The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #41992

Putting Affect in Context: Meta-Affect, Beliefs, and Engineering Identity

Alyndra Mary Plagge, Trinity University

Alyndra Plagge is an undergraduate Psychology student at Trinity University. She is majoring in Psychology and minoring in Education and set to graduate in May 2025. After graduation she plans to pursue her master's degree.

Dr. Emma Treadway, Trinity University

Emma Treadway received the B.S. degree in Engineering Science from Trinity University in 2011, and her M.S.E. and Ph.D. degrees in Mechanical Engineering from the University of Michigan, Ann Arbor in 2017 and 2019, respectively. She is an Assistant Professor in the Department of Engineering Science at Trinity University in San Antonio, Texas.

Dr. Jessica E. S. Swenson, University at Buffalo, The State University of New York

Jessica Swenson is an Assistant Professor at the University at Buffalo. She was awarded her doctorate and masters from Tufts University in mechanical engineering and STEM education respectively, and completed postdoctoral work at the University of Michigan. Her research work aims to improve the learning experience for undergraduate students by examining conceptual knowledge gains, affect, identity development, engineering judgment, and problem solving.

Danielle Francine Usinski, University at Buffalo, The State University of New York

Danielle Usinski is an undergraduate research assistant in the Department of Engineering Education at the University at Buffalo. She is currently in her final year and is set to graduate with her Bachelor of Science in Biomedical Engineering in May 2024. Next year, she will be graduating with her Master of Science in Biomedical Engineering in May 2025.

Putting Affect in Context:
Meta-Affect, Beliefs, & Engineering Identity

Abstract
In this research paper, we sought to understand how meta-affect influences the strength of engineering identity in first-year students, since strong engineering identity is correlated with retention. Meta-affect refers to affect about affect, cognition about affect, and monitoring of affect. Goldin's research on meta-affect has suggested that there is a cycle wherein students' beliefs establish meta-affective contexts that in turn shape the experience of affective pathways.

We analyzed transcripts of interviews conducted with students during their first year in an engineering program. The primary goal of the interviews was to gain insight into engineering students' affect towards math, science, and engineering and their engineering identity. For this comparative case study, we focus on three students with different engineering identities. Our goal was to investigate and provide evidence for the trends and relationships between beliefs, meta-affective-context, and affect and their influence on engineering identity.

We found relationships between meta-affect and engineering identity related to specific beliefs: beliefs concerning getting help, the challenges of engineering, and performance ability. These relationships had different implications for the students' identities depending on the students' meta-affective contexts and affect. Understanding the relationship between these factors can help instructors promote more productive beliefs and meta-affect. This could potentially help strengthen engineering identity and increase retention of students within engineering.
Keywords: Meta-affect, affect, beliefs, identity

1 Introduction

The decision for engineering students to switch majors or drop out of higher-education institutions commonly occurs during the first and second year of college [1]. Foundations of identity begin to form as students decide to continue pursuing an engineering major [2]. Unlike other majors, engineering has a low rate of migration into the major [3], making retention a major concern. In the process of developing interventions to increase retention rates in STEM fields, the research surrounding students' experiences in these fields has grown substantially. Significant research has focused separately on identity development within STEM fields [1], [4], [5], [6] and on the affective experiences [7], [8], [9], [10] of students. Some studies have investigated the overlaps between identity and motivation [11]. Other studies have investigated the emotions or affect students experience as they relate to problem-solving [10], [12]. For the purpose of this study, affect is defined as the emotions, attitudes, beliefs, and values a student holds or experiences in regards to math, science, and engineering [10], [12] and local affect is defined as the affective states that are rapidly changing.

In this study, we aimed to investigate the interaction between identity and affect in first year engineering students, focusing on the ways that beliefs interact with meta-affect (affect or cognition about affect). We sought to answer the following research questions.

RQ 1: What evidence is there in first-year engineering students to support the presence of the relationship between beliefs, meta-affective contexts, and local affect described by Goldin in [12]?

RQ 2: What are the implications of these relationships for students' engineering identity?

In the next sections, we will discuss the literature that guided the formation of our study, design, and analysis as well as define any key terms.

2 Background

2.1 Meta-Affect

Meta-affect refers to affect about affect, cognition about affect, and individuals monitoring their own affect [12]. Meta-affect and meta-affective contexts are what allows individuals to experience emotions in an unexpected way. Meta-affective context refers to the context that shapes the experience of emotion [12]. An example of meta-affect is when someone experiences a haunted house as exciting. The knowledge that the haunted house is safe serves as the context that allows the fear a person experiences to be exciting. According to DeBellis and Goldin's research on affect and meta-affect in mathematics, frustration and fear are common, and the feelings about these feelings are not always pleasurable [10]; they suggest that what is important is not eliminating the fear and frustration but rather encouraging the development of meta-affect that is productive to learning through reframing.

