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Self-Efficacy Development in Students in a Declared Engineering Matriculation Structure

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Self-Efficacy Development in a Declared First-Year Engineering Matriculation Structure

Introduction

Prior research has shown that students' self-efficacy is key in retention, particularly as it pertains to engineering. These previous works have explored self-efficacy in engineering students at various stages in the engineering curriculum, including the first year. However, since much of the previous work on competence beliefs broadly and specifically self-efficacy in first-year engineering has been conducted with students in general engineering (GE) matriculation structures [1]–[3], this paper is an exploratory qualitative study of how students in a declared engineering (DE) matriculation structure describe their self-efficacy development. Some engineering programs directly admit students into a specific sub-discipline of engineering. Others admit students as general engineering majors and offer generalized first-year programs that include all engineering majors together [4]. These students will be referred to as declared engineering (DE) students and general engineering (GE) students respectively.

While not a direct comparison to previous work with GE students, this exploratory study provided initial insights regarding the extent to which the experiences of DE students correspond to findings from previous work with GE students, in particular a study conducted by Hutchison-Green et al. [2] Using data collected from the NSF funded project "A Mixed-Methods Study of the Effects of First-Year Project Pedagogies on the Retention and Career Plans of Women in Engineering," [5], [6] this secondary analysis of data was conducted to answer the research question, *How do engineering students from a declared first-year matriculation structure develop engineering self-efficacy,* through first-level and pattern coding methods [7].

Perceptions of self-efficacy are formed by four sources: mastery experience, vicarious experience, social persuasions, and somatic and emotional state [8]. The most influential of these sources is *mastery experience* – the ideology that practice can make perfect and increase self-efficacy in attempting similar tasks at higher difficultly. *Vicarious experiences* influence self-efficacy when one has little to no experience in completing a desired task, but develops an increased belief in their ability to be successful through observing and/or modeling someone they can relate to completing the task [9]. *Social persuasions* influence self-efficacy through thoughtful praise or judgment from others towards a person's ability to complete a task. Lastly, self-efficacy is influenced by the *somatic and emotional state* a person is in while completing a task – if a person experiences increased levels of stress, anxiety, or physical pain while completing a task, their self-efficacy is more likely to be lower than someone who feels energized by their performance. Studies exploring self-efficacy in engineering have typically employed a quantitative methodology [3], [10]–[12]. While these studies are useful for understanding self-efficacy development in the first year broadly in the context of the general engineering matriculation structure, they did not take into account the specifics of the matriculation structure or, more importantly, how these learning experiences might be different if students were in a declared rather than general matriculation structure. We expected this impact to vary because research shows that belonging, identification, and self-efficacy are all affected by learning experiences, and in turn affect choice of major and retention discussions [13]–[16]. These learning experiences may also differ based on matriculation structure due to the different foci of those structures; DE structures typically focus on a specific discipline whereas GE structures focus on engineering broadly [17]. Given that 70% of ABET accredited institutions have declared first-year engineering matriculation structures [4], this study specifically aims to understand how self-efficacy is developed in students in the DE matriculation structure in comparison to previous works focusing on student in the GE matriculation structure.

This study was limited by the analysis of secondary data. The supra analysis that was conducted is an analysis in which the "aims and focus of the secondary study transcend those of the original research." [18]. The purpose of the original study was to explore the impact of project-based learning on the motivation of first-year students. The study considered several motivation constructs, including expectancy which is empirically indistinguishable from self-efficacy when measured with a validated survey instrument [9], [19], [20]. Nonetheless, participants did provide sufficient detail about their program experiences and perceptions in order to create and apply a detailed codebook of nuanced self-efficacy development codes.

