BOARD # 424: Preliminary Results - Understanding Interactions Between Affect and Identity in First- and Second-Year Engineering Students (PFE:RIEF)

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Abstract
Recent work has highlighted the importance of engineering students' emotions in their ability to think critically, consider wicked problems, and complete design challenges. Work in the field of mathematics education has highlighted another potential influence: the emotions that students experience while solving problems can have cumulative effects over time on their *global affect*, or their more stable attitudes, values, and beliefs towards the discipline. Gaps in the literature on affect in engineering students motivated us to examine students' affect about engineering, mathematics, and science across their first two years of undergraduate engineering coursework. Engineering identity, or a student's sense of themselves as an engineer, is discussed as having affective components (e.g., interest). However, the specific influences of local affect and other aspects of global affect (like recognition and self-efficacy) on engineering identity formation have not been systematically explored, which motivated this study. Using a mixed-methods approach consisting of surveys and interviews, our study has followed two cohorts of students longitudinally. Our work has revealed important differences between affect towards engineering itself and towards mathematics and science, as well as interactions between affect and identity.
Keywords: identity, affect, emotion, undergraduate engineering

Introduction and Background

This paper presents preliminary results from our NSF-funded grant exploring affect in undergraduate engineering students and its interactions with engineering identity formation. Affect consists of both the individual emotions that a student experiences during disciplinary work (local affect), as well as the more stable and long-lasting emotions, attitudes, values, and beliefs the student holds about a subject (global affect) [1]. In their work, DeBellis and Goldin suggested that affect is not simply a physiological side effect of cognition, but that it plays a role in students' problem-solving, carrying meaning and encoding information [1]. In engineering work, this might look like a student feeling frustrated after the failure of a particular problem-solving strategy during design projects or in their coursework, which signals the need for a new approach or trying another similar problem. Alternatively, frustration could continue if this need is not recognized, potentially reinforcing negative beliefs for their student about their ability to take on similar challenges in the future. For this reason, affect may influence students' understanding, engagement, and performance during disciplinary work.

Local affect can form affective pathways, which are the sequences of changing affect that students pass through during problem-solving [1]. These pathways may be positive (ultimately resolving puzzlement or frustration into positive emotions as a problem is overcome) or negative (where frustration may prompt the search for safe, rote procedures and escalate from frustration into anxiety or despair) [1]. Affective pathways interact with global affect: positive pathways may build positive global feelings toward the subject, while negative pathways may build aversion or dislike for the subject over time. In turn, global affect may set contexts for local affect, informing the student's experience of disciplinary work. Because much of engineering students' early coursework consists of required courses in mathematics and the sciences, our study seeks to understand affect in engineering students through the following research questions:

RQ1: How are 1st and 2nd year engineering students' local affect different or the same while doing engineering work vs. mathematics and science work?

RQ2: Over the course of their early college experiences with mathematics, science, and engineering, how do students' global affect about mathematics, science, and engineering change?

As students begin their undergraduate studies, they are typically trying to choose a major and career; prior work has tied the formation of engineering identity to retention in an engineering major [2], [3]. Engineering identity is a student's sense of themselves as an engineer, shaped through their experiences in engineering. Building on prior research in science and engineering [4], [5], Godwin developed a survey instrument to measure engineering identity, consisting of three components: interest, recognition, and performance/competence [6]. Many models of engineering identity (including Godwin's widely-used social identity model) include affective components as aspects of identity, but our work seeks to find connections between these two constructs (affect and engineering identity) that have previously been examined separately, motivating our final research question:

RQ3: How do students' local and global affect about mathematics, science, and engineering contribute to/interact with their identities, including engineering identity?

Methods

This longitudinal study follows two cohorts of students from a small liberal arts university in the American Southwest. Following a protocol approved by the university's institutional review board, we recruited participants from an introductory engineering design course in two consecutive years. Participants completed a pre-survey at the time of consent and opted to participate in either surveys or surveys and interviews at the end of each semester that they remained in engineering. We selected interview cohorts to represent a variety of demographic and interest factors (racial/ethnic identities; first-generation status; socioeconomic status; outside activities such as athletics or music; LGBTQIA+ identity; etc.). In each cohort, 29 students consented; in Cohort 1, 25 students completed at least one end-of-semester survey and 17 students completed at least one interview. In Cohort 2, 17 students completed at least 1 survey and 10 completed at least one interview. End-of-semester interviews, performed by the PI or Co-PI and professionally transcribed via rev.com, included questions designed to explore students' motivations for studying/continuing in engineering, their affective experiences in their coursework, and their identities. End-of-semester surveys included Godwin's identity instrument [6] as well as Likert scale questions for global affect and affective regulation. The surveys also asked students to describe typical affective pathways in their classes that semester [7]: "In the drop down menus below, select the sequence of emotions that you experience from start (top) to finish (bottom) of a challenging homework problem in a [math/science/engineering] class this semester." Survey responses are linked to interviews with a pseudo-anonymous identifier.

Last year, we reported on preliminary survey analysis from our project [8]. Here, we focus on bringing together preliminary findings from case study analysis. Interview analysis begins with a member of the research team coding each transcript for affect (local affect; affective transitions; meta-affect; global affect) and identity constructs (interest, competence, performance, or recognition). Utterances with affective transitions, meta-affect, global affect, and identity markers are copied into a worksheet for easy access, and notes/interpretations are entered by the coder. The coder then writes a 1-2 page memo summarizing the identity and affective patterns

from the interview, including any overlap between them that they noticed. Along with survey responses, the coded transcripts and worksheets provide the basis for case study analyses.

Results

Here we present a subset of results from cases of students in Cohort 1, which allow us to highlight some of our findings. In Table I we present aspects of four cases: two students who have remained in engineering throughout the duration of our study, and two who did not.