Factors such as beliefs can influence meta-affect [10], [12]. Beliefs are defined as cognitive configurations that the holder attributes some kind of truth to [12]. Goldin [12] has argued that there is a cycle in which beliefs establish meta-affective context which then shapes local affect (the in-the-moment emotions that a student experiences while performing disciplinary activities, as opposed to more stable global affect like attitudes). The local affect experienced, in turn, stabilizes the belief. Goldin gives the example that a student may hold the belief that speed and accuracy of computation are good ways to measure how well mathematics has been learned. The student may be good at these skills and believe that they are talented if they are in a meta-affective context where these measures are valued. In a competitive classroom they would feel personally validated and come to enjoy mathematics. The cycle between belief, meta-affective context, and local affect (enjoyment) maintains the belief. As the cycle repeats, it becomes more entrenched within cognition and supports the meta-affect. This cycle offers a good theoretical perspective on the role of meta-affect within the wider affective context, however, the work in which it is described [12] offers only generalized hypothetical examples rather than concrete evidence.

2.2 Identity Framework

There are many identity frameworks, including those considering engineering identity as composed of several other aspects of identity, those investigating perceptions surrounding a person, those consisting of cognitive, affective, and performance variables, and those characterizing engineering identity as the consequence of specific actions [13]. In this work, we employ an identity framework consisting of four sub pillars: competence, performance, interest, and recognition taken from the work of Carlone and Johnson [6], Hazari [5], and Godwin [4].

The first sub pillar, competence, is the ability [6] or belief in one's ability [5] to understand math, science, or engineering content. In some instances, competence could be combined with performance. In these cases it could be measured by looking at self-efficacy beliefs and task attainment [4]. Performance is the ability or belief in the ability to do things related to math, science, and engineering. Students could show performance through having the skills to perform scientific practices and task attainment, such as, getting good grades [6]. Performance could also be shown in one's belief in their ability to perform the required task [5]. Interest is the personal desire to learn or understand more [5] and do well [4] in math, science, and engineering. Interest (or lack thereof) could influence a student's desire to start and persist with a subject. Recognition is divided into two categories: recognition by others and self-recognition. Recognition from others was defined as being acknowledged by professors, peers, and parents as a good student in a specific subject [4], [5] or being recognized as a science/engineering/math person [6]. This type of recognition was an extrinsic factor for identity formation whereas self-recognition was an intrinsic factor for the formation of identity. Self-recognition shared the same definition as recognition from others with the exception that the source was internal. Self-recognition makes the individual's thoughts about themself important. Recognition is suggested to be one of the most important factors of identity formation within STEM [6].

3 Methods

3.1 Positionality Statement

The authors of this paper come to this work with different backgrounds in research and teaching and share a common interest in the experience of students and the influences of affect and identity. The first author is an undergraduate student with no background in engineering or engineering coursework, working towards a major in psychology and a minor in education. Two of the researchers are engineering professors with experience in mechanical engineering and engineering education research. All of the researchers are white women. The final author is an undergraduate student working towards a major in biomedical engineering.

3.2 Data collection

This study originated from a longitudinal case study looking at the general overlap between identity and affect in the creating of engineering identity. This case study was planned to span over students' time in an engineering science program for four semesters; this work relies on the first two semesters of data only. Students in a first-semester engineering design class at a small liberal arts university in the southern United States were given the option of participating in a study by completing a survey and an interview. In order to meet the requirements for participation, the students had to be taking their first semester of coursework in the engineering program. Participants were asked to complete interviews and surveys at the end of the fall and spring semesters. The interviews and surveys had participants reflect on their experiences in their math, science, and engineering classes and involvement in engineering activities. Questions from the interviews were based on the previously discussed models of affect and engineering identity.

This study uses data from the first two semesters. A total of 17 participants completed the first round of interviews and 13 participants completed the second interview. Three participants illustrating a range of strengths in their engineering identities were selected for further analysis in this work. The result of this was the selection of one participant with a very strong engineering identity, one participant with a very weak engineering identity, and one participant that was strong in some aspects but weak in others causing them to fall in the middle of the spectrum.

3.3 Preliminary Analysis

Preliminary analysis of the transcripts began by using thematic coding and discourse analysis. Transcripts were first coded for affective expressions or phrases conveying that the participant was expressing an emotion. For example "I felt really, really good" would be coded as an affective expression, but "I always had very good instructors" would not be. Next, we coded for global affect (relationships and attitudes towards math, science and engineering) and meta-affect, which was interspersed throughout the transcripts but was consistently described when participants were asked what emotions they felt when they solved a challenging problem. Finally, we coded for utterances meeting the definitions of the four pillars of engineering identity described above. Each transcript was coded in this manner. The researchers would then discuss the transcript together to clarify or settle any disagreements. This initial analysis for each interview was then synthesized into a memo summarizing the main themes, which was used to select three participants for this comparative case study.

