Interest-Driven Major Pathways for Mid-Program Undergraduate Engineering Students

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Interest-Driven Disciplinary Pathways for Middle-Year Undergraduate Engineering Students

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1 Introduction

This research paper explores how undergraduate engineering students make enrollment decisions as they identify additional disciplinary interests. Calls have been made to support the development of students' engineering identities alongside traditional competencies [1]–[3] as how students see themselves as engineers has implications for learning, persistence, and motivation [4]–[6]. Interest has been identified as a key element of engineering identity development as students think about who they want to become in the future as they author who they are in the present. While interest is not the strongest predictor for an engineering identity [7], it is still critical as it is unlikely an engineering identity will develop at all without it, especially for students from underserved populations [8]. Despite the importance of interest in identity development, engineering programs typically emphasize and cultivate students' engineering competencies and abilities at the expense of supporting interest [9]–[11].

There have been calls for longitudinal identity work and a more thorough understanding of identity development in relation to interests [12], [13]. Within engineering education, interest has been used to make sense of students' decisions to initially pursue an engineering major [7], [14], [15], the setting and pursual of goals [16], [17], and students' persistence to graduation [18]–[20]. In most cases, interest is either explored situationally around an activity or specific class [21], [22], or is evaluated for interest in engineering broadly [23]–[25]. Some work has started to evaluate interest on a finer, disciplinary level which adds nuance and allows for work that considers how interest can change and move within engineering. However, much identity work focuses on a singular engineering interest which does not account for the reality that students often have or develop multiple interests in disciplines other than their initial major choice. As students author their engineering identities, it is important to understand the specificity and multiplicity of changing interests as students make decisions to become who they want to be.

This study addresses the need for more longitudinal, interest-focused identity work by examining how undergraduate engineering students think about their changing interests and make subsequent decisions during their first six semesters enrolled in an engineering program. By including the middle years, this work seeks to expand the limited body of research that explores students' interests beyond the frequently studied first year [26]. Phenomenology guides this work as it seeks to understand the essence of lived experiences and is appropriate for longitudinal work seeking to understand change [27]. This work focuses on the specific decisions students make in the contexts of their changing disciplinary interests. The research question examined in this work is:

> RQ: How do undergraduate engineering students progressing through their degree programs make enrollment decisions as they identify additional disciplinary interests?

Four main decision pathways were identified as influenced by participants' additional disciplinary interests. One pathway describes the absence of an additional disciplinary interest while the other three are defined by enrollment decisions to pursue, switch to, or drop their new interests. Each pathway is described with an emphasis on the decision, the timing of such

choices, the characterizing features of the choice, and the features of the participants who followed the pathway in question.

2 Theoretical framework

To support the exploration of how undergraduate engineering students make interest-oriented enrollment decisions relative to time, this work leverages interest as situated within engineering role identity [23], [28]. Engineering role identity considers how students take on the role of an engineer by engaging with professional practices, developing social networks, and making sense of their personal interests compared to the demands and opportunities of the profession [29], [30]. Interest in engineering was initially regarded as an implicit aspect of engineering identity and as a foundation for students' personal actions that foster identification with the disciplinary community [24], [31], [32]. It has since been integrated as a key construct for the development of an engineering identity due to its critical relevance to students' decisions of who and what they want to become [23], [28]. How students understand their interests as consistent with their sense of self is an important consideration as they author their own unique engineering identities [23], [30], [33].

In relation to an engineering identity, *interest* is defined as "a person's likes, preferences, favorites, affinity toward, or attraction to a subject, topic, or activity [34, p. 1]." Interest is understood to consist both of how one feels about something as well as how they value it in relation to their future [35], [36]. *Engineering interest* typically focuses on the emotional or feelings aspect of interest and includes whether or not a student likes or enjoys the subject [7], [24]. This interest is initiated through a situational interaction between a person and momentary, environmental stimuli. This interest may or may not persist over time and develop into an individual interest. An *individual interest* is an interest that exists separate from the initiating stimuli and describes an abiding desire to engage with the content over time [35]. For this work, engineering and disciplinary interests are interpreted as an established, individual interest since participants made decisions extending beyond a situational context.

This work uses this operationalization of interest with the understanding that both interest and identity are not static, rather participants write and rewrite their personal narrative of who they were, are, and want to be as they evaluate their changing interests [29], [30], [33], [37]. We extend the current understanding of interest to move beyond the "strength" of an overall engineering interest to include a more nuanced, disciplinary approach. *Primary interest* refers to the initial engineering major that engineering students declared when they started their program. When considering how interests change, this establishes a starting focus for participants. *Additional disciplinary interest* is used to delineate interests that are beyond students' primary interest, including those outside of engineering. For this study, these disciplinary interest aligned with specific majors and minors at the institution. This framing pulls from literature that labels these interests as "other" or "competing [14], [38]." Rather, we use the term "additional" to refine the existing language to be more supportive of students' new interests as they bring their whole selves into their engineering programs.

