ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #36882

From a Mentor's Perspective: Discovering Factors that Foster Achievement Motivation in Engineering

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I am a Ph.D. candidate in Educational Psychology and Educational Technology in the Department of Counseling, Educational Psychology, and Special Education at Michigan State University (MSU). I am broadly interested in how students' motivational beliefs develop as a function of their unique experiences, and in turn, how these beliefs affect their achievement and career choices. To understand these processes, I use a variety of quantitative methods (growth mixture modeling, latent profile analysis, social network analysis, meta-analysis) and qualitative methods (case study) to examine the interplay of students' situations with their unique motivational beliefs and the role of strategically designing educational experiences to promote greater equity and achievement.

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Work-In-Progress: From a Mentor's Perspective: Discovering Factors that Foster Achievement Motivation in Engineering

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Author Note

This work was supported by the National Science Foundation under award number 1643723 and 1830269. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Science Foundation.

We have no known conflict of interest to disclose. This study was not preregistered.

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WIP: From a Mentor's Perspective: Discovering Factors that Foster Achievement Motivation in Engineering

This work-in-progress study investigated how a mentor supports engineering undergraduates' achievement motivation, and in turn, their persistence in engineering. Providing engineering students with mentoring has been proposed as a solution to closing the "leaky pipeline" [1]. To this end, engineering programs across the country have invested significant resources in developing and implementing mentoring programs [2]. Since motivation underpins achievement and persistence [3], it is important to understand how mentors can best support their mentees' development of adaptive patterns of motivation. There is a need to investigate how mentors interpret challenges that engineering students have in maintaining motivation and how mentors seek to address these challenges. We also need to understand the extent to which mentoring approaches align with prior research on achievement motivation [4, 5]. By examining the convergence of practice with research, we can better understand how motivation research benefits practice and gain insight into new areas to study. To investigate how a mentor seeks to support student motivation and the alignment of their approach with research-based practices, we used an integrated theoretical framework of achievement motivation [6] that pulls from expectancy-value theory [7], achievement goal theory [8, 9], [10], and self-determination theory [11].

Mentoring and Student Motivation in Engineering

Research suggests there is a positive impact of mentoring on academic achievement and persistence through enhanced motivational beliefs such as self-efficacy (i.e., the belief one has about their ability to be successful) [12, 13]. By providing access to someone that has experience in higher education, mentoring may also lead to increased persistence because it helps students navigate the university context [14]. Furthermore, hearing about a mentor's experiences may help students make connections between their coursework and future careers [15]. The benefit of faculty mentoring is stronger among under-resourced and underrepresented students as they often lack access to role models or advice related to courses and careers [16].

While research suggests that mentoring supports students' achievement and persistence, the psychological mechanisms underpinning this relation are not well understood. Additionally, despite the prevalence of mentoring programs, research on their effectiveness is limited, as there is a dearth of theoretical guidance, no common operational definitions, and inconsistency in program structures [17]. In the present study, we address this knowledge gap by examining how mentors can use an integrated theoretical approach to support students' motivation, and, in turn, their success in engineering. This study also provides new information about how mentoring can be operationalized within engineering programs using an applied theoretical approach.

Motivational Design Principles: An Integrative Theoretical Approach to Mentoring

Achievement motivation research provides useful information to engineering programs for promoting students' achievement and persistence by identifying how distinct cognitions (e.g., beliefs, goals) explain differences in students' behaviors (e.g., persistence, vigor) and choices [18]. However, having a multitude of different theoretical frameworks makes it challenging to apply them to program design [19]. Moreover, no single theory of achievement motivation captures all the processes that instigate and maintain engagement [6, 20, 38]. For example, when a student considers the question, *"why do I want to do this?"*, discrete beliefs (e.g., values, goals)

and emotions described by different theories help them answer this question. In other words, conceptually distinct constructs from multiple theories (e.g., expectancy-value theory and achievement goal theory) form a broader set of beliefs that lead to different patterns of motivation [21]. This indicates that integrating across multiple theories can provide clearer recommendations for adapting motivation research to practice, including effective mentoring programs in engineering [39]. The present study investigates how five motivational design principles (MDPs, see Table 1) that integrate several motivation theories (i.e., expectancy-value theory, [7]; achievement goal theory, [8]; and self-determination theory, [11]) can be applied by mentors to support engineering students. The MDPs provide educators with specific ways to support multiple forms of motivation [34, 35] (see Table 1). Using three case studies and a phenomenological approach [32], we explored the following research questions: (1) What does an engineering faculty mentor identify as the most important factors to engineering students' achievement motivation?; (2) How does the faculty mentor's approach to supporting students' achievement motivation differ depending on the unique challenges faced by each student?