3.4 Comparative Case Study Analysis

Once the three participants were selected for this case study, we sought to better understand the role of student's meta-affect in their engineering experience. An initial analysis of the meta-affective utterances of these three participants found during the preliminary analysis revealed connections between specific beliefs and meta-affect. Interest in this trend caused us to go through the transcripts again with more attention to beliefs, the meta-affective context they establish, and the affect they sustain. First, a list of shared topics for beliefs was compiled by the two undergraduate authors. The beliefs were then limited to those displayed by all three participants and occurred more than once. The first author then watched each interview recording while listening for descriptions of the selected beliefs that may not have been captured during the initial coding. The beliefs were examined for connection to meta-affective contexts. The meta-affective context was then examined for what local affect it established. Interpretations were debated by the research team.

4 Results

The trends that emerged relate to beliefs regarding the challenges in engineering, reaching out for help from others, and beliefs about performance and competence. Beliefs on each of these topics were expressed by all three participants, but differences in the beliefs themselves caused different impacts on local affect and identity. In order to better understand the results, it is important to be familiar with the participants, so we first present a summary of each participant's identity. It is followed by a more in depth look at each belief and the cycles that resulted.

4.1 Participant Identity Summary

The participant selected with a very strong engineering identity was Bob, a white man who described himself as lower-middle class. He had a high interest in engineering and positive performance, competence, and self-recognition when it came to his math, science, and engineering courses. When asked if he feels like he belongs in engineering during the spring interview he said, "I'm going through the thing that engineers go through, and I think I'm doing well. And so, I do think I'm on track to becoming an engineer." He expressed positive beliefs regarding his self-efficacy and recognized himself within the engineering social sphere of his university. He also had a positive global affect towards math, science, and engineering. Bob has a "fascination with machines and making things," enjoys "fixing things, solving problems, [and] helping people," and seems to be enjoying his coursework.

Emily was selected as a student with a weak engineering identity by the end of the first year; she is a Hispanic woman student athlete who described herself as middle class. By the end of the year, Emily had one of the weakest engineering identities. During the fall semester interview, she seemed to be enjoying engineering saying "It's been very, very good since I've entered it. And my college career has been very interesting and I've enjoyed every course that I've taken." However, over the course of the spring semester she experienced a shift in global affect: "I was really not enjoying myself in 80% of the courses, 75% of the courses. […] So if I didn't thoroughly, not even enjoy them, but even maybe just tolerate them a little bit more, that I would feel a little bit more confident in them." She was not enjoying her engineering classes except for her design course, and was not performing as well as she would have liked to. By the end of the spring semester, she did not recognize herself as an engineer and had a plan to switch to a different major, explaining that "I don't think I can go through courses barely passing because I don't feel like I gain, like, I just don't think I'm taking the best out of it." The more she did not enjoy her classes the less she felt like an engineer causing her to dread her classes even more, and she described "drifting" away from her peers who were continuing in engineering.

Projector Man was the final participant chosen, and described himself as a middle-class white male at the time of consent (in a later interview, the participant said that they were fine with any pronouns, but we use "he" in this paper as it reflects the period being analyzed). His engineering identity was neither overtly weak nor strong. Projector Man was chosen as a representative of a medium-strength engineering identity because he described characteristics pointing towards both strong and weak engineering identity factors. He had high self-recognition and high interest in engineering. However, he had some negative recognition from others and also had low performance: during the spring semester, he withdrew from Physics II and was failing Calculus II. When asked if he felt like he belonged in engineering, he responded, "There are a couple of people in my major who I'm not so friendly with, who have at points told me that I don't belong. And I have responded to them back with, 'I'm here.' Even if I don't belong, I have the perspective of, 'I'm going to be here no matter what.'" He knows that his performance is not what other people expect. He focuses more on the communication aspect of engineering. This quote also shows his strong interest in engineering. He separated his performance and competence in a unique way and believed that he had a positive competence. "Generally, I'm happy with my understanding of the content and when I'm speaking to my professor, I understand it well. It's just that I'm not able to express that understanding well on exams."

4.2 Beliefs About Challenges and Assistance in Engineering

The cycle that we observed being described by participants arose in the way that they handled the challenges they faced. Participants typically believed that they could overcome challenges but their strategies differed. The effects of the beliefs are summarized in Figure 1.