3 Methods

This paper reports longitudinal, qualitative results from an ongoing NSF-funded mixed-methods study (NSF grant # EHR-1833738) focusing on a cohort supporting socioeconomically disadvantaged, academically talented engineering students [39]–[44]. This phenomenology-informed exploratory study utilized semi-structured focus groups to understand participants'

lived experiences around identity-mediated interest changes and enrollment choices. The longitudinal element of this work allows us to evaluate when a new interest was identified and the choice(s) participants made regarding pursuing that interest as these two elements often do not occur in the same semester. A singular data point would not fully capture the story of changing interests and choices, rather we utilize focus group data from participants' first six semesters in an undergraduate engineering program. Data were analyzed using directed content analysis to support the exploration of the phenomenon while allowing for the integration of a theoretical framework including identity and interest. Matrix displays and thematic analysis were employed to identify primary interest-oriented, decision pathways participants followed as their engineering interests changed. The first, second, and last authors played a significant role in the data collection and analysis portion of this study while the other authors were part of the PI team, helped with the project's implementation, and/or contributed to the writing of this paper.

3.1 Location and participants

This study was conducted at a large, western land-grant, R1 university and focused on the lived-experiences of 12 undergraduate engineering students participating in a four-year cohort. Participants voluntarily applied to the four-year scholarship-based cohort program before starting their first semester and were selected based on financial need, academic ability, and letters of recommendation. Inclusion criteria for ongoing participation in this cohort include enrollment in an engineering major, a minimum GPA, attendance to cohort activities, and involvement in data collection. Participants with continued enrollment since Fall of 2019 are included in the present study. Data collection began during Fall of 2019 and at the time of this study, all participants had completed their 3rd academic year and engaged in 6 semesters of data collection. To understand changes in interest and subsequent enrollment decisions, the first three years of an engineering program are the most appropriate to focus on as most enrollment changes happen during the middle years [45]. Table 1 lists participants' pseudonyms, some self-reported demographic information, majors, and minors. As this cohort is an outward-facing program, race and ethnicity information is removed to protect the identities of our participants. This program had more participants who were first-generation and from underserved groups than the larger College population. We included decision pathways that were connected to participants' interests and excluded those related to convenience (i.e., a math minor that only required one additional course). 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, gender, majors and minors (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).

Pseudonym	Gender	Current Major	Current Minors
Michael	Man	CE	N/A
Kevin	Man	CSE	Math
Andy	Man	BME	N/A
David	Man	ME	N/A
Toby	Man	EE	Math
Roy	Man	EE	CSE
Stanley	Man	ME, Political Science	Math
Gabe	Man	CHE	Battery and energy storage, math
Pam	Woman	ME	Manufacturing, Math, Unmanned Aerial Systems
Darryl	Man	ME	Math
Oscar	Man	EE	N/A
Kelly	Woman	MSE	Math

3.2 Data collection

To explore participants' changing interests and enrollment decisions, this study drew on phenomenology's operationalization of experiences to include the historical contexts of previous decisions and interests, the actual decision made upon identifying an additional interest, and the reasoning for why participants made these decisions in relation to their interests [46]–[48]. This focus on interest and identity paired with phenomenology supported the choice of qualitative methods centered on participants' individual perspectives of an experience. A longitudinal approach was taken to appropriately capture the breadth of the experience including change which is insufficiently captured in a single data point. Focus groups were utilized since they facilitated the sharing of group experiences essential to the larger study about the benefits of the cohort while still allowing for individualized experiences enhanced by participants' ability to compare and contrast with each other [49], [50]. In alignment with phenomenology and to best support the exploration of personal, contextual, and perception-based phenomena of interest, a semi-structured approach was used when collecting data [51]. 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 all 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.

Guiding questions prompted participants to reflect on their interest in their current majors and minors (if applicable) as well as how this interest has changed since the previous focus group. The guiding questions targeting interest were derived from previous work that quantitatively explores undergraduate engineering identity and interest perceptions [23]. 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 participants to validate previous interests or to further discuss how their interests changed with a focus on experiences and subsequent actions.

Present enrollment was captured in the protocol questions, but enrollment decisions emerged through appropriate follow-up questions.

Table 2: Focus group guiding questions and common follow up questions (indicated by an indentation) presented with the targeted construct.

