Community, Belonging, and Identity in Mechanical Engineering Gateway Courses: Insights from Senior Students

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Abstract

Undergraduate engineering programs continue to experience persistently high levels of student attrition, particularly during the early years of the curriculum. While decades of research have documented institutional retention patterns, less is known about how students experience academically demanding core courses as formative environments that shape motivation, belonging, and professional identity. Foundational disciplinary courses, referred to here as *gateway courses* (e.g., Thermodynamics for mechanical engineering students), occupy a pivotal position in engineering curricula, marking students' first sustained encounter with disciplinary norms, epistemic practices, and peer learning cultures.

This exploratory mixed-methods study examines how successful engineering students retrospectively interpret their experiences in gateway courses, with particular attention to how academic challenge functions as a catalyst for community formation and identity development. Guided by Social Cognitive Career Theory, communities of practice, and engineering identity frameworks, the study integrates survey measures of motivation, belonging, and identity with qualitative reflections from senior engineering students approaching graduation.

Findings indicate that students frequently identify, without prompting, gateway courses as formative experiences that contributed not only to technical competence but to the development of enduring peer networks, help-seeking norms, and resilient academic identities. Rather than functioning solely as evaluative filters, these courses operated as sites where students acquired social and cognitive tools that supported persistence throughout the remainder of the curriculum. Quantitative results provide contextual support for these interpretations, while qualitative analyses illuminate mechanisms through which shared academic struggle became a community-building process.

This paper contributes to engineering education research by reframing gateway courses as socially situated learning environments that shape persistence through identity-relevant and relational processes, not merely through performance outcomes. The findings inform ongoing debates about rigor and inclusion by highlighting how structural and cultural features of gateway courses can preserve intellectual challenge while fostering belonging and sustained engagement in engineering pathways.

Introduction

Undergraduate engineering education is widely recognized for its academic rigor and demanding curricula. Yet despite strong employment prospects, undergraduate engineering programs in the United States continue to experience persistently high attrition rates: across more than six decades of data, U.S. engineering graduation rates have hovered around 50%, meaning that nearly half of students who enter an engineering program leave prior to completing an engineering degree [1–5].

These attrition patterns have remained remarkably stable over multiple decades, suggesting that they reflect structural features of engineering education rather than temporary fluctuations in student preparation or interest. Importantly, prior research has demonstrated that many students who leave engineering possess the academic capability to succeed but report disengagement driven by pedagogical climate, competitive cultures, limited belonging, and misalignment between expectations and lived experiences [1, 3, 4, 6]. These findings challenge deficit-based narratives that frame attrition as a necessary consequence of rigor or insufficient student ability [7–9].

A growing body of work has therefore distinguished between *necessary attrition* (students discovering a genuine mismatch of interests or goals) and *unnecessary attrition*, in which capable and motivated students depart due to addressable features of the educational environment [3, 4, 6]. Understanding this distinction requires closer examination of where and how students encounter pivotal challenges within the curriculum.

Gateway Courses as Critical Educational Contexts

In most engineering programs, the most consequential challenges occur not uniformly across the curriculum, but at specific transition points. Foundational disciplinary courses, commonly taken in the sophomore year, serve as gateways into upper-division engineering study. Courses such as Dynamics, Circuits, and Thermodynamics are often students' first sustained exposure to the epistemic norms, abstraction, and problem-solving practices that characterize professional engineering work. These courses can function as threshold experiences: they introduce conceptually transformative, "troublesome" ideas that reshape how students think and participate in the discipline [10].

Pivotal and challenging early-program courses have been described in the literature using a range of overlapping terms, including *bottleneck courses*, *threshold courses*, and *weed-out courses*. Each label foregrounds different aspects of the same phenomenon: high cognitive demand, elevated failure rates, and disproportionate contributions to student attrition [2]. While such courses are essential for developing disciplinary competence, they also represent points at which students reassess their sense of belonging, capability, and future in engineering [6].

This study adopts the term *gateway courses* to emphasize the dual nature of these experiences. Gateway courses function simultaneously as sites of intellectual transformation and as junctures where students' membership in the engineering community is implicitly negotiated. For some students, navigating these challenges fosters confidence, peer connection, and professional identity development [11]. For others, similar challenges precipitate isolation, disengagement, and departure from the field [3, 6].

