ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #37230

From knowing to doing: Changes in competency beliefs of developing engineers

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From knowing to doing: The varying competency beliefs of developing engineers

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1 Introduction

This research paper explores how undergraduate engineering students think about developing their engineering identities as influenced by their competency beliefs. Identity researchers encourage educators to include curricular practices that support students in seeing themselves as engineers [1]–[5]. Engineering role identity has been shown to influence learning, persistence, and motivation [6]–[8], highlighting the need for identity to be developed and maintained as part of an undergraduate engineering degree. How students think about their ability to understand and apply engineering practices has been shown to predict and support the development of these engineering identities [6], [9].

Wenger and colleagues illustrated that we "produce our identities through the practices we engage in [p. 164]" and that "identity is a form of competence [10, p. 153]" itself. Competency and performance have been conceptualized as constructs of engineering role identity. They have been well studied in engineering education [11]–[13] as they align with the content-centric approach of most engineering programs [13]–[16]. Despite the critical role competency plays in engineering identity development, most work considers these competency beliefs at one time point often, during the first year of an engineering program [6], [17]–[19].

This paper addresses the need for more time-oriented identity work [12], [19], [20] by taking a focused look at how students think about their own identity development needs and competency beliefs at various times in their program. The present study uses a phenomenologically informed perspective to consider how students perceive their development as engineers with respect to their educational experience. Phenomenology seeks to understand the essence of lived experiences with a phenomenon of interest [21]; here, the phenomenon of identity development is explored through participants' experiences as they make sense of their engineering identities in relation to their engineering competencies. The research question examined in this work is:

1) What do undergraduate engineering students perceive they need to further develop their identities as engineers?

We present four themes centered around students' self-described needs to see themselves as an engineer. These themes act as snapshots of different developmental needs in which students frame their needs around wanting to know or apply engineering in both domain-general and domain-specific contexts. We include one preliminary example of how these themes may emerge at different times during a student's first two years of an undergraduate engineering program.

2 Theoretical Framework

To explore how students perceive engineering identity development in relation to specific needs, we used engineering role identity and the construct of performance/competence. Engineering role identity considers how students take on the role of an engineer [15] by engaging in the practices of the discipline and through discourse [22], [23]. This paper views the ways students describe themselves and are positioned by others as an engineer as an ongoing, continuous process [10], [24] and favors a view of identity development through practices of identification [25], [26]. Practices of identification support an understanding of how students think of their engineering identity development by connecting it to tangible experiences or activities associated with the discipline of engineering.

In understanding how students take on the role of an engineer, the performance/competence, interest, and recognition framework [27] has been used in engineering education to support both qualitative and quantitative exploration [2], [28], [29]. Here we focus on performance/competence beliefs which include how well a student believes they can perform effectively in relevant practices and be competent in a particular domain [27], [30]. Cognitive, affective, and performance variables such as performance/competence have been considered a central element of engineering identity as they capture the ways students take on the roles and practices of an engineer [11], [15], [31]. Performance/competence is a significant predictor of an engineering role identity when mediated by the other role identity constructs [2], [3], [17], [32], making it both an initiator and gatekeeper to future identity development [13], [33]. We reconceptualize performance/competence as including students' beliefs regarding their ability to understand engineering concepts and their beliefs regarding applying their skills towards legitimately engaging in engineering practices [9], [34]. Engineering role identity and performance/competence connected through practices of identification were used to understand how students talked about the development of their own identities framed as specific competency-oriented needs.

3 Methods

This paper reports qualitative results from an ongoing NSF-funded mixed-methods study (NSF grant # EHR-1833738) that focuses on a cohort designed to support socioeconomically disadvantaged, academically talented engineering students [35]. This phenomenology-informed exploratory study utilized semi-structured focus groups to understand the participants' lived experiences regarding identity development and competency-oriented needs. The longitudinal nature of this study adds additional perspective to how participants' beliefs and needs vary as they navigated the first two years of their undergraduate engineering program. Directed content analysis was employed to support the exploration of the student's experiences and perceptions of the engineering development through the integration of a theoretical competency framework. A preliminary, individual narrative illustrates how a participant's needs differed as they gained new experiences and reevaluated their competencies.