Focus Group Question	Target Information
Please remind me what major you have selected?	Enrollment
Do you feel like it's a good fit? Why or why not?	Interest
Has anyone thought of changing majors this semester?	Enrollment, change
If no: Do you feel like there is a major that would be a better fit?	Interest
If yes: What is making you so sure of your major choice?	Interest
Has anyone thought about adding or added a minor this semester? Why?	Enrollment, interest, change
What do you enjoy learning about in engineering?	Interest
Has your interest changed since last semester? How?	Interest, change
If yes: How has it changed? Why do you think this is?	Interest, change
If no: Why do you think it has stayed the same?	Interest, change

Initial data collection started at the end of participants' first semesters in Fall of 2019 and has continued for participants' first six semesters in their undergraduate engineering program. Focus groups during the first semester were held in person but the following five were held via an online video platform due to the switch to remote learning as a result of the COVID-19 pandemic. 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 (QST International).

3.3 Data analysis

Directed qualitative content analysis facilitated the examination of participants' interests and enrollment decisions at various points of the undergraduate program. Qualitative content analysis is an approach used to understand the study of a phenomenon [52]. It lends itself well to the description and interpretation of textual data about participants' lived experiences through codes and patterns [53], [54]. Directed or deductive qualitative content analysis does this while extending existing theory to different contexts or situations. In this study, interest as a construct of role identity guided our understanding of participants' experiences and the choices they made.

First, transcripts were coded using a deductive pass in which codes are derived from existing theory and is recommended for longitudinal studies or ones with large quantities of data such as this [53], [55]. The guiding code "interest" was pulled from existing role identity literature and leveraged Hidi and Renninger's interpretation of individual interest to include positive feelings, stored knowledge, stored value, and repeated reengagement [35], [56]. Enrollment codes were used to identify whenever a participant discussed a minor or major other than the one in which they are currently enrolled to aid in keeping track of current registration. These codes are described in Table A1 in the appendix. Transcripts were team coded by the first, second, and last authors. Emergent ideas around interest were cataloged for future analysis.

Second, participants' additional interests and enrollment decisions were cataloged in a comparative matrix which considered when additional interests were acquired, pursued, or

dropped. This method is derived from case study work to compare across cases and allowed us to identify four main pathways participants followed based upon the presence of additional interest and the choices made hereafter [57]. Since many participants had more than one additional interest, we included them in the matrix per additional interest to understand pathways as an interest-by-interest decision rather than having participants be entirely described by one pathway. Because of this, participants are included in the matrix multiple times and can be seen as following more than one pathway. A modified version of this matrix with relevant time stamps and identified pathways is included in Table A2 in the appendix.

Third, transcript data initially coded as "interest" underwent a second deductive coding pass using an extended codebook derived from emergent interest concepts identified through first-pass coding. These new codes were used to identify patterns and ideas across the coded data which characterized the identified decision pathways [53], [55]. Relevant second-pass codes are provided in Table A1 in the appendix. The matrix pathway analysis and second-pass coding were conducted by the first author before being shared and discussed with the second and last authors. The following results section describes each decision pathway in detail along with the characterizing features of each one.

4 Results

Guided by the research question seeking to understand how disciplinary interests change and influence middle-year enrollment decisions, our longitudinal analysis identified four main pathways participants followed as influenced by their additional interests. The first of these pathways is unique in that it is characterized by the lack of an additional interest resulting in the absence of any relevant decisions. The other three pathways are defined by the specific actions participants took regarding their additional interests. These actions include the decision to pursue their additional interest through enrollment choices alongside their primary major, to switch majors from their primary interest to that of their additional interest, or to drop their additional interest by either delaying it or putting it aside. This paper focuses on the decision pathways participants took after identifying an additional interest but does not include the development of the additional interest. While valuable, the growth of new additional interests is outside the scope of this work.

With the exception of the singular interest pathway, the three decision-oriented pathways are not exclusive as participants may pursue more than one pathway either for multiple additional interests (i.e. a participant who is interested in history, psychology, and polymers) or as they make multiple, compounding decisions for a singular additional interest (i.e. someone who pursued an additional interest before dropping it). These pathways demonstrate not only that engineering interest can change in intensity and focus, but that participants make decisions around those changing interests as they author authentic engineering identities that allow for nuance in what it means to be their version of an engineer or engineering student. The following sections describe each pathway with an emphasis on defining decisions and the time-oriented characteristics.

4.1 Singular interest pathway

The singular interest pathway is defined by the absence of an identified additional interest and the lack of accompanying enrollment decisions. This is the only pathway that wholly describes a participant since someone following this pathway does not pursue, switch to, or drop an additional interest as there is no additional interest to make these decisions around.