Experimental Methods

An exploratory secondary analysis of interview data from a DE matriculation structure was employed for this study. The data were originally collected to explore student motivation with respect to problem-based learning (PBL), using expectancy-value theory as a guiding framework. Although the original study used expectancy-value theory, it is important to note that in practice, expectancy and self-efficacy are similar enough to be empirically indistinguishable [9], [19], [20]. Both self-efficacy and outcome expectations "stress the role of personal expectations as a cognitive motivator" [9]. The measurement of expectancy typically includes the individuals' beliefs about their own ability in addition to their comparative sense of competence (i.e. their competence beliefs compared to others), whereas self-efficacy focuses more on the individuals' beliefs of their ability with an emphasis placed on the ability to accomplish a task [19]. Additionally, expectancy is the judgement of an outcome an individual expects to receive when completing a task whereas self-efficacy is the belief or confidence in one's ability to do a task. These subtle, yet important nuances are examples of motivational theorists' inability to agree on how to conceptualize perceived competence; thus, several similar constructs, such as self-efficacy and expectancy, exist in the literature [9]. Both are broadly considered types of competence beliefs and Eccles classifies self-efficacy as an expectancy theory [19].

Given that prior research has explored self-efficacy in a single GE matriculation structure [2], this study provided an exploratory analysis of how students in a DE matriculation structure in a declared engineering course developed course self-efficacy in their first-year. However, engineering self-efficacy also emerged during the analysis as closely intertwined with course self-efficacy in this context.

Research Site

For this study, data were collected at a large public university [21] with a DE matriculation structure. The program explored in this study included an introductory engineering course offered in the Spring semester of students' first year, with the three major content topics: 1) build research skills; 2) design and conduct an experiment and analyze the data; 3) mathematically model a phenomenon [22]. At the time of data collection, the undergraduate population at this university was about 10,000 with more than half enrolled in the College of Engineering. This particular first-year program in this study included approximately 200 students. This university is located in an urban setting with a high racial diversity [5].

Data Collection

Data were collected via interviews at the end of the first-year engineering course, which was also the end of the first-year for participants, a year later at the end of the second year, and finally at the end of the third year for the same students. Both male and female students were interviewed for this study. Interviews from the first and second year were used for analysis in this paper. Year 3 interviews were not included in order to more narrowly focus on the immediate impact the first-year engineering matriculation structure had on participants' self-efficacy development. Individual, semi-structured interviews were designed to address a range of motivation constructs and lasted about 30-60 minutes. The interviews were guided by a list of questions but enabled the interviewers the freedom to follow-up on participants' responses as necessary [5].

Data Analysis

Modeling the deductive, qualitative data analysis done by [2], data were analyzed using first-level and pattern coding methods developed by [7]. Data used were from transcripts already cleaned. First-level coding was used for summarizing segments of data based on Bandura's four sources of self-efficacy [8]. An "other" code [2] was used as a fifth code for data that fell out of the scope of Bandura's theory. This round of coding was informed by a codebook developed specifically for coding self-efficacy. The preliminary codebook is presented in Appendix A.

Once first-level coding was completed, pattern coding was conducted to identify themes to describe different ways each source of self-efficacy was experienced by the participants and how the first-year engineering matriculation structure impacted that development. Each code was expanded to encapsulate the nuanced ways participants developed self-efficacy within the major categories of mastery, vicarious, social persuasions, and somatic and emotional state. The evolved codebook is presented in Appendix B. The results describe these codes in detail using illustrative quotations from the interviews.

Results and Discussion

The goal of this study was to compare prior studies of self-efficacy in a GE context, in particular to Hutchison-Green's study. In the second round of coding, excepts from interviews were examined more thoroughly in order to determine emergent codes from the data. As identified in Appendix B, each of the five original codes from Appendix A has been expanded to include emergent codes and their definitions from the data representative of the respective category. The following sections discuss in detail each of the codes that emerged from analysis.

The Tasks of Self-Efficacy

While the initial goal was to study participants' self-efficacy with respect to their DE FYE course broadly, in the interviews, the task changed depending on the context participants were describing.