Academic Challenge, Community, and Persistence

Research across motivation, identity, and learning sciences suggests that academic challenge alone does not determine persistence. Rather, students' responses to challenge are shaped by social context, instructional practices, and opportunities for meaningful participation in learning communities. Social Cognitive Career Theory highlights the role of self-efficacy and outcome expectations in sustaining engagement [12]. Situated learning and communities of practice perspectives further emphasize that learning and identity development occur through participation in shared practices, not solely through individual performance [13, 14].

Within gateway courses, these perspectives converge. When difficulty is framed as a shared and expected part of learning, and when students have access to supportive peer networks, academic struggle can become a source of collective sensemaking rather than individual threat. Conversely, competitive grading structures, limited collaboration, and opaque performance norms may amplify belonging uncertainty and undermine motivation, particularly for students from historically marginalized groups [3, 8]. A recent systematic review confirms that belonging remains a central predictor of retention, with particularly strong effects for women and students from ethnic minority backgrounds [15].

Despite extensive documentation of attrition patterns, fewer studies have examined how students who ultimately persist make sense of these formative gateway experiences. Recent work on engineering "survivors" has identified behavioral responses to failure among persisters [16], but the social mechanisms through which struggle becomes developmental remain underexplored. Retrospective perspectives from successful students can illuminate the tools, relationships, and interpretive frames that enabled persistence: insights that are often obscured when research focuses exclusively on early leavers.

Purpose of the Study

The purpose of this exploratory mixed-methods study is to examine how successful engineering students retrospectively understand the role of foundational coursework in shaping their motivation, sense of belonging, and engineering identity. Rather than treating gateway courses solely as evaluative filters, this study investigates how courses like these function as socially situated environments in which students acquire both cognitive and relational tools for persistence.

By centering the voices of students who navigated gateway challenges and remained in engineering, this work contributes to a more nuanced understanding of rigor that recognizes academic difficulty as a potential catalyst for belonging and identity development when embedded within supportive learning environments.

Theoretical Framework

This study is guided by an integrated theoretical framework that treats persistence in engineering not as a static outcome but as a developmental process shaped by motivation, identity, and participation within social learning environments. Rather than privileging a single explanatory lens, the framework synthesizes insights from Social Cognitive Career Theory, situated learning and communities of practice, and engineering identity research. Together, these perspectives emphasize that students' decisions to persist are influenced not only by academic performance, but by how they interpret challenge, experience belonging, and see themselves as legitimate participants in engineering.

Social Cognitive Career Theory and Motivation

Social Cognitive Career Theory (SCCT) provides a well-established account of how individuals develop and sustain interest in academic and career pathways [12]. Within SCCT, persistence is shaped by interactions among self-efficacy beliefs, outcome expectations, and goal commitments, all of which are influenced by contextual supports and barriers.

In engineering education, self-efficacy has consistently emerged as a strong predictor of persistence, particularly in challenging coursework [6, 11]. Importantly, SCCT emphasizes that efficacy beliefs are not fixed traits but are constructed through experience, including mastery experiences, social comparison, feedback from instructors and peers, and interpretation of struggle. Gateway courses therefore represent critical contexts in which students' efficacy beliefs may be either reinforced or undermined.

SCCT also foregrounds the role of environmental affordances. Supportive peer networks, accessible instructional practices, and norms that frame struggle as expected can function as contextual supports that buffer students against early setbacks. Conversely, competitive climates or opaque performance expectations may act as barriers, even for academically capable students [3]. From an SCCT perspective, persistence through gateway courses depends not solely on difficulty, but on how students experience and interpret that difficulty within a given learning environment.

Situated Learning and Communities of Practice

While SCCT accounts for individual motivational processes, it does not fully explain how students come to see themselves as engineers. For this, the framework draws on situated learning theory and communities of practice [13, 14]. These perspectives conceptualize learning as participation in social practices rather than mere acquisition of abstract knowledge.

From this viewpoint, engineering education is a process of becoming: students move from peripheral participation toward more central forms of engagement in disciplinary practices. Gateway courses often mark students' first meaningful encounter with the norms, discourse, and problem-solving approaches that define engineering as a community of practice. How students are invited (or excluded) from participation during this stage has lasting implications for identity and persistence.

Critically, communities of practice theory highlights that legitimacy is socially conferred. Recognition by peers and instructors, access to collaborative problem-solving, and shared sensemaking around difficult material all signal whether students are perceived (and perceive themselves) as legitimate members of the engineering community. When gateway courses foster collaborative engagement and normalize struggle, they can support trajectories of increasing participation. When they emphasize isolation or competition, they may stall or reverse those trajectories [3, 8].