There are few longitudinal interest change elements to this pathway as interest for the three participants started strong and remained focused exclusively on their primary interest across the six semesters. Occasionally a participant would describe their already high interest further intensifying but most of the time their primary interests remained stable. Participants indicated that they felt their primary interests and major choices were a good fit for them as was the case for David who said *"[mechanical engineering] feels like the perfect choice for me (semester 4)."* Another feature of this pathway is the high degree of certainty regarding participants' primary major choice. Participants shared the sentiment of Andy that they *"couldn't see myself doing anything else (semester 4)"* and if they could do it all over again, they would still pick the same major.

A unique characteristic of this pathway is the emphasis participants put on graduating in a timely manner *"mainly to get into the industry (David, semester 3)"* as soon as possible. Participants regularly mentioned the goal to *"stay on track for the four-year plan (David, semester 2)"* but in semesters five and six this started to include a devaluing of school and reframing of the degree as a box that needs to be checked so they could work. Darryl captures this change when he said:

> *"I have almost no interest in the schooling anymore. I'm interested in the career path afterwards so I'm just kind of trudging through [school] (semester 5)."*

This completion focused perspective was not shared by any other participants who identified additional interests and followed other pathways. It is possible that these participants did not permit or cultivate other interest as they may have felt this could impede their ability to graduate on their desired timeline thus keeping them from starting their careers. In addition to the absence of additional interest and enrollment decisions, the limited change in primary major interest and shared focus on timely degree completion characterized this pathway.

4.2 Pursued interest pathway

The pursued interest pathway is defined by participants' actions to pursue their additional interest through enrollment decisions to add a minor, add a second major, or take additional classes. All participants who chose to pursue their additional interest described a primary interest that initially grew in strength before stabilizing as a strong interest. A few participants described their primary interest stabilizing, no longer increasing or decreasing, as early as their 3rd semester while most participants following this pathway described their primary interest stabilizing during their fifth and sixth semester. Along with the stabilization of their primary interests, most participants felt their primary interests still changed in emphasis rather than strength and shared the idea that they *"wouldn't say it's like increased or decreased, it's just shifted around in focus (Pam, semester 6)."* The narrowing focus of participants' primary engineering interest was described by most following this pathway regardless of the scope of their additional interest.

While this was the most common decision pathway, there are some nuances depending on if a participant's additional interest was in a discipline outside of engineering, another engineering major, or is an extension of their primary interests (i.e. a minor situated within their current major). These are presented as sub-paths to the full decision pathway as these are distinguished by the focus or discipline of the additional interest while the full pathway is characterized by the action of pursuing the additional interest via enrollment decisions. Change in interest within this pathway and its sub-paths include the growth and stabilizing of their primary interest, the focusing of this primary interest, and the emergence of an additional interest.

4.2.1 Interest outside of engineering

For those that pursued an interest outside of engineering, many identified their interest within the first two semesters and made enrollment decisions within one semester. However, Toby deviated from this pattern as he identified and pursued his interest in philosophy during his sixth semester showing this path can remain open late into a student's academic career. Although these participants described strong primary interests, they varied in certainty of their initial major choice and differed in discussions about whether they would or would not choose the same major again. For those that pursued their interests in business administration, their decision was tied to career goals or opportunities. For others, the decision to pursue those additional interests often had something to do with integrating other elements of themselves into their education. Stanley explains his reasoning for adding a second major rather than switching majors when he says:

> *"I have this side of me that really is interested in other things…I feel like that fulfills this other half of me that's always been really interested in politics, but definitely, engineering is the bigger part of me that I've always been interested in (semester 1)."*

The desire to pursue other interests was shared by other participants but despite almost all participants mentioning an interest outside of engineering, few recounted any plans to pursue that interest, and even fewer actually pursued it.

4.2.2 Interest in another engineering discipline

Participants who pursued their additional interest in a different engineering major often did so much later in their program. Both participants who followed this sub-path did so during their sixth semester although for different reasons. Pam exhibited high degrees of certainty in her choice of mechanical engineering and frequently described the broadness of it allowing her to explore many other interests. She says:

> *"I do have other interests, but I think the thing I like about ME is I get to choose how far I go into those interests. So, I also like both EE and I like CS, but I wouldn't want those to be my whole major. I couldn't just do CS and I couldn't just do EE, but I really like being mechanical because it lets me explore them (semester 6)."*

Her enrollment decisions regarding both electrical engineering and computer science included taking additional classes, but she did not elect to enroll in additional minors. She connected her decision to pursue these two engineering disciplines alongside mechanical engineering with her interests in robotics and the desire to pursue careers down that path after graduation. Similarly to Pam, Roy also connected his additional interest to possible opportunities after graduation but he was the only participant following the main pursual pathway who did not demonstrate certainty regarding his primary interest. Rather he appeared more interested in his additional interest than his primary interest, but the late arrival of this additional interest influenced his decision to pursue rather than change. After realizing his strong interest in computer science, he felt *"it's a bit late in my career to switch majors (semester 5)."* He eventually decided to minor in computer science after deciding that it was beneficial both *to "know kind of hardware with electrical and software with [computer science] (semester 6)."* The integration of the additional interest with their primary interest as well as the connection to future goals were a key feature of this sub-path.