Method

Procedures and Sample

Mentoring Program and Meeting Notes

We collected meeting notes compiled from the student-faculty mentoring component of a scholarship program designed to support the persistence and achievement of academically talented engineering students with high financial need at a large, public Midwestern university. This component was designed to connect the scholarship recipients with a faculty member who could provide them with guidance and resources provided by the college (e.g., career services, tutoring) and to support students' motivation (see Table 2 for the mentoring meeting occurrence by the student, Table 3 for mentor meeting protocol, and Figure 1 for data collection process).

Sample Selection

During the initial review of available meeting notes, we applied a purposeful sampling strategy to focus our analysis on a single mentor within the program and her mentoring experiences with three mentees (see Figure 1 for rationale of sample selection) [33, 34]. The selected mentor was a female engineering faculty member with over 20 years of experience. The three focal students were all traditionally underrepresented students in engineering[1].

Retrospective Mentor Interview

We conducted a semi-structured retrospective interview with the mentor. The interview questions (see Table 4) were designed to triangulate the findings from the meeting notes and develop more detailed characterizations of the mentor's perceptions of each student's motivation and her efforts to support motivation by enacting the MDPs [35]. Therefore, the interview was conducted after analyzing the meeting notes, and the mentor was asked to provide feedback on some of the initial themes that emerged in the analysis.

Results

We pursued an iterative, two-step coding process (see Figure 1) to analyze the meeting

[1] To maintain the anonymity of the study participants we do not provide demographic information. The students are traditionally underrepresented because they identify with at least one underrepresented group in terms of: race (i.e., Black, Latinx, Indigenous, Pacific Islander), gender (female, non-binary, transgender), or disability status.

notes. Since this study uses qualitative methods and analyses, a commitment to transparency and self-reflexivity is important [36, 37]. Therefore, we considered each researcher's identity and how we were positioned in relation to the participants in the study throughout the analytical process (see Appendix A for researcher positionality statements). We provide an overview of the results in the same order as our three research questions.

RQ 1. Mentor's Retrospective Reflection on Key Factors for Engineering Student Motivation

Given her rich experience working closely with engineering students, we were interested in which factors the mentor found most important for students to maintain motivation throughout college. During the interview, the mentor identified three factors aligned with the MDPs: competence, relevance, and belonging. She recalled that students had an increased sense of **competence** when they were able to see others similar to them succeed in the field, "that if he could do it, I could do it, or if she could do it, I could do it." The mentor also identified that students' motivation was supported by the belief that engineering is **relevant** or useful to them. She recollected that students must think that "there is a place where all this stuff that I'm learning can be applied." The last factor the mentor mentioned was a sense of **belonging**, both with their peers and with faculty. She described this emphasis: "The camaraderie thing is very important for students who succeed, who get through the program." The factors the mentor identified as important for engineering student motivation aligned with three out of five MDPs.

RQ 2. Case Studies: Mentor's Tailored Supports for Engineering Student Motivation

Case Narrative #1: Peter

Meeting notes. The meeting notes indicated that Peter did not have any major challenges related to the MDPs. Peter consistently had high **competence** beliefs for engineering inside and outside of the classroom (see Table 5 for detailed evidence from the meeting notes for all three case studies). Discussion of **learning** and understanding was notably absent, perhaps due to Peter's confidence in his ability to succeed. The mentor provided strong support for Peter's **autonomy** and encouraged him to make decisions at several points (e.g., course choices). The mentor believed that Peter engaging in activities specifically related to his major, electrical engineering, contributed to his sense of relevance and belonging. For example, he sought out opportunities to connect with other electrical engineers among the scholarship recipients. Taken together, the meeting notes indicated that the mentor provided Peter with minimal specific guidance as he seemed to have high levels of motivation over time across all MDPs.