Engineering Identity Development

Engineering identity research provides a complementary lens for understanding how motivation and participation coalesce over time. Prior work has conceptualized engineering identity as comprising dimensions of competence, performance, and recognition [11, 17]. Persistence is more likely when students not only believe they can succeed academically, but when they are recognized by others (and recognize themselves) as engineers.

Gateway courses are especially consequential for identity development because they often serve as informal tests of "fit." Students frequently interpret their experiences in these courses as evidence about whether they belong in engineering at all. Godwin et al. demonstrated that identity-related beliefs mediate the relationship between performance and persistence: students with strong engineering identity may persist despite setbacks, while those with weaker identity may leave even when performing adequately [11].

Importantly, identity development is relational. Recognition by peers during collaborative problem-solving, shared narratives of struggle, and collective success in difficult courses can reinforce students' sense of belonging to the engineering community. These processes align closely with situated learning perspectives, reinforcing the need for an integrated framework.

Gateway Courses as Sites of Tool Acquisition

Synthesizing these perspectives, this study conceptualizes gateway courses as sites where students acquire *tools for persistence*. These tools extend beyond technical knowledge to include:

- strategies for navigating academic challenge (e.g., help-seeking norms, collaborative study practices),
- interpretive frames that normalize struggle rather than pathologize it,
- relational resources, including peer networks that provide both academic and emotional support, and
- identity-relevant experiences that support recognition and legitimacy within engineering.

From this integrated framework, persistence emerges not simply from individual grit or preparation, but from access to these tools within the social ecology of gateway courses [18].

Students who acquire such tools are better positioned to sustain motivation, interpret difficulty productively, and remain engaged in engineering pathways.

This framework guides the analysis presented in this paper by focusing attention on how students describe gateway course experiences as formative: not merely as obstacles overcome, but as environments that shaped how they learned, who they learned with, and how they came to see themselves as engineers.

Methods

This study employs an exploratory mixed-methods design to examine how successful engineering students retrospectively interpret their experiences in gateway courses. The design is intentionally structured to prioritize qualitative insight into meaning-making processes, while using quantitative measures to provide contextual grounding rather than hypothesis testing. This approach aligns with calls in engineering education research for mixed methods designs that integrate pattern identification with mechanism-focused interpretation [19, 20].

Research Design and Analytic Orientation

The study adopts a convergent mixed-methods design in which qualitative and quantitative data were collected concurrently and analyzed in parallel before being integrated during interpretation. The qualitative component serves as the primary analytic driver, consistent with the study's focus on retrospective sensemaking and identity-relevant experiences. Quantitative measures are used descriptively to contextualize participants' reported experiences and to examine broad relationships among constructs of belonging, motivation, and identity.

This design reflects a pragmatic research paradigm in which methodological choices are guided by the nature of the research question rather than adherence to a single epistemological tradition [19]. Because the goal is to understand how students interpret gateway course experiences rather than to establish causal relationships, the study emphasizes analytic generalization over statistical generalization [20].

Participants and Institutional Context

Participants were senior undergraduate engineering students enrolled in the mechanical engineering program at South Dakota State University, a medium-sized public land-grant university in the Midwestern United States. All participants were within one academic year of graduation at the time of data collection and had successfully completed the core engineering curriculum, including multiple gateway courses (e.g., Statics, Dynamics, Thermodynamics).

Focusing on senior students allows examination of gateway course experiences through the lens of persistence: participants have navigated early curricular challenges and remained in engineering through degree completion. This sampling strategy is appropriate for the study's purpose but introduces important limitations related to survivor bias, which are addressed explicitly below.

The institutional context reflects a traditional engineering curriculum with required foundational courses concentrated in the first two years, followed by discipline-specific upper-division coursework. Instruction in gateway courses is primarily lecture-based, supplemented by problem-solving sessions and recitation sections. While findings are situated within this context, the analytic focus is on mechanisms that may be transferable to similar institutional settings.

Data Collection

Data were collected using an online survey instrument consisting of three components: (1) selections from validated quantitative scales measuring belonging, motivation, and engineering identity; (2) demographic and academic background items; and (3) open-ended reflection prompts focused on experiences of success and challenge in engineering coursework.

Quantitative Measures

Quantitative measures were selected to align with the theoretical framework guiding the study. Engineering identity was assessed using a five-item abridged version of Godwin's engineering identity instrument [11, 21], drawn from the recognition, interest, and competence dimensions of the full 14-item scale and shortened to reduce respondent burden in this exit-survey context. Two items from this abridged scale, focused on perceived ability to succeed in engineering, were also examined separately as a composite *engineering success confidence* subscore, capturing students' specific beliefs about their own capability for engineering success rather than identity more broadly. Academic motivation was measured using the 28-item Academic Motivation Scale (AMS) [22], which yields seven subscales spanning intrinsic motivation, extrinsic motivation, and amotivation; for this administration, AMS items were rated on a 1–5 Likert scale rather than the original 1–7 to maintain a consistent response format across the survey instrument.