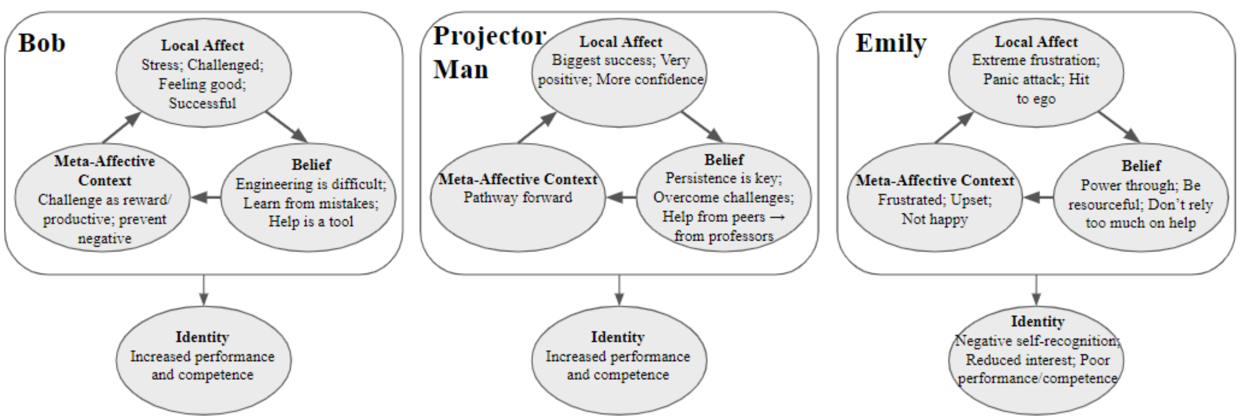

Figure 1: Challenges and assistance belief cycle for Bob, Projector Man, and Emily

Bob believes that engineering is supposed to be challenging. "Everyone has told me that this particular pathway [engineering] is really difficult." This belief establishes a meta-affective context where a difficult problem is interpreted as "challenging and rewarding," which is productive to learning. When talking to others he says, "I tell them it's challenging, obviously. Engineering is a very challenging subject, but I also very much enjoy it." The challenge does not get in the way of his enjoyment, instead it sustains and stabilizes his belief in his ability to overcome challenges. When asked if he believed he could typically overcome challenges in his Fall interview, Bob replied:

> I think I can. I do make a lot of mistakes, but I always learn from them and improve, and definitely there are some things I probably could have done better initially this semester, but I learned through my mistakes and overcame these challenges, and I think I could do it again.

He believes that the challenges are something that he can learn from, so bad performance does not mean the end of the world. This cycle influences Bob's engineering identity by directly improving his performance and competence. During the spring semester interview Bob expressed that, "I honestly feel like in a lot of cases just stressing about it, just being like, 'This is weird. This is crazy. Oh my God.' It's just not helpful." He is better at regulating his negative emotions allowing them to not influence his performance and competence.

When he was worried about the challenges of his courses he would seek out help from others. The belief that reaching out to others is okay establishes a meta-affective context that reduces stress when he encounters a challenge. When describing his emotions while solving a challenging problem in his fall semester physics class Bob says, "Most of the time I would go to office hours." This was a class that Bob found very challenging. He says, "It seems like that was probably the hardest class for most engineering majors this semester. But it all worked out. I would often go to office hours and learning lab and also peer tutoring in the library, and I got the help I needed." Physics was not the only class he sought out help in. During the spring semester, Bob also sought out help from the peer tutor for his statics class.

> Bob: And so, I guess emotionally talking, about before I went and got help and stuff for questions, I just felt like, "I don't get this. I'm worried, I'm going to go get some help with it." And I did.
>
> Interviewer: So, if you felt worried, you knew that there were people to go to for help?
>
> Bob: Yeah. And that feels really good.

The meta-affective context that he could rely on others counteracted the negative emotions like worry and supported more positive affect. The affective pathways serve to better establish the beliefs and meta-affective contexts. "I think with the help of others, I can definitely succeed and make it through these challenges."

Bob's beliefs that engineering is challenging but that he can overcome challenges by making use of resources (people) when needed established productive meta-affect and mitigated negative local affect in ways that strengthened his engineering identity, improving his performance and competence. Bob came to believe that he had a better understanding of the content and in turn performed better. This generalized to all of his classes during both semesters. Approaching others for help was one of his first responses to a challenge which also allowed him to establish connections with his peers and professors that he otherwise would not have.