3.1 Location and Participants

This study was conducted at a large, western land-grant, R1 university and focused on the lived experiences of two 16-student cohorts of undergraduate engineering students (32 students initial total). Participants voluntarily applied to the four-year scholarship-based cohort program before starting their first year and were selected based on financial need, academic ability, and letters of recommendation. All participants participated in a first-year general engineering course during their first semester before taking discipline-specific classes. Data collection for cohort 1 started in the Fall of 2019 and for cohort 2 in the Fall of 2020; for this study, cohort 1 had just finished their second year, and cohort 2 had just finished their first year. *Table 1* lists participants' pseudonyms, self-reported demographic information, and major at the time of the last interview. This sample's composition supports the transferability of the findings to similar populations enrolled in undergraduate engineering programs but cannot speak to the experiences of populations not included or identified.

Table 1: Participant pseudonyms, major, and self-reported demographic information (Major acronyms: BME = biomedical, CE = civil engineering, CHE = chemical engineering, CSE = computer science and engineering, EE = electrical engineering, ME = mechanical engineering, MSE = materials science and engineering, TBD = undeclared)

Cohort 1				**Cohort 2**			
Pseudonym	**Gender**	**Race/Ethnicity**	**Major**	**Pseudonym**	**Gender**	**Race/Ethnicity**	**Major**
Michael	Man	Hispanic	CE	Leslie	Woman	White	CHE
Jim	Man	White	ME	Ron	Man	White	CSE
Pam	Woman	White	ME	Jerry	Man	White	ME
Stanley	Man	White, Middle Eastern	ME	Donna	Woman	White, Chamorro (Guam)	TBD
Kevin	Man	Asian	CSE	Tom	Man	White, Asian	CSE
Oscar	Man	Asian	EE	Ann	Woman	Hispanic	CSE
Toby	Man	Hispanic	EE	April	Woman	White	BME
Kelly	Woman	White	MSE	Chris	Man	White	ME
Gabe	Man	White	CHE	Tammy	Woman	White	BME
Karen	Woman	Asian	CE	Ben	Man	White	EE
Andy	Man	Hispanic	BME	Diane	Woman, Genderqueer	White	BME
David	Man	Hispanic	ME	Mark	Man	White	CHE
Erin	Woman	White	CSE	Jeremy	Man	White	CSE
Darryl	Man	American Indian, White	ME	Craig	Man	Asian, Middle Eastern	CSE
Roy	Man	White	EE	Derek	Man	White	ME
Todd	Man	Hispanic, White	CSE	Sebastian	Man	Asian	CSE

3.2 Data Collection

To explore students' experience around changing competency beliefs, the study drew on phenomenology's focus on the essence of participants' experiences of a phenomenon as it happened [21], [36]–[39]. This focus and the constructivist paradigm of phenomenology supported the choice of qualitative methods centered on participants' individual perspectives of an experience and the shared, socially constructed elements of what it means to engage in engineering legitimately. Focus groups were utilized since they facilitated the sharing of group experiences essential to the larger study about cohort interactions and facilitated a shared understanding of their lived experiences around engineering identity and competency beliefs. In alignment with phenomenology and to best support the exploration of personal, contextual, and perception-based phenomena of identity development, a semi-structured approach was used when collecting data [40]. Focus groups consisted of four to five participants, lasted about one hour, and were conducted at the end of each semester. The first author led most focus groups, with the second or last author as a secondary interviewer and notetaker. At the end of each focus group, the first author compiled these notes, information on how the focus group went, and initial impressions of the data into summarized memos.

Initial data collection for cohort 1 started at the end of their first semester in the Fall of 2019. This study includes their first four semesters in their undergraduate engineering program and four focus groups: Fall of 2019 (semester 1), Spring of 2020 (semester 2), Fall of 2020 (semester 3), and Spring of 2021 (semester 4). Focus groups for semester 1 were held in person. The following three focus groups were held via an online video platform due to the switch to remote learning because of the COVID-19 pandemic. Initial data collection for cohort 2 started at the end of their first semester in the Fall of 2020. This study includes their first two semesters in their undergraduate engineering program and two focus groups: Fall of 2019 (semester 1) and Spring of 2020 (semester 2). Both focus groups were held virtually. All focus groups were audio and video recorded, professionally transcribed by Rev.com, and checked for errors before being uploaded to the coding software NVivo12 (QSR International).