Sense of belonging was assessed using a five-item abridged version of the Psychological Sense of School Membership (PSSM) scale [23], focused on perceived acceptance, inclusion, and fit within the engineering program. Internal consistency reliability for this abridged scale was lower than typically desired (Cronbach's $\alpha < 0.70$), and results derived from this measure are therefore interpreted with caution. Quantitative analyses are presented descriptively and are not used to support strong inferential claims.

In addition to composite scales, participants responded to single-item measures asking when they first felt like an engineer (nine response options spanning pre-college through "still don't feel like one") and when they felt most doubtful about continuing in engineering (five options). These items were analyzed as categorical variables and used to contextualize qualitative themes about identity timing.

Participants also rated the importance of seven types of experiences in contributing to their sense of belonging in engineering (e.g., internships, peer study groups, faculty mentorship; five-point scale from "not at all" to "very much") and reported the frequency of five behaviors during their freshman/sophomore gateway courses (e.g., studying with peers, seeking office hours; five-point frequency scale).

Qualitative Reflections

The qualitative component consisted of open-ended prompts asking participants to reflect on experiences that contributed to their success in engineering. Prompts were intentionally broad and did not explicitly reference gateway courses, allowing participants to identify formative experiences without explicit prompting about specific courses. Examples of prompts included:

- What initially motivated you to pursue engineering as your field of study? Has this motivation changed over time?
- Looking back on your journey in engineering, what has been the most challenging aspect? How did you overcome this challenge?
- Describe an experience that played a significant role in your persistence in engineering.

This approach was designed to surface experiences participants themselves perceived as formative, rather than imposing predefined categories of importance.

Analytic Procedures

Quantitative Analysis

Quantitative data were analyzed using descriptive statistics and bivariate correlations to examine relationships among motivation, belonging, and identity measures. As an exploratory follow-up, a screening-level two-path mediation model (belonging → identity → GPA) was estimated in R using sequential OLS regressions, with the indirect effect ($a \times b$) tested via a percentile bootstrap 95% confidence interval. Given the limited statistical power available with this sample ($N = 25$ with complete data on all three variables), the mediation result is presented as exploratory and is not interpreted as evidence of causal mediation. Given the exploratory nature of the study more broadly, the modest sample size, and the limited reliability of some scales, statistical analyses were used solely to contextualize qualitative findings rather than to test hypotheses. Effect sizes and patterns are reported where informative, but results are not interpreted as evidence of causal relationships. All quantitative results reported in this paper were generated programmatically from the raw survey data using a reproducible R analysis pipeline, ensuring full traceability from data to table.

Qualitative Analysis

Qualitative responses were analyzed using an iterative thematic analysis approach [20]. Initial coding focused on identifying references to specific courses, learning environments, peer interactions, and experiences of challenge. Particular attention was paid to unprompted mentions of gateway courses and descriptions of how students navigated difficulty.

Codes were then clustered into higher-level themes reflecting shared mechanisms, such as collaborative sensemaking, normalization of struggle, and identity-relevant recognition. Throughout the analysis, memos were used to document analytic decisions and to examine how emerging themes aligned with the study's theoretical framework.

To enhance credibility, analysis emphasized specificity: references to named courses, concrete interactions, and particular moments of challenge were prioritized over abstract generalizations. This strategy helps mitigate retrospective distortion by anchoring interpretations in detailed recollections.

Limitations and Reflexivity

Several limitations are inherent to the study design and are acknowledged explicitly. First, the focus on senior students introduces survivor bias: participants represent individuals who successfully persisted in engineering and may retrospectively interpret past challenges in ways shaped by their current identities and outcomes. The study does not claim that the experiences described here are representative of all engineering students, nor that similar experiences would necessarily lead to persistence for others.

Second, retrospective self-report data are subject to recall bias and narrative reconstruction. Participants' accounts reflect meaning-making processes rather than objective reconstructions of past events. This limitation is not treated as a flaw but as a feature of the research question, which centers on how students interpret and assign meaning to their experiences.

Finally, the single-institution context limits statistical generalizability. Consistent with qualitative research standards, the goal is analytic generalization: identifying mechanisms and processes that may be transferable to similar educational contexts [20].