When Projector Man was asked if he believed he could overcome challenges during the fall semester his response was, “Almost always, I have the perspective of if the thing that I don't try doesn't work, I'm going to try something else.” However, he did not hold this belief for one class: “I feel like the only class that I felt that I could not overcome a challenge was oftentimes calculus because there were some things that we weren't taught that I would have to go in and find on my own.” During the spring semester, he was “incredibly confident” in overcoming engineering challenges, “resigned” to solving difficult physics problems by doing them “the hard way,” and “significantly less confident” in overcoming math challenges. For Projector Man, feedback from his professors altered his meta-affect. “I think the feedback that helps me the most is feedback that gives me a path forward or feedback that tells me that there is a path forward. [...] having that path forward knowing, ‘Okay, it's uncomfortable now, but the more you solve, the better you'll get.’” The knowledge that there was a way forward provided a meta-affective context that shaped the discomfort generated by the challenges he faced, giving him the ability to push through struggles and follow the path forward. When asked what caused the strongest positive emotions in his classes during the spring, he said, “Whenever I was given a path forward, and I followed it and I saw results. [...] And, for me, in the case of [Statics], my exam grades went up 30 points throughout the semester on average.” The positive emotions he feels upon completion of a challenge and seeing the results of his persistence stabilize his belief that he can overcome challenges. His performance significantly increased causing his identity to strengthen. Since the increase in performance was in a class that was directly related to engineering, it gave him even more reason to identify as an engineer. In his Calculus class, where he felt that the feedback was “not helpful,” the opposite occurred, causing his strongest negative emotions of the semester.

One way Projector Man received feedback was by going to professors. During the fall semester, he expressed that he would rather try to work through a challenge first and then get help if he was still struggling. “I would often have to reach out to classmates or my professor and be like, ‘Can you explain this to me? Because I did not understand this.’ And that [asking the professor] is something that I do not think that I did enough, that I feel like I relied too heavily on my classmates.” Getting help, especially from professors, was not his first choice, but it was something that he wanted to start doing more after the fall semester. During the spring semester, he said he started “speaking to all my professors whose classes I might be doing subpar in.” When he did go to office hours he found it helpful, stating in his spring interview that, “I struggled with immensely with my personal [Statics] exam, but once I realized how bad I did, I began working with [the instructor]. And at the very end of the semester, I felt significantly more confident on my exams.” The original meta-affective context surrounding getting help was fairly neutral but as his grades worsened he sought out more help. The confidence built from going to his professors’ office hours created a more positive meta-affective context where he felt more comfortable and confident. This stabilized his belief in getting help from professors.

Projector Man's consistent belief that he could overcome challenges in his physics and engineering classes allowed him to persist through struggle, although he struggled more with both the content and his confidence in solving challenging math problems. His meta-affect in various classes was shaped in part by the type of feedback he received on assignments. As he progressed through his coursework, his belief in the value of getting help at office hours was strengthened: after talking to his professors he had felt more confident suggesting that he felt like he understood the material better. With this he saw an increase in his performance and competence, making him feel more like an engineer.

Emily experienced a change in beliefs concerning overcoming challenges in engineering and seeking help. During the fall semester, when asked if she believed that she can typically overcome challenges, she responded, "Yes. I think so. Especially whenever I do take that time to reconvene or I look through outward sources like a TA or I'll email a teacher or even I'll go to my peers. So, if I can't, I've been very resourceful in finding ways to get the problem done or to find a solution." Based on this we know that she does reach out for help but she prefers alternative methods first, such as taking "a small break." Overall, though, she believes that when dealing with the negative emotions associated with problem-solving, "It's a power through type of thing. You just got to get it done" By the spring semester her belief in her ability to overcome challenges had changed; in response to the same question she said, "Maybe for the most part of the semester, I felt like I could overcome this challenge. And then once I realized that I wasn't very happy always having to be so extremely frustrated, that's where I think my mindset changed." Her strategy of pushing through negative emotions was no longer effective for her. It sustained her feelings of resignation, frustration, and distress until her ultimate decision to stop pursuing engineering.

> So in the moment of me switching majors, I did suffer the repercussions of pushing things away. [...] So I had a major panic attack and then that day, I was like, we're switching. [...] So that was my bad repercussion. I don't think this past semester I had a lot of time to breathe. It really was seeing an end goal, just getting out of it.

A contributing factor in this shift was her belief about seeking help from others. Her views on reaching out for help changed during the spring semester. In the fall, she had expressed comfort with asking others for help since she felt she overall had the ability to succeed, but during the spring she began to believe that reaching for help, especially from professors, was not good. When asked what experiences in her spring semester courses had caused the strongest negative emotions, she replied, "Going through physics two and then when I failed the first exam, I was having to accept the fact that I have to go in for major tutoring and I have to go in for major office hours. That was, I think a big one for me, that hit to my ego." Her beliefs concerning getting help were more negative when she needed more aid, establishing a negative-meta affective context where she felt like she needed too much help. The meta-affective context sustained negative affect, such as the "hit to [her] ego".

