that they belonged in engineering and enjoyed taking on the challenge of the engineering curriculum, four students indicated feeling lonely or isolated as they approached their first threshold experience.

*What are the experiences and associated emotions of engineering students during their 1<sup>st</sup> year? Are there differences in these emotions with respect to gender, race, or ethnicity?*<sup>21</sup>

Students from different groups demonstrated varying emotional responses to similar experiences. The variability and severity of emotions, particularly if sustained over an extended time, can have implications for student persistence in engineering programs and their overall mental health.

The expression of emotions differed with respect to race, ethnicity, and intersectionality. High-valence, positive emotions, i.e. enjoyment, were not reported by URGs while high-valence, negative valence emotions, mainly stress and anxiety, were reported more by underrepresented students. Frustration, the feeling that results when a person's actions produce results inferior to those anticipated, was described by majority students (i.e., White male students).

Black students did not articulate frustration although the majority of emotions they experienced during the 1<sup>st</sup> year were negative. Instead, both Black and Hispanic students conveyed stress and anxiety. Having reported both high and low activation emotions, Black and Hispanic students experienced more negative emotions compared to other racial groups highlighting how little we actually know regarding the mechanisms by which emotions influence actions and decisions in educational environments.

Intersectionality in this study was introduced through the women of color. Specifically, Black and Native Hawaiian/Pacific Islander women were at the intersection of race and gender. With the exception of a sense of belonging, women of color expressed only extremes of emotions—high-activation—positive or negative. This finding suggests that women of color navigate the 1<sup>st</sup> year of engineering primarily experiencing extreme emotional poles, including emotions such as stress, and anxiety.

*How do emotions underpin the narratives of engineering students? What are the emotional trajectories of undergraduate students as they progress through an engineering program?*<sup>22,23</sup>

Undergraduate students in the engineering program experienced emotional turbulence as a result of their experiences throughout their undergraduate career. Emotional turbulence is a term coined by the research team to represent the variability in activation and valence of emotions associated with experiences within a short period of time. For example, during their first year in an engineering program, participants experienced a set of challenges related to the high school to college transition, both academically and socially. These challenges resulted in a flurry of emotions for students, as they felt encouraged and supported upon entering college and were quickly met with negative emotions (e.g., stress, isolation, and frustration) within their first semester of coursework.

When participants progressed into their second year, they became more accepting of their identities and positions as engineers and experienced more positive emotions. During this year, all three participants were involved in extracurricular activities and credited these social activities as a key experience to transition away from the stress of their freshman year.

During their third year, most student experiences were aligned with positive emotions as they were engaging with and enjoying the professional and academic sphere of engineering. For two participants, this was an internship experience in which students received on the job training. At this point in their undergraduate career, students began to identify as engineers and recognize that they would persist in their engineering degree.

In their final year, tensions and negative emotions reappeared as students began to make post-graduation plans. Participants struggled with their decisions to continue as an engineer professionally or academically, by pursuing graduate school. Participants described relationships with faculty members as mentors as one of the reason for deciding to attend graduate school.

*How do student identities develop as they experience an engineering program?*<sup>24</sup>

In this work, we constructed narratives for each participant, did a thematic analysis of each narrative, and compared across the individual stories to find emergent themes. The themes that emerged were: decision to enter the profession/major in engineering, empowerment, influence of faculty members, and extracurricular activities and maintaining balance.

This study showed the power of narratives in understanding identity development of engineering students. Most of the engineering students in this study experienced and described a moment of crisis or vulnerability at some point in their narrative. Prior work in life story and narrative research explains that during the adolescent stage of one's life, people are particularly vulnerable in the struggle of figuring out their identity.<sup>25,26</sup> In many of the narratives, students experience moments of crisis that result in turning points in their college experience. Depending on the student, crisis was experienced at different stages in their development. For some students the first crisis was encountered early in their college career as they found a major that aligned with their interests and future goals. For others, the first crisis arose later in the 2<sup>nd</sup> or 3<sup>rd</sup> years when they were faced with challenging coursework in their major.

Through this thematic narrative analysis, a common set of experiences was shared across students and demonstrates the rite of passage that undergraduate students experience in their quest to form a professional identity. Our findings suggest that as we are developing a deeper understanding of identity specific to engineering students it may be critical to expand our conception of identity beyond an engineering identity—developing a more robust understanding of the role of engineering in identity development.

## **Implications**

This study has many implications for practice. The following discusses implications that emerged from this broader research project.

**Advising:** Many students had stories of faculty and advisors recommending that students take reduced course loads and focus on their studies, resulting in giving up extracurricular activities. This advice unintentionally resulted in students experiencing engineering to be a difficult major where excelling as an engineer meant sacrificing other meaningful parts of their life.

**Weed-out Classes:** Without even experiencing weed-out classes, the students that were interviewed in this study had many intense negative emotions, especially in their first year. Subjecting students to more negative emotions in their first year commonly results in them feeling like they do not belong in engineering. A focus on a more engaging early college experience could result in students being more challenged, stimulated, and engaged in their engineering programs which could result in enjoyment in their first years.

**Failure as leading to learning:** A stronger articulation of the value in learning how to fail and the acceptance of failure as a pathway to success would be valuable for our engineering students. Many students enter college with few experiences of failure, thus they have great stress and anxiety when they experience any type of failure (sometimes manifest as making a B+ in an introductory class).

**Power of story:** In this narrative research project, we found that the power of an individual's story is difficult to ignore. Through students stories and their lived experiences in engineering, we can get a vibrant snapshot of engineering to begin to transform engineering education to attract diverse people to engineering and to ultimately be situated to address grand challenges that we are facing today.

**Sense of community:** In the second and third year, many students began to experience a sense of community and this was the time that they began to experience more positive emotions and demonstrated qualities such as ambition and resilience.

**Family influence:** In the fourth year, students from underrepresented groups had more stress as they felt pressure (sometimes only perceived pressure) to enter the job market over pursuing graduate school. When students discussed this with their families, they were usually encouraged to pursue graduate school. Family influence is critical for these students, especially during their first and fourth year as they experience more emotional turbulence.

**Internships:** Students who experienced internships or co-ops experienced a sense of empowerment that helped encourage them to continue in engineering. Professional development experiences for faculty members may help them better support undergraduate students so that they might gain this sense of empowerment through their curriculum.

**Student empowerment and persistence:** When students experienced intense, positive emotions, these emotions were often associated with empowerment and subsequent persistence in the major. Designing curriculum that engages, challenges, and stimulates engineering students will result in more positive emotions and can likely lead to empowerment and persistence—something critical as we are still struggling to attract and retain more students in engineering, and especially students from underrepresented groups.

## **Conclusion**

This research has demonstrated that emotions are critical in getting a more complete understanding of students' experiences that lead them to either persist or leave undergraduate engineering programs, and that impact their experiences in engineering programs that in turn

influence their learning. We described a series of research projects that used a single data set to initiate a dialogue around the role of emotions in engineering student learning. Future work is needed to develop an understanding of emotions in engineering programs across multiple contexts—this study was focused at a single Research 1 university with a small engineering program. If faculty, staff, and administrators become more attuned to emotions of engineering students, we may be able to create an environment that encourages students to become empowered as future engineers and thus be able to make a difference in our world.

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