Researcher positionality warrants substantial consideration. The corresponding author taught Thermodynamics (the gateway course most frequently named in participants' qualitative responses) and administered the survey to former students. Several respondents named the researcher directly or addressed him in the second person within their open-ended responses, indicating clear awareness of the researcher's identity at the time of writing. This response context introduces meaningful potential for social desirability bias, particularly in narratives concerning Thermodynamics, peer collaboration during Thermodynamics-related study groups, and the role of instructional support. Analytic decisions were guided by explicit theoretical frameworks and grounded in participants' language to reduce the influence of prior assumptions, but readers should interpret Thermodynamics-related themes with this response context in mind.

Results

Results are presented in two complementary parts. Quantitative results are reported first to establish descriptive patterns, measurement properties, and relationships among motivation, belonging, and identity within the sample. These results provide empirical context for the qualitative analysis but are not interpreted as causal or explanatory. Qualitative findings follow and constitute the primary analytic contribution of the study, illuminating how participants interpreted gateway course experiences as formative for persistence.

Quantitative Results: Descriptive Patterns and Context

Sample Characteristics

Twenty-eight senior mechanical engineering students completed the survey ($N = 28$). Table 1 summarizes participant characteristics. Participants were primarily male (60.7%), with 35.7% female and one respondent who did not report gender. Most participants were not first-generation college students; 7.1% identified as first-generation. Mean reported cumulative GPA was 3.47 ($SD = 0.45$), mean reported high school GPA was 3.79 ($SD = 0.24$; $N = 26$), and mean reported age was 23.1 ($SD = 2.0$; $N = 28$).[1] ACT Math scores were the highest subscore ($M = 28.9$), consistent with self-selection into engineering, while ACT English showed the most variability ($SD = 6.7$).

Table 1: Participant characteristics ($N = 28$).

Characteristic	Level / Summary	n	%
Gender	Male	17	60.7
	Female	10	35.7
	Not reported	1	3.6
First-generation status	No	25	89.3
	Yes	2	7.1
	Not reported	1	3.6
Cumulative GPA	$M = 3.47$, $SD = 0.45$	28	
High school GPA	$M = 3.79$, $SD = 0.24$	26	
ACT composite	$M = 27.5$, $SD = 4.8$	26	
ACT Math	$M = 28.9$, $SD = 3.9$	26	
ACT English	$M = 26.0$, $SD = 6.7$	26	
ACT Reading	$M = 28.4$, $SD = 5.9$	26	
ACT Science	$M = 27.2$, $SD = 4.9$	26	

[1] Two non-traditional students aged 29 and 30 inflate the mean and standard deviation; among the remaining 26 traditional-age seniors, $M = 22.6$, $SD = 0.5$, with ages ranging from 21.7 to 23.7.

Scale Reliability

Internal consistency estimates for the primary scales are shown in Table 2. Reliability was strong for the engineering identity scale (α = 0.83) and acceptable-to-strong for most motivation subscales. The belonging scale exhibited low reliability (α = 0.45; standardized α = 0.48), so belonging-related quantitative findings are interpreted cautiously and used as descriptive context rather than as a basis for strong inferential claims.

Table 2: Internal consistency reliability (Cronbach's α) for composite scales. See Table 3 caption for abbreviations.

Scale	**Raw α**	**Std. α**	**# Items**
Belonging (PSSM, abridged)	0.45	0.48	5
Engineering identity (abridged)	0.83	0.84	5
AMS: IM to know	0.74	0.74	4
AMS: IM toward accomplishment	0.70	0.71	4
AMS: IM to experience stimulation	0.58	0.63	4
AMS: EM identified regulation	0.74	0.79	4
AMS: EM introjected regulation	0.92	0.93	4
AMS: EM external regulation	0.79	0.81	4
AMS: Amotivation	0.76	0.79	4

Descriptive Statistics and Correlations

Descriptive statistics for key constructs are presented in Table 3. As expected for a senior persister sample, engineering success confidence, identity, and belonging means were high overall; however, meaningful variability remained across constructs. Motivation composites showed the expected pattern of high identified regulation and low amotivation.

Correlations among focal constructs are shown in Table 4. Engineering identity was strongly associated with engineering success confidence ($r = 0.786$, $p < .001$) and positively associated with cumulative GPA ($r = 0.450$, $p < .05$). Belonging was positively associated with identity ($r = 0.439$, $p < .05$), though belonging results are interpreted cautiously given the low reliability reported above.