These tasks have been reported as the foci of self-efficacy development, with the context being the dimension of self-efficacy development the participants were discussing. Students related various tasks to engineering because they took place within their FYE DE course. While data were initially coded for course self-efficacy, subsequent analysis of the coded segments revealed that course self-efficacy and engineering self-efficacy intersected as students reported a positive engineering self-efficacy due to their positive course self-efficacy (which in this context is an engineering course). An example of this intersection was reported by one participant who explained what qualities an engineer should have, how they developed those qualities in their DE FYE course, and how those qualities were applicable beyond their DE FYE course:

> *Well, according to what I've seen from, f[major] engineering, a good practicing engineer is, , okay on a team. He can – he or she can work well with a team and doesn't necessarily have to be by themselves at all times to get their work done. , there is […] research-gathering – , information-gathering, how 'bout that? , where you know what to look for, what not to, and , all that good stuff. And I think, I think that's about it.*
>
> *Well, now that I've taken [DE course], I'm starting to refine some of the skills I mentioned for a good engineer – the research and the effective team, I guess, working in teams – so, , definitely not there completely yet, but hopefully with more of these types of classes I'll get to where the good engineer is supposed to be. [135_Interview_Lam_M4_2010]*

Participants in this study described positive course self-efficacy regarding skills learned in their DE course and how this positive development influenced positive engineering self-efficacy. This relation of tasks as reported by participants demonstrates the intersection of course self-efficacy and engineering self-efficacy when the course is in engineering. While skills such as teamwork are commonly associated as an engineering skill, other skills such as communication and research skills are not; yet, these were the skills commonly reported by students when reporting their course and engineering self-efficacy development. This finding adds to the existing literature regarding 1) how do we actually define engineering and 2) the lines of course self-efficacy and field self-efficacy are blurred when the course is in the field. Bandura [8], [23] states that there are instances where self-efficacy development can co-vary or can be interrelated when different spheres of activities are governed by similar sub-skills. According to Bandura, in this context, engineering self-efficacy and course self-efficacy can be distinct spheres of activities. However, because the sub-skills in each of these spheres are very similar and not distinguished independently by participants, the relationship between these two spheres change as depicted in Figure 1.

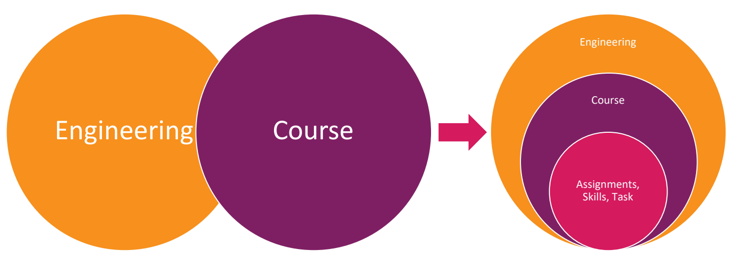

Figure 1. The overlapping relationship between the tasks of self-efficacy

Mastery Experiences

Students discussed their mastery experiences in terms of both the sources and the focus of the mastery experiences. There were four different sources of mastery experiences described: guided, figuring it out on their own, team development, and negative or failed experiences. Similarly, to the DE students in this study, GE students from previous studies such as Hutchison-Green et al.'s described sources of mastery to be help and teaming. The difference between the DE and GE students is that the DE students also reported developing mastery through figuring things out without the assistance of an instructor.

Examples of the sources of participant's mastery experiences are:

Guided Mastery

Students experienced mastery development with the support of a supervisor which, in this context, was often referred to as a facilitator. The term "Guided Mastery" was used to describe these experiences because most participants attributed their ability to understand and master the material due to the guidance or scaffolding provided by their facilitator.

> *He would basically support us in everything that we did. He'd ask us questions to kind of tickle our brains, to kind of think about— to think outside of the box. So he challenged us as well as supported us as well [935_Interview_Kahn_F1_Deidra_2011]*

These facilitators were not teachers in the sense of "here's a task, this is how to do said task, now you, student, should copy what I do." Instead, consistent with the literature on problem-based learning [22], [24], [25], most participants reported facilitators as guides through their experiences by asking probing questions, instructing students on how to verify their assumptions, and providing students with alternative measures to consider as relevant to the assignment.

Figuring It Out

Students experienced mastery development through independent trial and error without the assistance of a supervisor or superior.

> *So I think it's really interesting that you go into this like almost completely blind and you get this project and you're like, 'oh, my gosh, I'm never gonna be able to figure this out, what am I gonna do,' and then at the end, you're like, 'wait, hey, like I did something.' [135_Interview_Lam_F3_2010]*

Team Development

Students experience mastery development by working in teams in order to achieve a common goal. From these experiences, students learned that by working in teams, each member brought a particular strength that supported the success of the team as a whole.