Retrospective interview. Consistent with the meeting notes, the mentor reflected that Peter had high **competence** beliefs. The mentor shared, "He [Peter] didn't sweat grades so much. You know, it was kinda like, 'I'm going to do the best I can.'" Similarly, she recalled that Peter saw his engineering studies as highly relevant, but the source of relevance differed between the meeting notes and the interview. In the meeting notes, the mentor perceived Peter as deriving a sense of **relevance** from his involvement in extracurricular activities (i.e., the university's solar car team). However, in the interview, she identified getting a job in engineering as a source of relevance for Peter (e.g., She recollected Peter saying that "This is a good job. I need a job."). Finally, the mentor reflected that she had more difficulty developing a relationship and in turn a sense of **belonging**, with Peter: "Peter was harder to get to open up."

Case Narrative #2: Michelle

Meeting notes. Based on the notes, the mentor felt Michelle's biggest challenges were low **competence** beliefs and lack of **interest** in engineering. In response to Michelle saying that she was unable to master the material, the mentor provided guidance that aligned with the MDPs. Specifically, she provided informational, encouraging feedback to support **competence** and de-emphasized grades to redirect Michelle's focus to **learning**. Also, the mentor emphasized connections between Michelle's internships and engineering coursework as a potential source of **relevance** for engineering courses. There is evidence that Michelle derived a sense of **belonging** from her mentor meetings and being a member of a group of scholarship recipients.

Retrospective interview. A theme in the meeting notes was that the mentor provided Michelle with encouraging feedback to boost her **competence** beliefs. During the interview, the mentor provided new contextual information that Michelle may have been concerned about not being able to succeed in engineering because she felt a strong pressure to achieve and persist. The mentor recounted: "She [Michelle] has this… burden of her family on her shoulders because no one [else] had gone to college… I think she's carrying that around. The need to succeed, she had to succeed…And she would prove to herself that she could." From the interview with the mentor, it became clear why the meeting notes emphasized competence as a particularly important MDP for supporting Michelle's motivation. The meeting notes and interview similarly provided evidence that the mentor-student relationship helped to support **belonging**. The mentor shared her impression that she was able to develop a strong sense of belongingness with Michelle over time. In the mentor's view, developing a sense of belongingness by building a positive trusting relationship with Michelle was an important factor in supporting her motivation.

Case Narrative #3: David

Meeting notes. The meeting notes showed that David had a high sense of **competence** in engineering. Nevertheless, the mentor did de-emphasize grades and redirect David to focus on **learning**, as she perceived him to be focused on outperforming other students. The mentor also perceived David to be **interested** in engineering. David's interest and enjoyment of engineering seemed to be derived not only from his active involvement in co-curricular activities but also from a sense of **belonging**. Besides formal activities like research involvements, internships, and professional associations, David informally connected with other students and his faculty mentor, which may have enhanced his sense of belonging in engineering. In sum, as the mentor seemed to believe that David was highly motivated for engineering and had a high sense of competence and interest, she provided David with limited specific or informational feedback.

Retrospective interview. The mentor's reflection about how best to support David's motivation aligned with our interpretation of the meeting notes. For example, the mentor recalled that David had high competence beliefs but was inclined to compare himself to other students. Therefore, the mentor emphasized **learning** orientation. She recalled that "he [David] was, actually, competitive with grades with another student… He would always talk about, 'I didn't get as good a grade as [the other student],' or, 'I got a better grade than [the other student].'"

Cross-Case Discussion

The multiple-case study design allowed us to explore how a mentor supported motivation for students with different backgrounds, experiences, and needs. We examined how the

frequencies of motivationally supportive practices presented in the meeting notes differed by the student (see Table 6). Integrating these observations with the mentor's reflection provided context for understanding how the mentor sought to support each student's unique challenges. For example, the mentor emphasized **learning**, rather than grades, with Michelle and David, but not with Peter, and this was not solely based on their levels of **competence** beliefs. According to the meeting notes, both David and Peter had high levels of competence beliefs, but the mentor emphasized learning more with David than Peter, which may be due to David's competition with other students. In contrast, the mentor emphasized learning with Michelle because the mentor felt she had a lower level of competence beliefs. This pattern of the mentor providing tailored guidance was found across all five MDPs (see Table 7) and aligned with the mentor's statement, "There has to be a lot of flexibility in mentoring."