This cycle weakened her engineering identity. Emily started the fall semester with positive relationships and attitudes towards math, engineering, and science which established the belief that she could overcome the challenges she faced. However as she faced more challenges her meta-affective context was twisted. Sustained negative local affect altered her belief in her own ability to overcome challenges. When she did reach out for help, she viewed her own competence and performance as more negative. These changes resulted in her no longer recognizing herself as an engineer. When asked if she saw herself as an engineer she said, "No. No. No, I don't. I think parts of me still enjoy doing very creative things that involve aspects of engineering." Despite this, she lost interest in math, science, and engineering as a career, saying that engineering was "not my cup of tea." She said, "I think I dreaded going on to the next course" in regards to her relationship with science. When asked about her relationship with engineering she said, "when I started to get into the real nitty gritty of a lot of it, I realized that it wasn't for me."

4.3 Beliefs About Performance & Competence

The three participants all described beliefs related to how they viewed their performance, competence, and intelligence. These patterns are summarized in Figure 2.

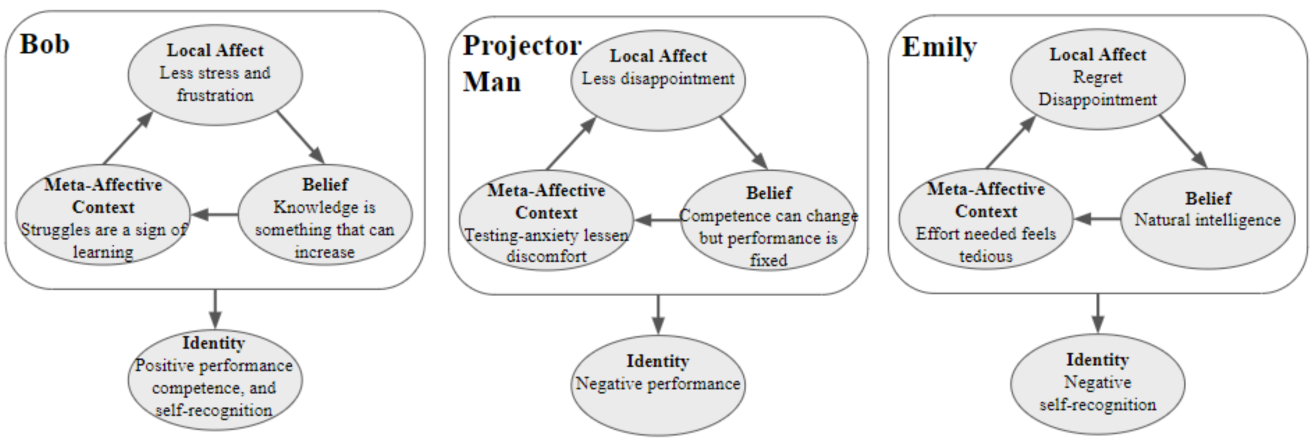

Figure 2: Performance belief cycle for Bob, Projector Man, and Emily

Bob believes that if he works hard enough he will do well, and that knowledge is something you work on to increase over time. His biggest success in the fall was "Academically, physics. At the beginning of the semester, I barely got a C on my first exam. And then at the end, my final midterm, I got an A." He put in a lot of effort into improving his grade because he did not believe the first exam reflected the best he could do, which established the meta-affective context where struggling and working hard was interpreted as more positive. The meta-affective context was sustained by his achievement and the feeling of success that it produced, reinforcing the belief that intelligence as measured by understanding the material could grow and change. This meta-affective context combined with his past experiences created a stable cycle centered on his beliefs concerning growth of knowledge. An example of this can be seen when Bob describes his relationship with math in his fall semester interview. He says:

> I have not had significant challenges with math. I've always seemed to be able to do it just fine. It doesn't really stress me out that much. But I do really try hard to understand something when I don't understand it. For example, right before my final in calculus, I didn't completely understand u-substitution. And so I did a lot of work trying to understand that, when I figured it out. So it all worked out.

Because he believes that continuing to work through something develops understanding Bob doesn't get as frustrated or stressed when challenged. He develops a better understanding which allows him to perform better on assessments. This all serves to stabilize his original belief. Bob's understanding of knowledge as something that changes over time and through hard work encourages him to work through his struggles and gives him the ability to persist though what would be stress and frustration. His positive performance and competence let him acknowledge himself as a person who is good at math, science, and engineering.

Like Bob, Projector Man also believes that intelligence grows with time and work, but implies that competence can be changed while performance is more fixed or difficult to alter. In the spring he says,

> I personally struggle immensely with exams to the point to where in calculus, I had my professor asking me why I was failing so bad when in his office hours, I was able to do problems incredibly quickly. Exams have always been a massive struggle for me, and I have incredible testing anxiety.

He has the belief that his poor performance is due to testing anxiety. This excuses his poor performance and creates a meta-affective context that lessens the discomfort it causes. This belief allows him to see his performance on tests as distinct from his problem solving abilities, since "generally, I'm happy with my understanding of the content and [when] I'm speaking to my professor, I understand it well." This sustains his ability to see his competence in the face of poor performance.