4.2.3 Interest within primary major

Participants whose additional interests were extensions of their primary interest often identified this interest during their first three semesters and pursued it within the next semester or two. Along with their strong primary interest were high degrees of certainty in their initial major choice. When asked if he had ever thought of changing majors, Kevin best described this shared sureness when he says *"I have not changed. Nor will I consider changing it, nor have I considered changing it (semester 5)."* Similarly to the other participants following interests outside of their primary major, those following this pathway and sub-path connected their decision to pursue this additional interest to certain types of jobs they hoped to obtain with it. This was particularly the case of Gabe who enrolled in his minor to foster his career goals to work at a specific battery manufacturer. While explaining the pursuit of his minor, he said *"I'm still really interested in [that job]. I'm trying to figure out the best way to achieve it…and just kind of figuring out what's the best method to go about it (semester 4)."* The connection to careers and the certainty of their initial major choice were the hallmark features of this sub-path.

4.3 Switching Engineering Interest Pathway

The changing engineering interest pathway is defined by participants' decisions to switch majors from their initial primary engineering interest to that of their new additional engineering interest. As our population only includes participants who remained in the engineering cohort, this pathway only includes those who moved between engineering majors and does not capture the experiences of those who switched to a major outside of engineering. The two participants who followed this pathway did not describe any certainty about their initial major and upon identifying their additional interest in their first semester they changed within the first year. Roy was simultaneously moderately interested in both his primary and additional interest and expressed his interests as *"kind of like switching off between electrical and mechanical (semester 1)."* For both participants, the switch was initiated by the realization they did not like certain elements of their initial major. Toby explained:

> *"I picked BME because it was the broadest. And then I switched because I realized I didn't really like the biology part too much and the chemistry part…I felt really good about switching. Because I knew that I didn't want to keep going with that stuff (semester 2)."*

Roy had a similar drop in interest in some topics which was paired with a growth in interest elsewhere as he realized he was *"seeing more electricity, how much I enjoy it (semester 3)"* which helped him identify the direction of his major switch. After switching to their new major, participants described a stronger interest in their new major and confidence that they made the right choice. In detailing this change, Roy shared that *"I'm glad I switched. I'm really enjoying all the classes a lot more, and I can really see myself being an electrical engineer in the future maybe compared to mechanical (semester 4)."* Participants following this path did not tie their decision to switch majors to their future goals or careers but were rather driven by the flipping of their major interest. Interest change in this pathway is characterized by a moderate but not strong initial interest that rapidly decreased early on while an additional interest is identified and rapidly intensified to a strong interest.

4.4 Dropped Interest Pathway

The dropped interest pathway is defined by the lack of enrollment decisions despite the identification of an additional interest. Although most participants mentioned many interests

beyond their primary major interest, additional interest specifically refers to interest participants described alongside plans of pursuing. For example, there is a difference between someone who says they like art and someone who says they plan on pursuing art classes. The inaction defining this pathway is layered with participants explicitly stating that they are no longer planning on pursuing or no longer actively pursuing an additional interest.

When participants in this pathway identified their additional interest ranged from first semester to fifth semester. Almost all participants dropped this interest during their fifth or sixth semester. Independent of when an additional interest was acquired and dropped, participants described three main reasons they may have dropped their interest. The first was that participants felt they did not have enough time left in their program to pursue that interest via a minor or a major change without it delaying their graduation and costing money. Stanley describes how even though he would like to switch to electrical engineering, he cannot for *"financial reasons…I only have enough money for four years. Anymore after that and it's financially not feasible for me (semester 6)."* For interests that required graduate school such as an MBA, some also dropped this interest as they felt they *"want to get my life started (Michael, semester 4)"* and believed the continued pursual of their additional interest would keep them from starting their career.

A second reason is that participants felt their additional interest lacked congruence with their career interests and goals. Michael was initially interested in construction management, but this changed as he redirected his focus towards design. He explains he decision to move away from construction management when he says:

> *"My main interest was in the civil aspect, but the construction side of things. And now it's shifting towards, maybe trying out the design side and seeing what that side's all about… my interests are gearing more towards design now. Instead of staying in construction (Michael, Semester 6)."*

Those who dropped for this reason typically had a consistently strong primary interest and certainty in their initial major choice.