Implications and Limitations

In this study, several implications emerged related to the enactment of MDPs to support engineering student mentoring. First, mentoring seems to be important for promoting students' sense of **belonging** in engineering and the belief that engineering is **relevant** to them. Our case studies also suggested that mentoring can promote students' **competence** beliefs and **learning** goals but that the support for these needs to be differentiated based on each student's specific situation. Support for **autonomy** may be especially important for mentoring engineering students since they tend to follow a fairly common pathway of courses with limited choices. A final implication is that there may be a benefit of mentors seeking to support students' **belonging** beyond engineering as a way to promote their success in engineering.

As with any study, there are limitations to the present study that could be addressed by future research. First, the meeting notes are the mentor's summary of their discussion with a small sample of students, so they capture the aspects of the conversation that the mentor perceived as being most important, but need to be interpreted with caution. In future research, it may be better to record and transcribe the meetings to more fully capture the content of these conversations and increase the sample size. A second limitation is that the interview was conducted retrospectively over a year after the last formal mentoring meeting occurred, so there may be gaps in what the mentor was able to recall. A future direction for this area of research would be to interview the mentor on a more regular basis to gather their reflections about mentoring as it occurs. Finally, it may also be enlightening to understand the students' perspectives of mentoring as a support for their motivation in engineering, as prior research suggests that the mentor may have a biased view [40].

Conclusion

This study explored how a faculty mentor sought to support engineering students' motivation and whether their mentoring practice was aligned with an integrated theoretical approach to motivation. We found that the faculty mentor perceived belonging and competence beliefs as the most important factors for engineering students' motivation. We also found that even though belonging and competence beliefs were identified as important for engineering students' motivation generally, the mentor provided differential supports for student motivation depending on their unique needs. Our findings suggest that an approach that promotes multiple forms of motivation may provide a helpful framework for engineering faculty-student mentoring.

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Table 1

Five Motivational Design Principles (MDPs) and Relevant Mentoring Strategies

MDP 1. Support competence through challenging work and informational and encouraging feedback.

Relevant motivation theory	*What is a competence belief?*	*Why is this important?*
● Self-efficacy theory [23] ● Expectancy-value theory [7] ● Self-determination theory [11]	● Students' belief about whether they can be successful on a particular task or domain. ● Students' answers to the question such as "Can I do this task?" or "Can I do well in this domain?"	● An affirmative response to these questions is positively associated with persistence, engagement, achievement, value, and positive emotions [40]. ● Competence is one of three innate psychological needs that must be met for optimal, intrinsic motivation [11].

How can faculty mentors support students' competence beliefs?

- Provide students with encouragement: Verbal persuasion and social influences are theorized to increase a sense of competence [22]
- Provide students with informational feedback to help them identify better strategies to succeed and identify areas of improvement [25]

MDP 2. Support autonomy through opportunities for student decision making and direction.

Relevant motivation theory	*What is autonomy?*	*Why is this important?*
● Self-determination theory [11]	● Students' feeling that they have control over their actions and that they can act in a way that is consistent with their values and interests	● Autonomy is one of three innate psychological needs that must be met for optimal, intrinsic motivation [11]

How can faculty mentors support students' autonomy?

A recommended practice is to provide suggestions to students but also affirm their sense of agency in making decisions. For example:

- Provide students with choices that allow students to make decisions [24]
- Minimize controlling language and practices (e.g., "You should") [26]

MDP 3. Select relevant, interesting activities that provide opportunities for active involvement.

Relevant motivation theory	*What are relevance beliefs or interest?*	*Why is this important?*
● Expectancy-value theory [7]	● Students' answer to the question, "Why do I want to do this?"	● Students' belief that a task is relevant and/or interesting for them motivates the students to choose to engage and persist in it.

How can faculty mentors support students' relevance beliefs or interest?