Actually, it's good to make mistakes in your group because nobody's perfect. [I: Right.] Everyone needs to learn, so if you learn here, good maybe you will walk with them later, so that they will benefit from them. Yea, this is kind of something like if I speak loud I'll have my idea heard, maybe sometimes I no guarantee that everything I heard is good, maybe something ideas suck, but there's certain ideas that are good. So if they heard me, they say "wow this idea's good" maybe they can change, they can change the direction and walk the group way. So even though you make mistakes, but you're also bringing your ideas to the table, other people benefit. So it's not really a big deal to let everyone make mistakes. [1205_Interview_Sennett_M2_2010]

Many participants reported having positive teamwork interactions especially given that some students observed teams that faced challenges amongst team members and with their respective facilitators. Thus, while the participants for this study developed mastery through positive experiences, based on reports from these participants, a positive experience may not have been consistent in the course.

Negative or Failed Mastery Experiences

Students' mastery development was stalled due to poor performance on a task.

I would be very, discouraged and unmotivated by seeing, , that with your ridiculous amount of time and effort that I've put into the class and into helping the group out, just having a sixty appear in front of me or a fifty or something that's not reflective of the effort, put in, that would just be discouraging and I think it would probably make me try less, because if I know a hundred percent effort is gonna give me fifty percent of the grade, then I can scale it down, right? I can do less and get about the same. [135_Interview_Lam_M4_2010]

But, another found these negative experiences served as fuel to fire their desires to do better in the course:

And for someone to tell you, 'I feel like you didn't—you weren't really as—as on point with the situation as you should have been.' So now that kind of helps me to sit back and think outside of the box and analyze every problem that I'm faced with. [935_Interview_Kahn_F1_Deidra_2011]

There were very few instances where participants reported negative or failed mastery experiences; in fact, given the positive spin on one of these experiences shows that in this particular case, students rarely had negative experiences in this course.

Practical or Transferable Experiences

The focus of the mastery described by DE students included practical and transferable skills. These skills were identified more specifically with regard to communication, transferability to courses other than their DE course, conducting research, and applicability to the industry of their major. Similarly, GE students from other studies described the focus of their mastery with regard to technical and professional skills and computing. The difference between the GE and DE students is that GE students reported working assignments and problem-solving skills as a focus of mastery development, whereas GE students do not. These foci support how mastery is typically developed: gaining of knowledge, practice using the knowledge, and learning when to apply the knowledge [26].

An example of the foci of participant's practical or transferable experiences are:
External course related experiences: students developed mastery in their current first-year engineering course that they knew would be applicable to courses they would have to take in their future.

> *it all makes more sense that the way [DE course] kind of sets up students' minds to think this way. And then you have this pattern developed so when you go into your conservation principles classes, your biomechanics classes, it's kind of preset that you break down the problem this way. [935_Interview_Harper_M2_2011]*

Understanding how the DE course related to other courses outlined in the students' curriculum was a rare occurrence amongst participants. There were very few instances where students reported understanding how this course fits into the bigger picture of their degree program.

Technical or industry related experiences: students described their mastery development through the learning of skills that may be applicable to future career options.

> *I feel like it's less of a class and more like job training. It's more of, it's getting you into the real thing, showing you what the future of your job might be like, or will be like, and it just gives you more work-type experience more than just academic learning-type experience, just knowledge [1205_Interview_Kahn_M1_2010]*

Several participants reported mastery development through skills that were applicable beyond the immediate coursework.

Social Persuasions

Participants in this study described two types of social persuasions and that was through constructive support and criticism and discouragement. This study's DE students reported these types of persuasions with regard to the sources noted previously. Most positive persuasions reported were directly related to the DE course. Negative persuasions reported took place in the first year, but independently of their DE course. These types of social persuasions are similar to how GE students from previous studies describe social persuasions which they received verbally. The difference between the types of social persuasions in GE and DE students is that GE students also reported non-verbal persuasions and were mainly negative persuasions within their GE course.