A third reason to drop an additional interest was to better support the pursual of other interests. Kevin describes interest in his minor shrinking and his primary major interest growing which ultimately lead to him dropping his minor. Gabe was the only participant who dropped an interest before his fifth or sixth semester and did so he could focus on a minor he felt aligned better with his primary interest and career goals. He explained that he changed his minor from computer science to battery storage *"because I felt it would fit better with my major (semester 2)"* but added that "*sometimes you just don't want to stretch yourself out too far. Rather than being just average or good in a few areas (semester 2)."* This differs from the previous reason for dropping an interest as the decision was not just due to lack of enjoyment but rather to allow another interest to better develop.

5 Discussion

This study identified four main decision pathways that participants followed as they identified additional interests during the first three years of an engineering program. These resultant pathways corroborate and extend existing work on interest and engineering identity, connects interest with other achievement motivation theories, and illustrates how program design may limit students in the development of authentic interests and identities.

5.1 Interest changes

Theoretically, it is understood that interest changes as people move beyond their first experiences with a subject through various stages of commitment [33], [35]. Interest is initially treated as a state which is situationally triggered but eventually becomes engrained as a trait, something that is relatively constant over time [58]. The transition from situational interest state to interest as a individual trait as been explored in engineering education [56]. With respect to engineering identity, engineering interest is looked at broadly and in terms of strength rather than specificity or commitment [23]. When evaluated as so, it has been quantitatively shown to not change significantly between the first and fourth year [13]. While we did note that some participants described their disciplinary interest changing in "strength" by either growing (singular, pursued, and dropped pathways) or shrinking (change pathway), most of this happened during the first few semesters and almost all participants experienced a stabilizing or leveling out of interest by their fourth semester. Stabilization of interest meant that participants described their primary engineering interest as staying the same from semester to semester during their middle years. This lack of change in strength of interest corroborates existing work looking at engineering interest respective to time.

This work extends previous ideations of engineering interest by taking a more nuanced look at change that goes beyond something being higher or lower but rather including the scope, their focus, their interrelatedness, and their interest development. Our participants described stories of change across six semesters that often focused on the narrowing or specializing of their primary interests, the shifting of their primary interest to allow for the growth of new interests, and how these new interests may be enmeshed with their primary interests or eventually dwindle and be replaced or forgotten. The experiences of participants that pursued or changed to their additional interest supports and extends work within engineering education that seeks to understand the process by which an interest becomes an interest trait. These changes in scope and direction emerged and were acted upon relative to participants' time in their program. This work pushes interpretations of interest to include perspectives beyond those currently considered and enhances the field's understanding of engineering interest over time.

5.2 Engineering interest versus disciplinary interest

Presently a broad interpretation of interest as "engineering interest" is taken on in engineering role identity work [8], [23], [24]Godwin. Our work illustrates that "engineering interest" is likely too broad to evaluate change or to understand the individualized engineering identities of our participants. Rather, changing interest was best understood when evaluated on a disciplinary and sub-disciplinary level. This aligns with work showing students make decisions based on their major-level interests [4], [59], [60]. Almost all of our participants described consistently high levels of engineering interest but provided more details when asked about their own majors and minors. Engineering interest broadly may be adequate to understand a snapshot of a participant or populations general engineering interest but in terms of development, a more focused look may more suitable as programmatic and curricular changes are implemented to support identity development especially during the middle years.

5.3 Interest and goals

Previous work in engineering education has started to quantitatively explore engineering identity and achievement motivation theories [4], [59], [61]. This study corroborates the findings that engineering interest has significant relationships with how students think about their future. With the exception of the changing interest pathway, decision pathways were characterized by how

participants thought about their interests relative to their future goals. For the singular interest pathway, the lack of additional interest may be connected to their desire to get started at their careers. For those that pursued an interest, participants described how they felt supporting their additional interest could help them follow particular career paths. For those that dropped an interest, the lack of alignment between their additional interest and their career plans was a common reason to discontinue an interest. In the first three semesters, participants did not make as many connections between their interests and careers but this changed during the fifth and sixth semesters. The relationship between interest and goals has been explored independent of identity [17], [35], [62] but this work illustrates that how participants think about who they want to be or identify as in the future includes their present interest and their future goals.

5.4 Limiting authentic identities by limiting diverse interest

It has been argued that the current engineering education system is designed to support a singular, narrow engineering identity that is rooted in whiteness and maleness [63], [64]. When work exclusively considers engineering broadly, programmatic and curricular practices may be developed that also support this narrow interpretation of interest and identity. Almost all participants mention an interest outside of engineering, fewer described this interest with a degree of commitment, and even fewer actually integrated this interest by pursuing it through classes, a minor, or a double major. A key reason for not doing so was the limitations of time in their program and the fear it would impact their graduation time or cost them too much money. However, many participants had a math minor despite the lack of connection between it and their interests or goals. The ease of adding this minor without it impacting their graduation time was the biggest factor in this decision whereas other interests were not as easily integrated. The full courses of study for undergraduate engineering programs and this institution made it difficult for participants to explore and pursue additional interests alongside or integrated with their primary interest. This extends work that describes the low-choice culture of undergraduate engineering which may limit choice opportunities for students [65]. By upholding these traditional major credit requirements, we may be limiting the development of authentic identities through varied interests that may be critical to attract and retain a diverse population of students [8], [66].