Emily's view of intelligence provides a sharp contrast to Bob. When asked to describe an engineer during the spring interview after she has decided to switch majors, she replies:

> I think it's someone that is a problem solver in anything that has to do with math or in the culmination of math, science, math and sciences and maybe engineering courses [...] And then they can be very creative people. And I think that a lot of it is a lot of natural intelligence, it takes a lot of tedious effort and it's a very meticulous curriculum.

This shows she believes intelligence is natural and a person either has it or they don't, creating a meta-affective context that mitigates the negative feelings associated with her poor performance that were described in the previous belief cycle. Instead of strong negative feelings, it feels tedious to her. This also causes her to lose self-recognition as an engineer. She places more value on natural capacity for engineering, which is something she does not believe she has:

> Engineering as a whole, I think I was really, the idea of it, I was excited for, and then when the actual practical things started to come up, maybe on the other side of it, maybe a little bit, how do I say it? I respect those that do it, I just know it's not my cup of tea type of thing. I do know that it takes a lot of work and I think that there are people that are meant for it. I'm just not one of them. It takes a special bunch to get through that.

The idea that she is not meant for engineering is reinforced by the negative local affect that she feels when she does not perform up to her expectations or when she has to go to office hours, as described in the last section. She was attached to a certain idea that she had of what engineering was but her experiences did not match the idea. She feels a certain level of regret and disappointment in her actual experiences with engineering causing her to lose interest.

5 Discussion

After an in depth analysis of Bob, Emily, and Projector Man's transcripts there is evidence to support the belief, meta-affective context, and local affect cycle proposed by Goldin [12]. All three students described beliefs that established meta-affective contexts which in turn stabilized local affect. The local affect then further reinforced beliefs and created a stable pathway. We found these patterns for beliefs about overcoming challenges and asking for help as well as beliefs about performance. Slight shifts in beliefs were associated with great differences in pathways. Even when Projector Man and Bob shared similar beliefs they had very different meta-affective contexts allowing them to regulate their local affective states. Emily's beliefs also created meta-affective contexts that allowed her to regulate her emotions, although not in a way that was productive to her continued interest in engineering. From the data, we see that constructive beliefs concerning getting help and overcoming challenges and belief in changeable performance and competence are more productive for stronger identity formation. Here, we see links to prior work on growth and fixed mindset [15], [16].

Not only do these findings support Goldin's previous work [12] with concrete examples, but they also allow for it to be connected to engineering identity formation. For these three students, the relationship between belief, meta-affect, and local affect have major implications on their engineering identity. In the cases of Bob and Projector Man, their belief cycles strengthened their identity. Belief in positive results that come from challenges for Bob and Projector Man justified the struggle so they were more motivated to push through and had increased positive performance or competence. For Emily, the cycle resulted in resigned acceptance of challenges, weakening her self-recognition. The belief cycles concerning asking for help strengthened competence and performance for Bob and Projector Man but even further weakened Emily's self-recognition. One possible reason for this was that Emily reported coming from a cultural background in a "conservative [...] predominantly Hispanic" community where there was a "stigma" surrounding mental health and getting any outside help. Even when starting with the same belief the results of the cycle were different. Bob and Projector Man both believed that knowledge could be changed through work; however, this belief affected Bob's performance and competence but only Projector Man's competence. For Emily, her belief cycles weakened her identity to the point that she no longer identified herself as an engineer. The direction of identity development is highly dependent on the belief that students hold and their environment.

6 Conclusion

Through this work, we have demonstrated that the beliefs students come into class with have an impact on the formation of their engineering identities through their interactions with emotions and meta-affect. To our knowledge, this is the first work to examine the role of meta-affect in the development of engineering identity. While our comparative case study methodology has allowed us deep insight into these students' experiences, future studies could look at larger sample sizes with more variability in participants.

Our findings suggest that it is important for professors to understand how beliefs influence students' affective states and identities. With a deeper understanding, professors can help students change or develop beliefs that sustain meta-affective contexts that are productive to learning and feeling like an engineer and support the development of engineering identity. An example of this is when professors support constructive beliefs in getting help, making it easy and encouraging students to do so. These methods would create a constructive meta-affective context that supports the belief that getting help is a positive thing, enabling them to get recognition from others and potentially improving performance and competence. Another example of this is when a professor believes in a student's ability to overcome a challenge and encourages the student to express the same belief. The professor's belief and support acts as recognition of the student but also helps them develop more constructive meta-affective contexts when they succeed. This belief from the professor increases recognition from others and can also increase the performance, competence, and self-recognition of the student. Strengthening students' engineering identities may increase the likelihood of students staying in engineering programs.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 2204726. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] J. A. Henderson, B. L. McGowan, J. Wawire, L. S. S. Benjamin, K. L. Schaefer, and J. D. Alarcón, "Photovoice: Visualizing the engineering identity experiences of sophomore students," *J. Eng. Educ.*, vol. 112, no. 4, pp. 1145–1166, Oct. 2023, doi: 10.1002/jee.20555.