A recommended practice is to provide students with a potential answer to the question, "Why do I want to do this?" For example, within the context of engineering education:

- Encourage students to pursue various opportunities for involvement: Active engagement in different activities can help students contextualize their learning. This in turn, may allow students to see the relevance of their engineering coursework and foster their interest in engineering [28, 29].
- Provide students with explicit rationales for engaging in engineering-related courses and activities to increased perceptions of relevance [27]

MDP 4. Support feelings of belonging among students and with faculty

Relevant motivation theory	*What is sense of belonging?*	*Why is this important?*
● Self-determination theory [11]	● Students' feeling that they are connected with others [28] ● Within the context of engineering education, students may feel a sense of belonging with their peers and with faculty members.	● Belonging (which is also referred to as relatedness) is one of three innate psychological needs that must be met for optimal, intrinsic motivation [11]. ● Sense of belonging positively predicts emotion and academic outcomes [32, 33].

How can faculty mentors support students' sense of belonging?

- Facilitate student-teacher relationships through formal mentoring [30]
- Express caring and provide social support [29]
- Encourage students to tap into "interpersonal opportunity structures" (e.g., engaging with peer study groups) to enhance students' sense of belonging with other students [31]

MDP 5. Emphasize learning and understanding and de-emphasize grades, competition, and social comparison.

Relevant motivation theory	*What does it mean by focusing on learning goals as opposed to performance?*	*Relevant motivation theory*
● Achievement goal theory [8], [9], [10]	● Focusing on learning goals (i.e., mastery goals) makes students think about acquiring new knowledge and expertise. ● On the other hand, focusing on performance goals makes students think about how they perform in comparison to others.	● Students who adopt learning goals develop more adaptive patterns of motivation. ● They are also more likely to persist on challenging tasks and have greater achievement than those students who prioritize performance goals.

How can faculty mentors support students' adoption of learning goals?

- De-emphasize grades, competition, and social comparison
- Focus instead on mastery of the content and improvement

Table 2
Mentoring Meeting Instances by Semester

		Fall 2017	Spring 2018	Fall 2018	Spring 2019	Fall 2019	Spring 2020
Peter	Cohort 1	2 meetings	1 meeting	1 meeting	1 meeting	Email check-in[1]	--
Michelle	Cohort 2	--	--	2 meetings	1 meeting	2 meetings	1 meeting
David	Cohort 2	--	--	2 meetings	1 meeting	2 meetings	1 meeting

[1] The notes from the email check-in were not included in the analysis.

Table 3
Mentor Meeting Protocol

Question for student	MDPs supported
1. How's life in general? Are you happy? What are you excited about?	**Belonging:** Develop warm, caring relationships; Show your enthusiasm for the field; Provide opportunities for peer connection
2. Are you seeing a connection between what you're learning in class or out-of-class and your future goals?	**Relevance:** Point students to activities that align with their interests; Encourage discussion of how courses and activities are important or relevant to students; Active involvement: extracurriculars, internships, student-led initiatives **Autonomy:** Provide/highlight opportunities for choice; Provide opportunities for students to share their perspectives; Give rationale and explanations that highlight personal relevance; Use non-controlling language
3. Tell me about some successes and challenges you've had this semester.	**Competence:** Help students identify approaches that may lead to success in the future (e.g., develop better study strategies); Encourage students to attribute failure to internal, controllable, unstable causes (e.g., lack of effort, poor strategy use); Foster the belief that ability is changeable (not fixed) **Learning:** Recognize growth toward goals and learning objectives (rather than grades and social comparisons); Provide specific feedback and opportunities to revise (goals, academic skills, professional skills); Recognize students' efforts and strategies

Table 4

Mentor Interview Guiding Questions

1. In your view, what characterizes the students that are successful in engineering vs. not successful?
2. How would you prioritize the MDPs? If you had to choose, which MDP should be focused on first? Why?
3. What are your primary aims in mentoring the scholarship recipients? Describe your mentoring approach.
4. Please share your reflections about each student you mentored that are a part of the present study (i.e., Peter, Michelle, David).