Guiding questions prompted participants to reflect on their engineering identity and their performance/competence beliefs in the past, present, and future to best capture change over time. The guiding questions emerged from previous work that quantitatively explored students' engineering identity and performance/competence perceptions [34], [41]. Questions relevant to this study are presented in *Table 2*. The open-ended nature of the focus groups allowed for follow-up questions and permitted researchers to gather rich detail about participants' experiences. Follow-up questions often asked students to validate responses or describe changes from previous focus groups.

Table 2: Relevant focus group questions used for the collection of data used in this study

Focus Group Question	**Target Information**
Do you see yourself as an engineer?	Identity
What do you need in order to see yourself as an engineer?	Identity development
Are you confident in your ability to understand/apply engineering?	Performance/Competence

3.3 Data Analysis

Directed qualitative content analysis facilitated examining participants' engineering identity, performance/competence beliefs, and differences and various points in their undergraduate program. Qualitative content analysis is an approach used to understand the study of a phenomenon [42]. It lends itself well to the description interpretation of textual data about participants' lived experiences through codes and themes [43], [44]. Directed or deductive qualitative content analysis does this while extending existing theory to different contexts or situations. In this study, engineering role identity and performance/competence theories guided our understanding of participants' experiences and how they viewed themselves as engineers at different times in their undergraduate program.

First, transcripts were coded using an inductive descriptive first pass to categorize the data. This coding method is suggested for longitudinal studies or ones with large quantities of data [45]. All transcripts were team-coded by the first, second, and last authors, who worked to form a consensus on codes. The codebook was developed during the initial coding pass of the first focus group transcripts from Fall 2019. This codebook was subsequently used to code transcripts from the following semester. The first author recoded previous transcripts using the new or modified codes as the codebook was refined. Codes pertinent to this study are described in *Table 3*.

Table 3: Relevant codes used for the analysis of data in this study

Code	Definition	Example
Engineering Identity	If and how a participant is identifying as an engineer.	*"I saw myself as an engineer when we built the [project]"* - Michael, Semester 1
Emerging Identity	Participant describes a partial or in-progress engineering identity.	*"I definitely feel like an engineering student, not quite an engineer."* - Kelly, Semester 4
Understand	Participant's beliefs about their ability to understand engineering content.	"*Yes and no. Parts of it I get, but others I'm kind of lost.*" - Erin, Semester 1
Apply	Participant's belief about their ability to apply engineering content or do tasks.	*"You have to be researching that as you're implementing it. I feel pretty confident in that."* - Jeremy, Semester 2
Change	Instances participant notice changes in their identity.	*"So I think it's gone up just a little bit."* - David, Semester 4
Development	Participant identified needs related to seeing themselves more like an engineer.	*"I feel like if I was part of a group project working towards something, I would definitely feel like more of an engineer."* - Todd, Semester 2

Second, the transcripts and codes underwent a second deductive pass by the first author. This pass considered patterns and ideas across the coded data set to develop underlying ideas or themes [45]. Directed content analysis was used to generate four themes by taking a deductive approach to the data in which the existing theory of performance/competence was used to support the analysis [43]. The themes were shared with the second and last author, discussed, and refined until a consensus was reached. The other authors on this project were part of the PI team, helped with the project's implementation, and contributed to the writing of this paper and the interpretation of results to change programmatic features.

Finally, we developed an individual narrative that illustrates a common path participants took between the themes using the themes generated. This narrative presents an individual account of identity development and brings chronological order and meaning to the data [46]. We focus on how all major themes manifest separately yet connectedly in one participant's two-year experience in an undergraduate engineering program by presenting one narrative.