Table I: Responses from Cohort 1 surveys and interviews at the end of students' 2nd semester studying engineering. The affective pathways for engineering pertain to a design class.

	Interview Response to "*Why did you pursue engineering coursework this semester?"*	Affect survey responses: (1) affective pathway while completing a challenging problem or design project; (2) global affect: response to *"My feelings/attitude about ____ are generally positive"*		
		Mathematics	Science	Engineering
Hope	I think it's probably the only thing I can see myself doing.	*Pathway*: Distress, frustration, uncertainty, confusion, happiness, excitement *Global*: neutral	*Pathway*: Confusion, uncertainty, curiosity, accomplishment *Global*: strongly agree	*Pathway*: Puzzlement, curiosity, encouragement, satisfaction *Global*: strongly agree
Noelle	So I can graduate in five years [...] it's like, "well, you're late into [starting the major], you're locked in at this point." It's a good major, there's good people here.	*Pathway*: N/A (no mathematics course this semester) *Global*: neutral	*Pathway*: Anxiety, uncertainty, curiosity, frustration, enjoyment, accomplishment *Global*: slightly agree	*Pathway*: Curiosity, excitement, happiness, stress, enjoyment, uncertainty, frustration, encouragement, satisfaction, confidence *Global*: slightly agree
CJ	I knew that I liked math and I liked physics. [...] So I figured I would give it that first semester. And then I had thought about switching, but [...] I wanted to make sure that I was correct in my feelings about not wanting to do engineering.	*Pathway*: Anxiety, confidence, curiosity, frustration, excitement, uncertainty, satisfaction *Global*: strongly agree	*Pathway*: Confidence, enjoyment, excitement, pride, anxiety, stress, satisfaction *Global*: strongly agree	*Pathway*: Confusion, frustration, puzzlement, stress *Global*: slightly agree
Skye	My artwork uses elements of engineering, [...] which inevitably does involve it [engineering] but not to the degree that you need a B.S. for.	*Pathway:* Uncertainty, stress, distress, frustration *Global*: slightly disagree	*Pathway:* Distress, confusion *Global*: agree	*Pathway:* Stress *Global*: strongly disagree

Hope is strongly committed to becoming an engineer, as seen in her interview response; elsewhere in her interviews, she expresses strong engineering identity in terms of interest and competence, which seems to create a very positive global affect towards engineering. This positive engineering affect outweighs her less positive affect towards mathematics in her decision to remain in the major. Noelle's case shows a more moderate case of a student persisting in the major: after switching into engineering later in her college career rather than beginning as a first-year student, her global affect towards engineering is not as positive as Hope's. Still, her positive affective pathway through an engineering design project gives us indications of why she persists: elsewhere in her interviews, she discusses enjoying the "emphasis on application" in her

classes, and by the third semester of the study (the semester following the one shown in the table) her response about global affect towards engineering had improved to "agree."

CJ and Skye both left engineering after the second semester of the study (the one shown in the table), but had very different experiences. CJ described strong performance and competence throughout their interviews, while Skye discussed struggling with performance in her engineering, math, and science coursework. These vastly different experiences are illustrated in the contrasting affective pathways reported in their surveys. Despite these differences, the commonality across their interviews (also seen among other students who left engineering) is that their global affect towards engineering was reduced by their de-identification with engineering: both students described having academic/career goals distinct from engineering (art for Skye; mathematics and architectural studies for CJ) that held more interest for them. Looking across all of the students shown here, the use of "satisfaction" at the end of an affective pathway (mathematics for CJ; engineering design for Hope and Noelle) reflects global interest, and is conspicuously absent for Skye (for whom none of these subjects is well-aligned with interest).

We have elsewhere published several other case studies examining interactions between participants' identities and components of local or global affect. In [9], three students' experiences provide evidence that cycles of beliefs shaping the context in which students experience their local affect can simultaneously reinforce the original beliefs and influence students' sense of engineering identity. In another paper accepted to this conference [10], the case of Projector Man is explored: this student has a unique focus on problem-solving that enables positive engineering identity despite reports of poor exam performance.

Discussion and Conclusions

While we had room here only to analyze a small portion of each case, these excerpts address aspects of all three research questions. In terms of RQ1 (differences in local affect while doing engineering vs. mathematics and science work), patterns in local affect diverge as students decide whether or not to continue in engineering: students intending to persist (like Hope and Noelle) often report more positive emotions associated with completing challenging problems in their engineering design class than their mathematics or science classes. Students leaving the major (like Skye and CJ) do not have this same positive local affect associated with design.

In terms of RQ2 (changes in global affect), we previously reported in [8] that students uniformly began with positive global affect towards engineering, mathematics, and science. We see here that students who decide to pursue other majors develop more negative global affect over time, while students remaining in the major tend to remain positive towards at least engineering, even if their global affect towards mathematics or science becomes more negative.

The setting of this study at a liberal arts institution highlights a different perspective on engineering identity and persistence in engineering than is often seen in papers that feature studies conducted at large institutions [11], because our participants had not declared a major at the start of the study. We have found that when students' deeper interests and career goals are not aligned with engineering, students do not have strong positive global affect surrounding engineering and switch majors. The cases of the students who remained in the major highlight the importance of exposing students to authentic design experiences early in the curriculum,

since students can persist in engineering despite strong negative emotions and global attitudes related to mathematics and science, as long as the negative affect is balanced by strong positive affect towards engineering and/or strong engineering identity development. In these case studies we see that interest as an affective construct strongly influences the formation of engineering identity (RQ3). Deeper analysis of RQ3 with respect to local affect is currently under review.

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