The focus of the social persuasions described by GE students included frustrations with their GE course policies. As mentioned previously, GE students reported negative verbal and non-verbal persuasions with regard to their GE course indicating that course policies were "weed-out" in nature [27].

Constructive Support and Criticism

Participants in this study described three sources of social persuasions and that was from family, supervisors, and peers. Although most instances occurred during the first year, most familial influences were encouraging DE students to persist in engineering broadly. Sources of persuasions from instructors and peers typically occurred within the DE course and were generally positive. These positive affirmations may have positively influenced DE students' self-efficacy by also positively developing their sense of belonging in their engineering major, a construct that has emerged in previous studies exploring engineering self-efficacy [28]–[31]. There were also some instances where negative persuasions arose from peers of the participant. Sources of persuasions described by GE students were from the FYE course policies and mainly reported as negative persuasions. These policies were described as harsh with a goal to weed-out students, particularly as it pertained to grading.

Examples of the sources of constructive support and criticism participants received came from:

Supervisors: Participants expressed that facilitators were encouraging in their pursuit of a solution such as when one participant states:

> *He always congratulates us on our strengths and tells us how to improve in different areas. So he's good at what he does, essentially, being, he's a good facilitator [1205_Interview_Kahn_M2_2010].*

There were other instances where constructive criticism was provided that served as an impetus for the participant to reevaluate their approach to the problem:

> *the coaching thing, like if some person has weakness like what to do, it definitely has to use experience to say 'ok you have to do this and then you'll get better.' You have to make you feel confident, like maybe you feel like, oh maybe it will be ok, if you are really trying hard to do this, you really can do well [1205_Interview_Sennett_M2_2010].*

This code is different from "Guided Mastery" in that students discussed facilitators being encouraging and providing verbal encouragement regarding their competency whereas with "Guided Mastery" students discussed facilitators providing concrete assistance in a manner that enabled students to come to a solution or achieve mastery on their own.

Peers: these affirmations were received either in peer reviews or in conversations.

> *I'm fairly confident because of, , every so often we'll do, , peer reviews of our different classmates and I haven't, like I haven't, I haven't received many, like, negative comments. People are always like, I'm always on time, that I contribute significant enough, , in meetings and out of meetings, so I kind of, , judge by my peers and my instructors given me similar comments. I think I am succeeding in this course. [1205_Interview_Kahn_M2_2010]*

Persuasions from peers were always positive and were received by participants within their DE course or in conversations with other students about the DE course. This code is different from “Team Development” in that students discussed their competency being reinforced due to feedback from peers whereas in “Team Development” students discussed mastering the ability to work in a team on a project.

Family: these persuasions were either through intentional conversations, *“oh you should go into engineering because your grandfather was an engineer” [1205_Interview_Kahn_M2_2011],* or being in the same space as close family members in engineering fields:

> *Both of my parents are engineers, and they both work for big companies like [Company 1] and [Company 2], and, like, I grew up – I used to always go in with my mom to lab, and I’d, like, play around with the solder and, just, like, melt things and I just thought it was so cool, so. [305_Interview_Tostig_F2_2010].*

These forms of social persuasions align more with constructive support given the desire of familial persons wanting the best for the participant. One participant expressed this sentiment as:
I think I’m passionate about it, I think, like I said, I think it’s the end-goal that keeps me going, it’s like, “this is horrible right now” – ‘cause my dad went to [University], like I said, and he always is like, you know, “[Participant], I know it’s hard now, but I promise you, it’ll be worth it at the end.’ [935_Interview_Harper_F1_2010]

While this form of social persuasion was not directly tied to the DE course, given that the interviews took place in students’ first and second year of their engineering major does provide insight to how participants were supported in their engineering program outside of class.