6 Implications

The four decision pathways illustrated in this paper shed light on how undergraduate engineering students' interest changes over time and how these changes influence their decisions. Our work provides insight for both instructors and administrators making programmatic changes.

For engineering educators, firstly to support students' identity development across an entire engineering program one must be cognizant that the scope of students' interests changes. Supporting a general engineering interest during the first few semesters may be appropriate while a more discipline-specific approach could be taken starting in the middle-years that allows students to identify specific interests they may wish to pursue. Secondly, as students bring with them and develop interest outside of their primary major, it is also important to help students figure out how they can integrate those interests with those of their own majors. Activities that encourage students to reflect on their various interests and do some exploration to see where there may be crossover between them and engineering may prove fruitful as students develop more integrated, and authentic engineering identities. Thirdly, encouraging students to be reflecting on their future career goals and their current interests may help them set goals they are

more invested in achieving. Finally, students' interest outside of engineering could be reframed as a positive aspect that allows them to pursue aligned future goals. By dissuading interests that exist outside the bubble of engineering, we may be limiting the development identities that extend beyond the normative ways of being an engineer thus limiting who can join this disciplinary community.

7 Limitations and Future Work

Although this work exploring decision pathways and interest has valuable findings for both research and education, there are limitations that must be made explicit to clarify its transferability. The inclusion criteria for the cohort and study required enrollment in an engineering major and sought those who were identified as high achieving. As a result, survivorship bias for those persisting in engineering excluded the experiences of those who left engineering or the cohort. Additionally, the included population had a much higher percentage of minor enrollment than the larger engineering population at their institution with the same registration and graduation semesters (66% versus 47%). Future work could look at populations with more representative inclusion criteria that allowed for a larger variety in grade based achievement and be expanded to include participants who do not persist in engineering. By doing so, more transferable pathways may be crafted as well as allowing for the emergence of other interest driven decision pathways.

This work corroborated findings that illustrated the relationship between interest and goals. Future work considering interest and engineering role identity could seek to better incorporate work in the motivation space to understand how interest and goals support the development of integrated engineering identities. Additionally, interest has already been situated within engineering role identity alongside other constructs like performance/competence beliefs (ie. confidence they can understand or perform engineering). Future work could extend this study's findings to understand how students' performance/competence beliefs influence decision pathways and interest-oriented goals.

8 Conclusion

This work explored how undergraduate engineering students' interests changed to include interests beyond their initial major and what decisions they made as they identified these additional interests. Operationalizing interest as situated within engineering role identity, four decision pathways were identified which include those with no additional interests to follow, those who pursued their additional interests, those who changed to their additional interest, and those who ultimately dropped their additional interest. This work extends the existing literature on identity development and interest by presenting longitudinal findings that capture interest change with more fidelity as disciplinary interests and explores how these changing interest impact decisions in relation to time and future goals.

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11 Appendix

Table A1: First and second pass coding table with code names, definition of code, and a participant example.