Table 5

Summary of Key Findings from Qualitative Coding by Focal Student

Motivational Design Principle (MDP)	Peter	Michelle	David
Competence	High competence beliefs (e.g, "Things are going well in and outside of class.")	Mentor provided support for competence due to low beliefs (e.g., "I again reinforced that she is doing all the right things in attending tutoring sessions, talking with the instructor, reworking old exams")	High competence beliefs (e.g., "David's attitude continues to be positive. He feels well prepared for final exams.")
Autonomy	High level of autonomy for course selection (e.g., "Peter is clearly filtering out the electrical engineering courses that interest him and those that don't.")	Minimal autonomy evident in meeting notes in terms of course selection	Minimal autonomy evident in meeting notes in terms of course selection
Relevance/Interest	Sense of relevance/interest derived from extracurricular involvement (e.g., "Peter is taking his first electrical engineering course and sees immediate applications in his work on the Solar Car Team.")	Sense of relevance/interest derived from internship experience (e.g, "Michelle worked as an intern at [company] last summer. She is clearly seeing the connection; the internship flipped the switch").	Sense of relevance/interest derived from courses (e.g., "He enjoys all of his classes as a junior in chemical engineering.")
Belonging	Sense of belonging within specific engineering discipline (e.g., "He is also excited about the chance to mentor the incoming group of [scholarship recipients] and hope that he will be paired with someone in his discipline.")	Sense of belonging within scholarship program (e.g., "In addition she really likes the contact that she has had with other [scholarship recipients] and with the mentors. It helps her feel connected.")	Sense of belonging with other students (e.g., "He enjoys working on teams") and from scholarship program mentor (e.g., "I see David fairly frequently.")
Learning	Minimal explicit support for learning and understanding in meeting notes, which may be due to high competence beliefs	The mentor provided support for learning by de-emphasizing grades (e.g., The mentor tells the student that "grades do not define the person.")	The mentor provided support for learning by encouraging the student to be less focused on social comparison (e.g., "David remains competitive-minded about his grades.)

Table 6
MDP Frequencies by Student

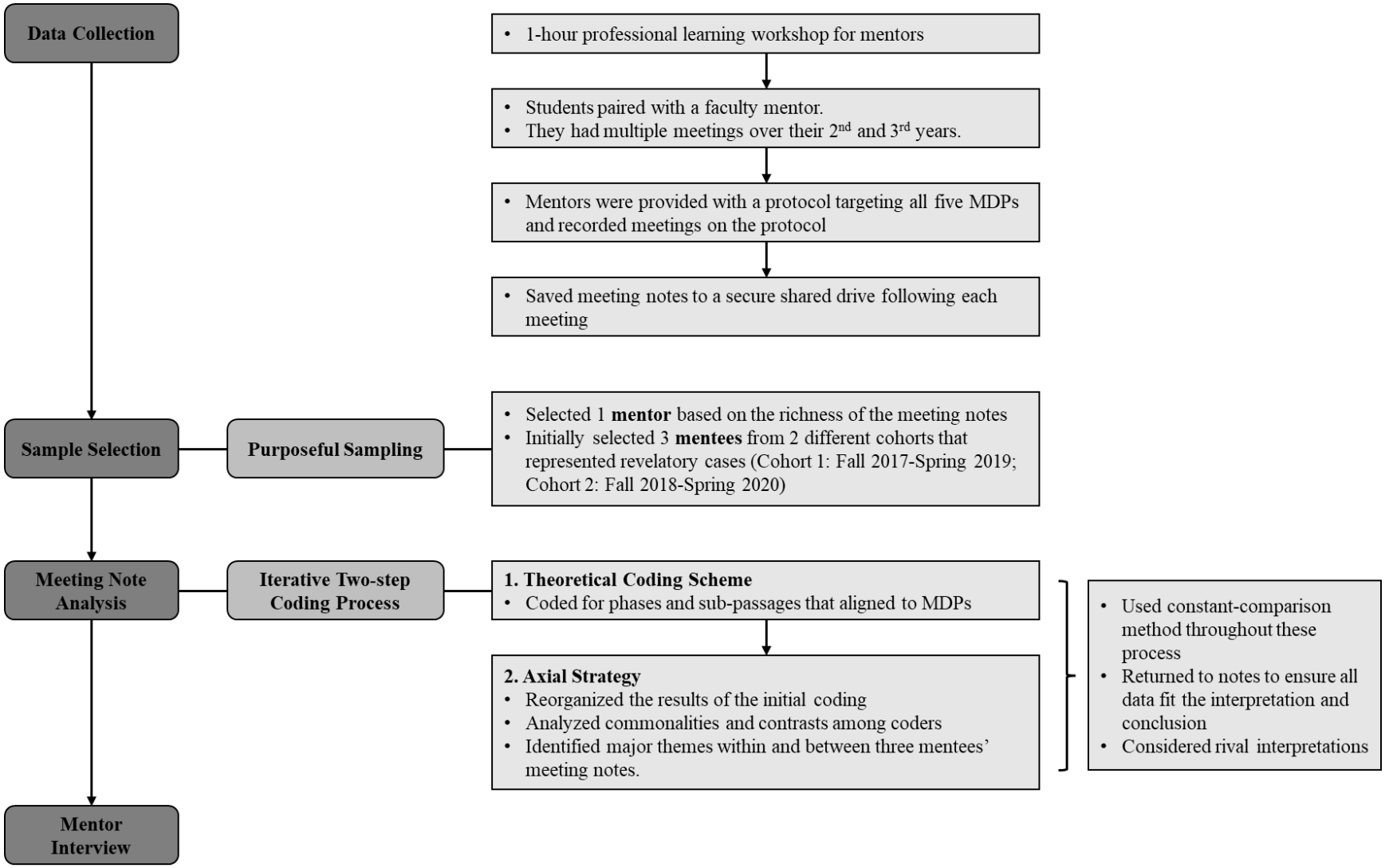
	Competence	Autonomy	Belonging	Relevance	Learning
Peter	9	5	9	9	2
Michelle	17	2	11	3	12
David	11	5	17	13	7