Discouragement

Some of the dissuasion participants encountered occurred in broad contexts such as in a lecture where students were presented other majors as options to switch to should the decide to leave engineering. Other dissuasions came from direct conversations participants had with other people who would “bet you fifty bucks you’ll drop” out of engineering, as expressed by one participant:

> *People are like, “oh, you’re definitely gonna switch by the end, blah blah blah.” But people like saying stuff like that just makes me like wanna do it more. You know, like if someone like tells me I can’t do something, that makes me wanna do it like ten times more. [135_Interview_Lam_F3_2010]*

This participant also reported a conversation where someone mentioned their poor chances of getting hired due to their major:

> *a lot of people like criticize [major], they’re like, “what, you know, what are you gonna do with that, like nobody’s hiring that field,” but I mean, I feel like it’s definitely like a growing field, you know. [135_Interview_Lam_F3_2010]*

Several participants reported being discouraged by others to pursue engineering however, each participant that expressed having these negative conversations also expressed not being dissuaded from pursuing their particular field of engineering.

Vicarious Experiences

Participants in this study reported sources of vicarious experiences as peer examples. DE students reported instances where they were exposed to upperclassmen in their major or alumni of their degree program within their DE course. These instances were described positively impacting their self-efficacy and wanting to emulate those examples. While some of the instances reported took place outside of the FYE program, there were some instances, that were directly tied to the FYE program. One participant described this experience in their DE course as: *"But with more, with each, and each passing day , seeing more alums, seeing what they're doing. It's, gotten me pretty confident [1: Mhm.] that I, if I put my mind to it I can do a lot" [135_Interview_Lam_M4_2011]*. Peer examples were the most common form of vicarious experiences regarding students' self-efficacy development. This development is different from "Team Development" and social persuasions in that students do not discuss their learning in comparison to their peers or discuss their competence being validated by their peers, but rather identified how seeing other people succeed supported their own self-efficacy.

In contrast to the DE students, GE students reported vicarious experiences through performance comparisons with a focus on comparing themselves to their peers by speed, contribution to team, mastery developed relative to peers, and grades of peers. GE students reported their peers as a benchmark of their success, mainly in the first semester. Hutchison-Green et al. [2] reported that using peers as a benchmark in the first semester may be due to the timing at which the study was conducted and projects taking place in the FYE course had not come to fruition and that interviews conducted after the first semester showed that students recognized and reported more of their mastery development than vicarious experiences through performance comparisons.

Somatic and Emotional State Experiences

Evidence of DE students' somatic and emotional state were reported being comfortable in their learning environment or being afraid and uneasy. DE students described evidence of comfort in their FYE course as being in a space where they could learn from their mistakes and rely on their group to help bridge knowledge gaps. However, DE students also reported evidence as fear of performing poorly in their FYE course, particularly as it pertained to oral presentations. As a contrast, GE students in existing studies reported evidence of somatic and emotional state through enjoyment, interest, and satisfaction and satisfaction from success. This evidence provided by GE students were typically focused on increased interest and satisfaction from learning the FYE course material.

The focus of the somatic and emotional state experiences described by DE students were with regard to their enjoyment of their FYE course and their major. The experiences from the DE FYE course were reported by students as validations that they made the right choice regarding their engineering major. However, the focus of somatic and emotional state experiences described by GE students were with regard to their frustration with their FYE course policies. These results indicate that DE students generally had a positive learning environment supported by their peers and their instructors, whereas GE students did not. Marra et al. [28] states that difficult curricula combined with poor teaching are major factors influencing students to leave engineering. Conversely, an emphasis on demonstrating a level of care for students can have positive impacts on students persisting in engineering [1].

Examples of the somatic and emotional state experiences of participants are:

Comfort

Students described their somatic and emotional state as feeling comfortable in their learning environment. This feeling of comfort positively affected participants' self-efficacy by providing support in learning course materials.

> *Yes, really comfortable, lots of people there, they're really friendly. I really appreciate that. They could be just kind of, let me do certain things, they're not taking the whole thing otherwise I'd be left alone or some sort of that, they help me to speak up. This is the only, like speak out, speak loud about my idea, they really support me So, I really feel, I really enjoy this class. [1205_Interview_Sennett_M2_2010]*

This was the least common form of self-efficacy development through somatic and emotional state experiences as reported by participants.