Pass	Code	Definition	Example
1st	Interest	Participant describes an interest in any major, minor, subject, class, activity, etc.	*"Engineering was just the one that seemed more interesting." - Kevin, S1*
	Major change	Participant describes changing or wanting to change their major.	*"I've definitely thought about changing from mechanical to electrical." - Stanley, S5*
	Minors	Participant mentions a minor in any capacity.	*"This semester I decided to get a minor in Unmanned autonomous systems" - Pam S1*
2nd	Change	Participant describes interest changing in any way.	
	Increase	Participant describes their interest increasing or growing.	*"I think mine kind of grew." - Michael, S5*
	Decrease	Participant describes there interest decreasing or shrinking.	*"I've been a little less interested." - Roy, S6*
	Narrowing	Participant describes their interest narrowing, focusing, or specializing on certain topics.	*"It's narrowed a little bit I think." - Oscar, S6*
	No Change	Participant explicitly states their interest has not changed.	*"My interest has remained fairly constant." - David, S3*
	Other interests	Participant describes an interest outside of the current major.	*"it's kind of like switching off between electrical and mechanical" - Roy, S1*
	Decision	Actions students mentions wanting to take or taking in relation to a new interest.	
	Drop	Participant describes dropping or delaying a new interest. Focus is the last of action.	*"I'm probably going to try to dip out of big data next semester." - Kevin, S5*
	Add	Participant describes adding classes, a minor, or additional major to support new interest.	*"I'm planning on at least getting a minor." - Stanley, S1*
	Switch (Same as Major Change)	Participant describes switching to a new major aligning with their new interest.	*"I've definitely thought about changing from mechanical to electrical." - Stanley, S5*
	Certainty	How certainty participants talk about their commitment to their current major interest.	
	Certain	Participant sounds certain or sure of their major choice.	*"Engineering is definitely what I want to stay in." - Gabe, S2*
	Uncertain	Participant sounds uncertain or unsure of their major choice.	*"Long-term, I'm still debating on what I really want to do." - Daryll, S6*
	Initial Major Choice	Participant describes reasons for selecting initial major.	*"I chose it because, like he said, I always found interest in math and science. " - David, S1*
	Nothing More Interesting	Participant describes there being not hinging more interesting than current major.	*"Nothing else has really interested me more than what I'm doing right now so." - Any, S6*
	Completion Focused	Peritonitis describes a very strong desire to complete their classes and graduate.	*"I just want to be hands on into the field. The schooling's just something extra for me."*
	What They Like	Specific elements that participants like or describe as interesting.	
	Broadness	Participant likes their majors broadness of topics or job	*"Specifically, I like the broadness of it, because I didn't really know what career I wanted." Pam, S1*
	Specific practices, tasks, or tools	Participants describe specific practices, tasks, or tools they enjoy doing or engaging in.	*"I really like Solid Works and then I'm learning to enjoy working with MATLAB." - Darryl, S5*
	Specific topics	Participant describes a specific topic they enjoyed learning about or want to learn more about.	*"Some areas that sound really cool to me or like thermodynamics or wind resistance" - Roy, S1*
	Utility	Participant likes the utility or usefulness of what they are learning.	*"My construction material classes have been really interesting because it's related to what I do at work a little bit. " - Michael, S5*
	Supported by	How or where participants interests are supported or new interest emerge.	
	Classes	Participant mentions classes are places their interests were	*"Dynamics is the one that I've found the most interesting." - Pam S3*
	Internships/UREs	Participant describes internships or undergraduate research experiences as places their interests were supported or identified.	*"I think a lot of that also had to do with last summer, which I spent at Tesla. Like I learned that I enjoy industry, but definitely not as much as I enjoy school. " - Stanley, S5*
	Mentorship	Participant describes how a mentoring relationship influences their interest or decision.	*"I met with Dr. Kirn, and he's a biomedical too, and he helped me realize that this is what I wanted to do"*
	Projects	Participants describes how projects were where they got to do things they liked.	*"getting to build the hovercraft was the best part for [class] because I enjoy building things and working with my hands." - David, S1*

Table C2: Pathway matrix for participants' additional interests with the semesters they acquired, pursued, and/or dropped an interest. Semester 1 may also include interests that were acquired before starting at the university. Major acronyms are provided in Table 1.

Path		Psudonym	Initial Interest	Additional interest	Change?	Integrate or Extend?	Semester Aquired	Semester Pursued	Semester Dropped
Singular		Andy	CEE	N/A	No	No			
		David	ME	N/A	No	No			
		Darryl	ME	N/A	No	No			
Extend	Within major	Pam	ME	Unmanned Aerial Systems (ME)	No	Yes	1	3	
		Michael	CEE	Construction Management (CEE)	No	Yes	3	4	
		Kevin	CSE	Cybersecurity/big data (CSE)	No	No	3	4	
		Gabe	CHE	Batteries and energy storage (CHE/MSE)	No	Yes	2	2	
	Within Engineering	Roy	ME	CSE	No	Yes	5	6	
		Pam	ME	CSE	No	Yes	4	6	
	Outside of engineering	Stanley	ME	Political Science	No	Yes	1	2	
		Oscar	EE	Buisness Administration	No	Yes	3	4	
		Oscar	EE	Political Science	No	Yes	1	2	
		Michael	CEE	Buisness Administration	No	Yes	2	5	
		Toby	BME	Philosophy	No	Yes	4	6	
Change		Roy	ME	EE	Yes	Yes	1	3	
		Toby	BME	EE	Yes	Yes	1	2	
Drop		Gabe	CHE	Big Data (CSE)	No	No	1		1
		Gabe	CHE	CSE	No	No	3		5
		Stanley	ME	EE	No	No	5		5
		Oscar	EE	Political Science	No	Yes	1		6
		Michael	CHE	Construction Management (CEE)	No	Yes	3		6
		Michael	CHE	Buisness Administration	No	Yes	2		6
		Kelly	MSE	History/psych/other	No	No	4		6
		Kevin	CSE	Cybersecurity/big data (CSE)	No	No	3		6