Identity Timing and Formative Experiences

To contextualize the qualitative themes that follow, participants were asked when they first felt like an engineer. Table 5 presents the distribution of responses. No participant identified the pre-college or first-year period, and nearly one in five reported still not feeling like an engineer at the time of the survey. The most common response was "during an internship or co-op" ($n = 6$), followed by "I still don't feel like an engineer" ($n = 5$). Among participants who did report a specific timing, gateway-course milestones (sophomore through junior coursework) and applied experiences (internships, technical electives, senior design) were most frequently cited.

Table 3: Descriptive statistics for key constructs (composite variables). AMS = Academic Motivation Scale; IM = intrinsic motivation; EM = extrinsic motivation. All scales 1–5 except where noted.

Construct	**N**	**Mean**	**SD**	**95% CI**
Cumulative GPA	28	3.47	0.45	[3.29, 3.64]
Belonging (PSSM, abridged)	25	4.15	0.43	[3.98, 4.33]
Engineering identity (abridged)	25	4.22	0.53	[4.00, 4.44]
Engineering success confidence	25	4.38	0.63	[4.12, 4.64]
AMS: IM to know	24	3.93	0.51	[3.71, 4.14]
AMS: IM toward accomplishment	24	3.35	0.72	[3.04, 3.65]
AMS: IM to experience stimulation	24	1.83	0.50	[1.62, 2.05]
AMS: EM identified regulation	24	4.27	0.68	[3.99, 4.56]
AMS: EM introjected regulation	24	3.09	1.24	[2.57, 3.62]
AMS: EM external regulation	24	4.02	0.86	[3.66, 4.38]
AMS: Amotivation	24	1.06	0.21	[0.97, 1.15]

Table 4: Correlations among key outcomes. Entries are Pearson's r with significance indicated by * $p < .05$, ** $p < .01$, *** $p < .001$.

Variable	**1**	**2**	**3**	**4**
1. Cumulative GPA	–			
2. Engineering success confidence	0.426*	–		
3. Engineering identity (mean)	0.450*	0.786***	–	
4. Belonging (mean)	0.322	0.225	0.439*	–

Table 5: When participants first felt like an engineer (N = 24; 4 not reported).

Response	**n**	**%**
Before college	0	0.0
First year of college	0	0.0
After completing sophomore foundational courses	4	16.7
During junior-year specialized coursework	3	12.5
During internship/co-op	6	25.0
During technical electives	2	8.3
During senior design project	2	8.3
Passing the FE exam	2	8.3
I still don't feel like an engineer	5	20.8

To examine whether the timing of identity formation related to current belonging, participants were grouped into those who first identified as engineers during or shortly after gateway courses (response options 3–5, encompassing the period when most gateway courses are completed; $n = 13$) versus those who identified later or not yet ($n = 11$). Students who formed engineering identity during the gateway-course window reported significantly higher current belonging ($M = 4.37$, $SD = 0.21$) than those who identified later or not yet ($M = 3.85$, $SD = 0.45$; $t = 3.49$, $p = .004$, $d = 1.51$). Notably, the two groups did not differ significantly on current engineering identity ($p = .65$), suggesting that the *timing* of identity formation (not merely its current level) may have lasting implications for belonging.

Participants also rated the extent to which seven types of experiences contributed to their sense of belonging in engineering (Table 6). Internship and co-op experiences were rated highest, followed by hands-on project experiences and peer study groups. Research experiences and student organization involvement were rated lowest, suggesting that belonging was built primarily through collaborative and applied academic experiences rather than extracurricular involvement.

Table 6: Rated contribution of experiences to belonging in engineering ($N = 24$; 1 = Not at all, 5 = Very much).

Experience type	**Mean**	**SD**
Internship/co-op experiences	4.17	0.92
Hands-on project experiences	3.96	0.86
Peer study groups	3.92	1.21
Success in challenging “weeder” courses	3.63	1.01
Faculty mentorship	3.54	1.06
Student organization involvement	2.58	1.35
Undergraduate research experiences	2.04	1.49

When asked about behaviors during their freshman and sophomore gateway courses, participants most frequently reported feeling a sense of common struggle with peers ($M = 3.92$, $SD = 1.06$) and studying with peers from their engineering classes ($M = 3.63$, $SD = 1.21$). Seeking faculty office hours ($M = 2.88$) and using academic support services ($M = 2.54$) were less common. Notably, considering changing majors was rare ($M = 1.46$, $SD = 0.93$), consistent with the persister framing of this sample.