Table 7

Cross-Case Analysis of Mentor's Tailored Supports for Engineering Student Motivation

MDP 2. Support <u>autonomy</u> through opportunities for student decision making and direction.
There were also distinct differences in the meeting notes in terms of explicit support for **autonomy.** There was minimal evidence of autonomy-support among Michelle's meeting notes (e.g., two instances of autonomy-supportive practices; see Table 5), but somewhat strong evidence of autonomy in Peter's and David's meeting notes (e.g., five instances). According to the meeting notes, Peter seemed to take a more active decision-making role in his selection of courses (choosing those with hands-on labs) and David sought advice about potentially applying to graduate school, which resulted in the mentor providing greater support for autonomy in comparison to Michelle.
MDP 3. Select <u>relevant, interesting</u> activities that provide opportunities for active involvement.
There was variability in the frequency of **relevance and interest** as a point of discussion in mentoring meetings among the three students. According to the meeting notes, the mentor had more frequent conversations with Peter (9 instances of relevance-related discussion) and David (13 times) about their sense of **relevance and interest** in engineering than Michelle (3 times)The mentor recalled that this was because Michelle did not seek guidance related relevance and interest due to her early and stable professional experience in the field (e.g., "Michelle was locked into an internship, well, early in her career, the same one, she worked for [company]. And so she stayed with them because they wanted her to come back all the time").
MDP 4. Support feelings of <u>belonging</u> among students and with faculty
The mentor perceived the students as having different levels of **belonging** with others in engineering. Michelle seemed to have a more limited sense of belonging with other engineering students than David and Peter. Specifically, the meeting notes indicated that David enjoyed working in teams and Peter had a sense of belonging with other electrical engineering students, but Michelle's sense of belonging seemed to be more specifically derived from connecting with a smaller pool of students (i.e., other scholarship recipients). The three students also seemed to develop different levels of belonging with the mentor. During the interview, the mentor mentioned that she developed a particularly strong sense of belonging with Michelle and David, but not as much as with Peter.

Figure 1
Study Procedures



Appendix A. Researcher Positionalities

The different identities the authors of this study influenced our experiences as students and educators and, therefore, also how we interpret the educational experiences of others. The second and fourth authors identify as Asian, while all other authors identify as non-Hispanic White. The third and fifth authors identify as male, while the other authors identify as female. All of the authors are highly educated and consider themselves to be middle- or upper-middle class. Regardless of their identity, all of the authors of this paper are invested in contributing to research that informs how to promote the achievement and persistence of students traditionally underrepresented in engineering.

Five of the six authors of this study work within the field of educational psychology. They have shared research interests that are focused on understanding how students develop and maintain achievement motivation within engineering. As part of this work, they collaborate with faculty that work in engineering, one of whom is the fifth author of this paper. The present study is a result of this collaboration, and the authors from inside and outside of engineering provided unique insights into the interpretation of the data.