Fear or Uneasiness

Students described their somatic and emotional state as feeling scared or nervous about completing engineering task which, subsequently had a negative impact on their self-efficacy development. It is important to note that these negative impacts were temporary for majority of participants as students described these experiences as getting a "slap in the face" before regrouping to move forward with the goal of being more successful on the next task. An example of this, as stated by one student:

> *And I mean, [DE course] was a sl— you know, a slap in the face for those who do think they're very talented. They don't have to do a lot of work to achieve things. Because for that class you had to work hard because otherwise you weren't going to succeed. [935_Interview_Kahn_M1_Frank_2011]*

Students reported having fear or uneasiness infrequently as a form of somatic and emotional state experiences.

Enjoyment

Students described their somatic and emotional state as enjoying and loving what they are doing in two contexts: 1) Course Related; and 2) Major or Career Related.

Course Related: Through the completion of tasks in the course, participants expressed enjoying learning new things, being academically challenged, and succeeding at tasks that once seemed difficult. One participant describes their enjoyment as:

> *before I wasn't very sure if I wanted to stay with [major]. , I was thinking about CS, maybe, too. But once I took this [DE] class, it showed me more of what the actual major is and what kind of job you would get afterwards, and it made me wanna stick with [major], actually, because I enjoyed working in groups and talking to people and working with people, so this class made me get an idea what [major] is. [1205_Interview_Kahn_M1_2010].*

Many participants discussed how they felt their enjoyment of the course material further reassured them that they were on the right path regarding their major and subsequent career.

Summary

The purpose of this manuscript was to conduct an exploratory secondary data analysis In answering the research question: *How do engineering students from a declared first-year matriculation structure develop engineering self-efficacy?* nuanced aspects of self-efficacy development emerged from data analysis outlined in Table 1.

Table 1. – Nuanced ways in which engineering students from a DE matriculation structure develop engineering self-efficacy

Bandura's Theory of Self-Efficacy Development	Emergent Aspects
Mastery experience	Figuring It Out
	Guided Mastery
	Negative or Failed Mastery Experiences
	Practical or Transferable Experiences
	Team Development
Social persuasions	Constructive Support and Criticism
	Discouragement
Vicarious experience	Peer Examples
Somatic and emotional state	Comfort
	Fear or Uneasiness
	Enjoyment

As outlined in Table 1 all four ways in which self-efficacy is developed were present in the data, but only some closely tied to the DE matriculation structure such as the mastery experiences, constructive support and criticism, and vicarious peer examples. The other sources, though they may have emerged during the first-year, were not linked directly to the DE FYE matriculation structure.

Implications and Future Work

From this study, we can conclude that there are some similarities in how the FYE matriculation structure impacts self-efficacy development in DE and GE students. This qualitative analysis of a DE FYE matriculation structure adds to existing literature of previous studies that have explored self-efficacy more broadly in engineering [29], [32]–[36] confirming that mastery experiences are still a common form of self-efficacy development in FYE students. Additionally, this study contributes to the current understanding of self-efficacy in DE students as a contrast to a GE matriculation structure [2], [3].

The impact this study may have on the engineering education community includes broadening a conversation typically dominated by quantitative studies, potentially uncovering better practices for first-year engineering programs and understanding how impactful the matriculation structure of the first-year can be on a student's major choice. As discussed in previously, there are various studies that use quantitative methods to explore self-efficacy but very few that use qualitative methods. Through the use of qualitative methods to explore this phenomenon, the results of this manuscript have provided more insight into the development of self-efficacy of first-year engineering students. An example of this insight comes from mastery experiences, which are still the most common way in which students report self-efficacy development. But, in addition to knowing that mastery experience is a common form of self-efficacy development, the results of this study show that there are three sources of this development (they figure it out independently, they get assistance, and learn through teamwork), students recognize this development (through trial and error), and students communicate their understanding of content material when the content is practical immediately (other courses) or in the future (career focus). This addition to existing literature will hopefully encourage FYE program directors to consider curriculum development along the axes outlined in Appendix B.