Qualitative Results: Gateway Courses as Sites of Tool Acquisition

Analysis of open-ended responses revealed that participants frequently identified early disciplinary courses as pivotal to their persistence in engineering. Importantly, these references emerged without prompting: participants were not explicitly asked to discuss gateway courses (or any courses in particular), yet such courses appeared repeatedly in narratives of challenge, growth, and success.

To provide descriptive grounding for course prominence in the qualitative corpus, Table 7 summarizes the number of respondents whose open-ended responses mentioned each course (computed via keyword search across all qualitative response fields). Thermodynamics and Senior Design were each mentioned by nearly half of respondents; Senior Design is included for completeness as a frequently referenced course, though it functions as a capstone rather than a gateway experience. Thermodynamics was referenced far more frequently than other gateway courses, providing empirical grounding for the analytic emphasis on Thermodynamics in the themes below.

Table 7: Respondents mentioning specific courses in qualitative responses (N = 28; courses mentioned by more than two respondents shown).

Course keyword	**Respondents**	**%**
Thermodynamics	13	46.4
Senior Design / Capstone	13	46.4
Dynamics	5	17.9
Fluid Mechanics	4	14.3
Design of Machine Elements (DOME)	3	10.7

Three interrelated themes characterize how participants described some courses as particularly formative: (1) shared struggle as a catalyst for community formation, (2) development of durable academic and relational tools, and (3) identity-relevant recognition through persistence in demanding contexts.

Shared Struggle and Community Formation

Participants commonly described gateway courses as environments in which academic difficulty was both intense and widely shared. Rather than interpreting struggle as evidence of individual inadequacy, many students emphasized how collective difficulty fostered peer connection and mutual support.

Several students explicitly reflected on early attempts to work independently and how those approaches proved insufficient in demanding gateway contexts. One student described the most challenging aspect of their engineering journey as:

> "Trying to do it all by myself. I feel I could have done a better job of using office hours or communicating with my peers. I overcame this by studying a lot. And also eventually being less of an introvert, and actually talking to people."

Several participants described how the difficulty of gateway coursework drove the formation of durable study groups. One student reflected:

> "I think Thermo 1 really allowed me to find a good study group because the content

> was extremely challenging, and access to past exams to practice and grind on allowed us to connect on a deeper level."

The quantitative finding that "feeling a sense of common struggle with peers" was the highest-rated gateway-course behavior ($M = 3.92$) provides convergent support for this pattern. These accounts suggest that gateway courses functioned as social sorting mechanisms not only in evaluative terms, but in relational ones. Students learned who to collaborate with, how to study collectively, and how to interpret challenge as a shared rather than personal burden. This process aligns with situated learning perspectives in which mutual engagement and participation are central to learning and identity development [13, 14].

Thermodynamics as a Prominent Gateway Experience

Among the gateway courses referenced, Thermodynamics was the most frequently named (Table 7). A substantial proportion of participants named Thermodynamics as the most difficult course they encountered, yet also described it as transformative. Importantly, these references were not uniformly negative. Instead, Thermodynamics was frequently framed as a turning point that reshaped students' confidence, study practices, and sense of belonging. As noted at the close of this subsection, however, this prominence likely reflects the survey's response context as well as the course's intrinsic features.

Participants characterized Thermodynamics as conceptually abstract and cognitively demanding, often requiring a shift from procedural problem-solving toward deeper conceptual understanding. Several students described how the collective experience of difficulty became central to peer connection during the course:

> "My main memory is being in a random classroom in Crothers from 8–12 the night before a thermo exam (especially the second exam in thermo 1) and we're all in a collective panic, so it was oddly comforting."

Importantly, students framed persistence through Thermodynamics not merely as academic survival, but as identity-relevant validation. Successfully navigating the course was interpreted as evidence of legitimate membership in the engineering community. As one participant reflected when describing when they began to identify as an engineer:

> "After passing and understanding the difficult classes [. . .]. Having difficult classes like thermodynamics [. . .] finally click were definitely milestones for me throughout my education"

Thermodynamics' prominence in these narratives must be interpreted in light of an important contextual factor: the survey was administered by the corresponding author, who taught

Thermodynamics to many of these participants. Several respondents named the researcher directly in their open-ended responses, and Thermodynamics' high mention rate (46.4% of respondents) likely reflects this response context in addition to course-level mechanisms. With that caveat noted, participants' narratives across multiple courses consistently emphasized peer interaction and shared struggle rather than individual aptitude or instructor influence. The analytic emphasis here is therefore on threshold-experience mechanisms (academic challenge, collaboration, and identity negotiation) rather than on Thermodynamics as a uniquely formative course.