4 Results

Through the time-oriented analysis of the focus group data, we identified four themes capturing what students perceived they needed to see themselves as engineers. These themes represent separate yet interrelated ways of thinking that participants moved within and between as they considered the development of their own engineering identities. As participants compared their current competencies to what practices they believed professional engineers did, themes built around certain aspects of performance/competence emerged. Participants described wanting to learn more about engineering generally, learn more major-specific content, apply engineering generally, and apply engineering in industry or research. This paper presents the four themes, including the specific identity development supporting needs and what experiences participants described meeting those needs. The themes are followed by a preliminary individual narrative that illustrates a path through the themes many participants experienced during their first few years in an undergraduate engineering program.

4.1 General Engineering Knowledge

General Engineering Knowledge served as a broad theme that captures the need to learn more about engineering generally to start seeing oneself as an engineer. This theme is hallmarked by participants' reassessment of their previous knowledge as they realize, "*I don't really know what I don't know (Darryl, Semester 2)." Many felt that they "definitely need more knowledge (Gabe, Semester 1)"* and that they *"feel like [they] have a lot to learn (Tammy, Semester 1)."* Although participants described feeling overwhelmed by how much there was to learn, most of them felt like this was part of the process and *"you got to learn, and that comes with time (David, Semester 1)."*

Needing time or *"needing a few more years under [their] belt (Mark, Semester 1)"* was a common sentiment and did not seem to negatively influence their perceptions of how they would see themselves in the future. Chris emphasized that although *"I don't consider myself an engineer yet, I'm on the path to one (Semester 1)."* Jerry connected his current sense of self and his definition of an engineer as someone who solves problems to how he will view himself in the future. He said he sees himself *"as kind of an engineer in training...I feel like I definitely have what it takes within me to become a true problem-solver...but I just need more tools and resources to expand that (Semester 2)."*

This relatively short-lived theme predominantly describes participants in the first or second semester of their engineering program. This participant expressed need was met as students gained general engineering skills such as critical thinking, and the engineering design process and felt that their *"mind has evolved in solving things (Michael, Semester 2)."* For many participants, this need was met through their introductory engineering class taken during their first semester.

4.2 Major Specific Knowledge

Students identified needing to learn more about engineering to feel like an engineer and needing to learn specific, contextual knowledge relevant to their specific sub-discipline. This theme was characterized by a reassessment of their existing knowledge, as was the case of David, who stated that when he began *"to actually learn the engineering stuff, it's like, there's a lot more to it than what I thought I knew (Semester 3)."* Participants felt that their current understanding of engineering was not enough to support them in solving professional engineering problems. Tom illustrated this by saying, *"I don't really have the knowledge to reach the solutions that I would consider engineering level (Tom, Semester 2)."* Michael highlights that to *"solve more complex problems, you obviously need more a skill set for those things (Semester 4)."*

Participants felt that to know enough to solve engineering problems, they needed certain classes, as was the case of Andy who said *"I think it's just taking those harder classes, those* *more specific major classes. I think that will really help me [feel like an engineer] (Semester 2)."* They emphasized that *"even though [they] have taken one or two engineering classes, it's very introductory (Oscar, Semester 2)."* David adds to this when he said: "*I need to take those higher-level engineering classes because everything else feels more like it's all general education right now (Semester 3)*." This theme typically included participants in their second and third semesters. It was met once participants felt they had learned enough specific engineering content they could start solving problems within their specific engineering sub-discipline.

4.3 General Engineering Application

Participants emphasized needing to apply engineering to see themselves as an engineer. Dianne captured this shared feeling when she said, *"I think when I start applying…I will feel more like an engineer in that way (Semester 2)."* This desired application was typically very broad and didn't focus on specific disciplinary practices or contexts outside of school. A difference between this theme and the previous two is that participants started to consider professional engineering to focus on more than knowing how to solve problems but to include actively solving problems. Ben explained this extension beyond knowing enough about context as, "*I don't think studying engineering makes you an engineer alone. I think it also requires you to be solving problems (Semester 2)."* This theme is characterized by a desire to build or make something as was the case of Kelly, who said what makes her *"feel like an engineer comes from things like hands-on experience (Semester 4)."* Participants described hands-on tasks as those related to physically or virtually making things and were strongly connected to participants' ideas of what an engineer was. Gabe clarifies this relationship when he said, *"Being able to physically apply is part of what I understand as learning how to do engineering and becoming an engineer in general (Semester 2)."* Karen emphasized the importance these experiences play in her view of herself as an engineer:

> *"When I'm doing classes, I just feel I'm just doing my classes and just trying to pass…But definitely, when I do get hands-on experience, I really feel like an engineer…when I'm doing AutoCAD, I really feel I'm doing something cool (Semester 3)."*

This theme typically described students in their second and third semesters, many of whom felt this need to apply engineering generally could be supported through their curriculum either by "*taking a few more application courses (Stanley, Semester 3)"* or through projects. Many participants described when doing projects they felt most like an engineer, which Darryl specified is *"because you have a task that you have to complete, then you go through a process, then you get a result so it's a lot more like having a job (Semester 3)."* Kelly specifically mentions the desire to use what she has learned previously through "*practice and then having the option to be a bit creative with a couple of things. To do some trial and error with ideas (Semester 2)."* Although they felt this need could be met in classes, many did not feel they had the opportunities to do so, which left them unsure about their abilities to apply. Ben describes this when he says, *"I feel I have a good amount of knowledge for [engineering], but I just wouldn't know how to apply it because I haven't done something to that extent yet (Semester 1)."*

4.4 Industry or Research Application

This theme describes the funneling of students' perceived needs for identity development around the application in industry or research. Almost every participant used the term real-world to describe engineering existing beyond the classroom. Most second-year participants described being partially or fully in this theme by the end of their fourth semester. The transition to this specific application need was catalyzed by the feeling that what they have learned previously may not be transferable to industry or research jobs. Oscar explained this shift: *"I don't feel like much of the things that I've learned is super practical, or it can be like applied in the real-world. Cause a lot of it is just theoretical stuff (Semester 3)."*

Participants are more selective about what experiences count as real-world applications. For this developmental need to be met through curricular experiences, participants emphasized that projects need to be more than *"just to learn whatever thing we just [were taught in class] (Erin, Semester 2)."* Jerry described that *"opportunities to apply [projects] to real life, opportunities to collaborate with others, opportunities to solve open-ended problems (Semester 2) "* were critical for these in-class experiences for them to help with identity development.

Most participants in this theme felt that this need to apply engineering in professional contexts could only be achieved outside of the classroom through an *"internship or research experience where I can actually apply my knowledge in the real-world (Oscar, Semester 3)."* Diane directly connected needing these experiences for her identity development when she said: *"actually applying what we're learning in real-world settings, like a job or an internship, would make me feel more like an engineer than I do right now (Semester 2)."*

4.5 Illustrative Narrative

We present the story of Pam to illustrate how the various themes can show up as separate needs relative to a participant's time spent in their program. We selected this narrative since it reflects a common path taken by many participants through the four themes and offers insight into how one may move from theme to theme based on their experiences and reevaluation of competencies.

Pam started her mechanical engineering program with little previous engineering experience or physical projects. Pam primarily mentioned needing to learn more before feeling like an engineer during her first semester. She said: *"I don't feel like I know enough. I think that's one of the reasons I was avoiding doing like an internship this year because I am terrified of being thrown into it and knowing nothing (Semester 1)."* Pam held the need to learn more and apply more simultaneously, but she felt she needed to accomplish one before the other. She described an engineer as someone who is "*able to think of a solution but then uses your knowledge to actually make it (Semester 1).*" Despite feeling like she had much to learn, this did not seem to detract from how she will see herself in the future. She said: "*I don't feel like I'm in the wrong place where I'm like, 'Oh my gosh, I can never do this.' I can totally see myself being an engineer. I just need to gain some more knowledge right now (Semester 1)."*