[2] D. T. Flynn, "STEM Field Persistence: The Impact of Engagement on Postsecondary STEM Persistence for Underrepresented Minority Students," *J. Educ. Issues*, vol. 2, no. 1, p. 185, May 2016, doi: 10.5296/jei.v2i1.9245.

[3] M. W. Ohland, S. D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra, and R. A. Layton, "Persistence, Engagement, and Migration in Engineering Programs," *J. Eng. Educ.*, vol. 97, no. 3, pp. 259–278, Jul. 2008, doi: 10.1002/j.2168-9830.2008.tb00978.x.

[4] A. Godwin, "The Development of a Measure of Engineering Identity," in *2016 ASEE Annual Conference & Exposition Proceedings*, New Orleans, Louisiana: ASEE Conferences, Jun. 2016, p. 26122. doi: 10.18260/p.26122.

[5] Z. Hazari, G. Sonnert, P. M. Sadler, and M.-C. Shanahan, "Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study," *J. Res. Sci. Teach.*, pp. 978–1003, 2010, doi: 10.1002/tea.20363.

[6] H. B. Carlone and A. Johnson, "Understanding the science experiences of successful women of color: Science identity as an analytic lens," *J. Res. Sci. Teach.*, vol. 44, no. 8, pp. 1187–1218, Oct. 2007, doi: 10.1002/tea.20237.

[7] J. Radoff, L. Z. Jaber, and D. Hammer, "'It's Scary but It's Also Exciting': Evidence of Meta-Affective Learning in Science," *Cogn. Instr.*, vol. 37, no. 1, pp. 73–92, Jan. 2019, doi: 10.1080/07370008.2018.1539737.

[8] N. Kellam, K. Gerow, G. Wilson, J. Walther, and J. Cruz, "Exploring emotional trajectories of engineering students: A Narrative Research Approach," *Int. J. Eng. Educ.*, vol. 34, no. 6, pp. 1–15, 2018.

[9] J. Lönngren, T. Adawi, and M. Berge, "'I don't want to be influenced by emotions'—Engineering students' emotional positioning in discussions about wicked sustainability problems," in *2020 IEEE Frontiers in Education Conference (FIE)*, Uppsala, Sweden: IEEE, Oct. 2020, pp. 1–5. doi: 10.1109/FIE44824.2020.9273946.

[10] V. A. DeBellis and G. A. Goldin, "Affect and Meta-Affect in Mathematical Problem Solving: a Representational Perspective," *Educ. Stud. Math.*, vol. 63, no. 2, pp. 131–147, Oct. 2006, doi: 10.1007/s10649-006-9026-4.

[11] A. Godwin and A. Kirn, "Identity-based motivation: Connections between first-year students' engineering role identities and future-time perspectives," *J. Eng. Educ.*, vol. 109, no. 3, pp. 362–383, Jul. 2020, doi: 10.1002/jee.20324.

[12] G. A. Goldin, "Affect, Meta-Affect, and Mathematical Belief Structures," in *Beliefs: A Hidden Variable in Mathematics Education?*, vol. 31, G. C. Leder, E. Pehkonen, and G. Törner, Eds., in Mathematics Education Library, vol. 31. , Dordrecht: Kluwer Academic Publishers, 2002, pp. 59–72. doi: 10.1007/0-306-47958-3_4.

[13] J. R. Morelock, "A systematic literature review of engineering identity: definitions, factors, and interventions affecting development, and means of measurement," *Eur. J. Eng. Educ.*, vol. 42, no. 6, pp. 1240–1262, Nov. 2017, doi: 10.1080/03043797.2017.1287664.

[14] J. Huff and M. Ross, "Advancing an Integrative Perspective of Identity in Engineering Education," in *International handbook of engineering education research*, A. Johri, Ed., New York, NY: Routledge/Taylor & Francis Group, 2023, pp. 183–198.

[15] J. L. Burnette *et al.*, "A systematic review and meta-analysis of growth mindset interventions: For whom, how, and why might such interventions work?," *Psychol. Bull.*, vol. 149, no. 3–4, pp. 174–205, Mar. 2023, doi: 10.1037/bul0000368.

[16] D. S. Yeager *et al.*, "A national experiment reveals where a growth mindset improves achievement," *Nature*, vol. 573, no. 7774, pp. 364–369, Sep. 2019, doi: 10.1038/s41586-019-1466-y.