Lastly, given that the results have shown that there are little differences in how FYE matriculation structure impacts self-efficacy development indicates that self-efficacy may not be the appropriate lens to research the impact FYE matriculation structures have on the persistence of engineering students. It may also indicate that pedagogical choice may influence self-efficacy more than matriculation structure given the PBL structure of the course in this study and the fact that PBL has a positive link to self-efficacy development [37]. Because of the positive relationship between PBL pedagogy and self-efficacy development, it is difficult to differentiate the big influencer in these participants' self-efficacy since in this study, we compared a PBL DE course to a non-PBL GE course. Additionally, given the nature of this study (secondary analysis, different construct used for analysis relative to initial protocol), there may be differences that could emerge from the data if the study was originally designed to measure self-efficacy. With that said, further exploration of how self-efficacy is developed in DE students in comparison to GE students both within the same major, will be explored in future work.

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Appendix A: Preliminary Codebook for First-Year Student's Development of Self-Efficacy

Bandura's Theory of Self-Efficacy Development		
Code	Definition	Operational Definition
Mastery experience	The more successful one has been in mastering an event, the higher their self-efficacy is to attempt similar tasks at higher difficultly	Students describe experiences in which they succeeded or failed in an engineering context
Social persuasions	a person's self-efficacy through thoughtful praise or judgment from others towards a person's ability to complete a task	Students describe experiences in which feedback on their engineering related task was provided
Vicarious experience	a person's self-efficacy is influenced though observing and/or modeling someone they can relate to completing the task	Students describe experiences in which they modeled their actions after observing someone doing an engineering related task
Somatic and emotional state	If a person experiences increased levels of stress, anxiety, or physical pain while completing a task, their self-efficacy is more likely to be lower than someone who feels energized by their performance	Students describe experiences in which their mood was impacted while completing an engineering task
Other		Preliminary codes that fall out of the 4 methods of self-efficacy development

Appendix B: Evolved Codebook for First-Year Student's Development of Self-Efficacy

Mastery Experiences		Students describe experiences in which they succeeded or failed in an engineering context
Sources	Guided Mastery	Students develop mastery with the assistance of a supervisor (teacher, facilitator, etc.)
	Team Development	Students developed mastery through working in teams in order to achieve a common goal
	Figuring It Out	Students who developed mastery through independent (without supervisor assisted) trial and error
	Negative or Failed Mastery Experiences	Students' mastery development was stalled/halted due to poor performance on task
Focus: Practical or Transferable Experiences	Communication Related	Students developed mastery in communication skills either via public speaking w/ projects or communicating with group members
	External Course Related	Students developed mastery in DE that was applicable in future courses (reflective)
	Research Related	Students developed mastery in the form of research skills development
	Technical or Industry Related	Students developed mastery in the form of technical skills development that will be useful in industry
Social Persuasion		Students describe social interactions in which feedback on their engineering related task was provided
Sources	Constructive Support and Criticism	Feedback from supervisors and/or peers supported students' SE development
	Familial Influence	Students were encouraged to pursue engineering due to familial encouragement or familial employment as an engineer.
	Instructors, Facilitators, Supervisors	Students were encouraged to pursue engineering by instructors, facilitators, or job supervisors
	Peers	Students were encouraged to pursue engineering by peers.
	Discouragement	Students received negative feedback in relation to their SE development. Students generally took this feedback as fuel to do better rather than as a sign to quit.

Vicarious Experiences		Students describe experiences in which they modeled their actions after observing someone doing an engineering related task
Sources	Peer Examples	Students exposed to/following in the footsteps/confirmation in choice of engineering via peers
Somatic and Emotional State Experiences		Students describe experiences in which their mood was impacted while completing an engineering task
Emotion	Comfort	Students described feeling comfortable in their learning environment positively affecting their SE in being successful.
	Fear or Uneasiness	Students express being scared or nervous in completing engineering tasks in DE course negatively impacting their SE.
	Enjoyment - Course Related	Based on the definition of somatic experiences, experiencing joy while completing a task is a positive SE development and students here express how they love and enjoy what they are doing. This joy has been expressed through the completion of tasks in the course, validation that they made the right major/career choice, and/or how the validation of picking correctly will bring personal satisfaction. Focus of enjoyment is on the course
	Enjoyment - Major or Career Related	Focus of enjoyment is on the student's major choice