After Pam felt like she had learned enough about engineering generally and mechanical engineering specifically through her introductory classes, she shifted her self-identified needs towards applying her skills. This transition started during her second semester as she focused on her lack of building or making experience. She says: *"In terms of being an engineer, that has always kind of been my worry is I haven't learned how to do a lot of hands-on things. Like I didn't grow up, like with power tools in my hands or anything (Semester 2)."* She felt that her classes did not support her in meeting this need and that the theory she had been learning was not sufficient to help her get this type of application experience. Tying it back to her understanding of an engineer as someone who understands and applies, she felt when she gets building experiences, she would *"have two halves of the whole instead of just half of it (semester 2)."* To meet this need, Pam started to participate in engineering clubs with a making element where she describes the "*few glimmers of moments that I've kind of felt like an engineer was when…somebody was teaching me the laser cutter or something (Semester 3)."*

During Pam's fourth semester, she started an internship with a local mechanical engineering company. She had many opportunities to design and build things that met her needs regarding hands-on application. Pam valued physical application experiences and directly connected those to her increases in engineering identity but felt like they "*helped [her] with a baby step towards feeling more like an engineer (Semester 4)."* After this need was met, she identified new needs around applying her knowledge to solve more *"complex problems and being able to come up with a type of solution for it (Semester 4)."* As her needs shifted towards solving more complex problems she believed she would see in industry, she started to feel like she needed to learn more specific information in her engineering classes. The way she balanced her needs to understand and apply to feel like an engineer seemed to tip back and forth depending on her experiences and the reevaluation of her knowledge.

5 Discussion

Throughout this work, we presented the nuanced ways students think about their engineering identity development through specific performance and competency needs. We also gave an initial illustrative example that describes how a student's identity needs vary relative to their experiences and time spent in their program. These time-oriented results corroborate and extend existing theories for engineering role development and competency beliefs.

5.1 Change in competency beliefs

Quantitative work has presented findings that show that students' engineering identities and performance/competence beliefs vary based on their time spent in a traditional four-year undergraduate engineering program [20]. This study corroborates these findings by showcasing how participants thought about their own identity and competencies as moving between four themes. This study extends work on identity development by examining how participants' competency-oriented needs vary depending on their experiences in their program. The story of Pam adds direction to the various needs by providing an example of how one may determine, address, and reassess what they must do before seeing themselves as an engineer. She illustrated how many participants felt they must satisfy certain learning needs before addressing application-oriented ones and that this was part of becoming an engineer.

Pam's story described the shared process of reassessment in which participants felt they learned enough content to start solving problems and started seeking application opportunities. The fixation on making and building becomes prominent in early application themes before centering on *real-world* problems. Pam also showcased how students can move back to previous themes as they learn more about engineering. The four themes and the story of Pam brought attention to the main finding that students think about and reevaluate their engineering identity in terms of changing competency needs and that the path to an engineering identity may not be linear.

These findings align with existing work that conceptualizes identity development as continuous and ongoing [10], [24] and highlights the practice-oriented perspectives of our participants. As our participants started to join the engineering community, they focused on specific competencies, tasks, or skills they needed to develop and practice to become engineers. They constantly compared their current performance/competency beliefs to what practices they perceived they would do as professional engineers. Through this constant reevaluation, they considered new information they were learning about engineering to identify specific needs they needed to join the community and become an engineer [10].

5.2 Evolving competencies

Our results extend existing work on performance/competency to look beyond understanding content and include aspects of application. Current qualitative work on identity has looked at performance/competence as a combined construct that may capture general ways students think about their skills [47] but fails to capture the specific ways students think about their abilities to understand and apply engineering practices. This work illustrates that as students work towards and develop an engineering identity, the ways they consider their competency beliefs vary depending on what practices they currently associate with being an engineering professional. In terms of understanding engineering content, participants thought about understanding engineering both generally and within their specific disciplines. They also frequently centered their needs around applying what they had been learning. The story of Pam illustrated the difference she saw between the theory of her classes and the application she did in her internship. Participants also tied their current competency beliefs to how they expected they would do on future engineering practices, which helped them identify their specific needs [6], [48]. To design engineering curriculum that supports identity development across an entire undergraduate program, understanding the variance in students' competency needs is necessary to create temporally relevant opportunities for students to learn and apply.

6 Implications

The competency-oriented themes presented in this paper shed light on how students think about their engineering identity development through the lens of their abilities and performance of engineering practices. Our work provides insight at the instructor and programmatic levels. For the engineering educator, the results of this study indicate the students perceive specific identity supporting needs and that these needs vary at different points of their program. When integrating identity supporting practices within their curriculum, they could be designed around the reflective needs of their population. First-year classes in which students typically feel they need to learn more about engineering generally and their major specifically could focus on outcomes around problem solving, critical thinking, and major exploration. Late first-year and early second-year classes where students focus on hands-on application could include projects where students use tools and programs to make a finished product. Project-based learning could be used to support students' needs in these classes [49]. Late sophomore classes could aim to make their projects reflective of professional engineering or research and center on complex problem solving. We suggest projects include industry or peer elements in which their work stands to be used by someone else. Content taught in class could be tied clearly to industry and research applications so that students feel they are becoming more qualified to answer professional engineering problems, not just theory. Problem-based and inquiry learning could support students' competency needs in these classes [50], [51]

At a programmatic level, students could be enrolled in at least one major-specific class starting no later than their sophomore year. First-year students are likely well supported in their development with a general engineering class, but students quickly desire context-specific knowledge. Engineering programs may also consider ways to create equitable access to extra or co-curricular engineering opportunities like clubs, undergraduate research experiences, or internships. These opportunities may be a way to aid students in getting application opportunities in professional contexts that may be hard to replicate within a classroom.

7 Limitations and Future Work

This study sought to understand students' perceived needs better to further develop their engineering identities. While participants in this study were academically talented with financial need, these factors were not explicitly considered in this analysis. The high achieving nature of the participants in this study may be presenting survivorship bias; future work should evaluate other students' competency beliefs, including those who may be struggling academically or choose to leave engineering altogether. Although the population is relatively diverse in terms of racial and educational background, additional social identities, particularly those not included in this study, should be examined to understand the transferability of the results.

Conversations around who has the opportunities and access to competency-supporting experiences that help students fulfill their perceived developmental needs may be important as we explore different pathways within identity development. This paper presented a familiar path, but additional work should explore how students move back and forth between themes or hold multiple themes simultaneously. Future work should continue investigating students' competency beliefs for the duration of an engineering program, as this study only examines students' first two years of study.

The interview protocol used in this study was focused on multiple constructs and concepts to fulfill the larger study's goals. Future work should consider explicitly exploring student longitudinal competency beliefs in relation to their engineering identities to explore development over time. Identity trajectory theory [24] may prove a valuable tool in exploring how students understand and combine their past, present, and future experiences as part of an ongoing and continuous process.

This study did not discuss student identity development in relation to other identity constructs commonly seen in engineering education [11]. There have also been critiques regarding competencies as they currently emphasize technical skills that may minimize other engineering practices and fail to create opportunities to merge personal identities with their engineering identity [13]. Future work should explore how students' competency beliefs influence and are influenced by other aspects of their identity so that wide-reaching practices can be developed with holistic identity development in mind.

8 Conclusion

Participants' varying competency beliefs were used as a lens to conceptualize how students viewed what they needed to further develop an engineering identity. Specific competency beliefs of students included wanting to learn about engineering generally, learn about their specific discipline, engage in hands-on application, and perform application in industry or research. The findings extend existing work to understand how students' perceptions evolve alongside their identities during their time in an engineering program. The results also extend existing identity work and provide new implications that could guide pedagogical practices in engineering.

9 Acknowledgments

This research was supported by a grant from the National Science Foundation (NSF grant #EHR-1833738). The authors wish to thank the PRiDE research group for their constructive comments and reviews that improved this article's quality. Specifically, the authors thank Derrick Satterfield and Mackenzie Parker. The authors thank the other members on the NSF grant that helped organize and run the cohorts from which this data was collected: Ivy Chin, Joseph Bozsik, Candice Bauer, Meg Fitzgerald, Julia Williams, and the peer mentors. Finally, we would like to thank our participants for their openness in sharing their experiences of identity.

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