Development of Academic and Relational Tools

Beyond specific courses, participants described acquiring tools that supported persistence across subsequent coursework. These tools extended beyond technical skills to include effective study strategies, comfort with seeking help, and expectations about the pace and difficulty of engineering learning.

Many participants contrasted their early approaches to coursework (often characterized by solitary effort and reluctance to seek assistance) with later practices shaped during gateway courses. One student noted:

> "Study groups with friends made me realize I wasn't the only one lost on a subject. With mutual knowledge that some of us were lost, we joined forces and really worked hard to master the content. The professors were also always open to helping us if we needed it."

These tools were described as transferable and durable, influencing how participants approached later coursework and collaborative projects. Gateway courses thus served as training grounds where students learned not only disciplinary content, but how to function effectively within the engineering learning environment more broadly.

Identity-Relevant Recognition and Persistence

Finally, participants' narratives frequently linked persistence through gateway courses to shifts in engineering identity. Successfully navigating these courses (often after periods of doubt) was described as evidence of legitimacy and fit within the discipline.

Several students described moments when passing a particularly difficult course or mastering challenging material altered how they saw themselves:

> "Getting a 100 on one of the Thermo 1 exams really helped me reaffirm that what I was doing I was making the correct decisions. Understanding something like Thermo at such a level that I got done and was able to double check everything I had done and know why everything was right, it felt good, and I hadn't felt that level of understanding or mastery per say in a while or if at all."

These identity shifts were often reinforced through recognition by peers or instructors, further strengthening commitment to engineering pathways. These patterns align with prior work showing that engineering identity helps explain why some students remain engaged despite difficulty [11].

Taken together, the qualitative findings indicate that gateway courses functioned not merely as evaluative hurdles, but as socially situated environments where students acquired cognitive, relational, and identity-relevant tools that supported long-term persistence.

Discussion

This exploratory investigation examined how graduating mechanical engineering students describe the experiences and tools that enabled their persistence, with particular attention to gateway courses as formative learning environments. Rather than attributing success primarily to pre-existing traits or individual resilience, participants consistently described acquiring new capacities through participation in socially situated academic challenges. In this section, we synthesize these findings, interpret their implications through the study's theoretical framework, and situate them within broader debates about rigor, belonging, and persistence in engineering education.

What Tools Do Students Acquire?

Participants' accounts suggest that successful persistence is supported by an integrated set of tools developed through early disciplinary coursework. These tools include collaborative practices such as peer problem-solving and collective sensemaking, help-seeking norms that legitimize using office hours and peer support, generalized self-efficacy grounded in repeated encounters with difficult material, and identity-relevant validation reinforced through recognition by peers and instructors. Importantly, students did not describe these capacities as innate or pre-existing. Instead, they framed them as learned responses to the demands of challenging courses.

A key interpretive pattern across narratives was a shift in how students understood struggle. Early difficulty was often initially interpreted as personal inadequacy or isolation. Over time, however, shared academic challenge was reframed as an expected and collective feature of engineering learning. This reframing altered how students approached subsequent coursework, enabling them to interpret difficulty productively rather than as a signal of misfit. From a social cognitive perspective, these experiences functioned as mastery experiences that supported durable self-efficacy development [12]. From a situated learning perspective, they represent movement toward more legitimate participation within the engineering community of practice [14, 24].

The quantitative experience ratings reinforce these qualitative patterns. Participants identified internship/co-op experiences, hands-on projects, and peer study groups as the most important contributors to their sense of belonging, all of which are collaborative or applied learning contexts. By contrast, student organizations and research experiences were rated lowest, suggesting that belonging in this sample was built through shared academic experiences within the curriculum rather than extracurricular participation. The weak quantitative associations between retrospectively reported gateway-course behaviors and current belonging warrant caution in over-interpreting behavioral frequency as a proxy for relational quality. The divergence between strong qualitative themes and modest quantitative relationships may reflect limitations of retrospective self-report, measurement inadequacy in belonging instruments, or the possibility that what matters most is not how often students collaborate, but how collaboration is experienced and interpreted.

Gateway Courses as Sites of Tool Acquisition

Perhaps the most striking exploratory finding is the central role students attributed to gateway courses as sites where these tools were acquired. Participants described certain high-challenge courses not primarily as content filters, but as environments that catalyzed shifts in study practices, peer relationships, and self-concept. In these contexts, academic difficulty created conditions that made collaboration necessary, normalized help-seeking, and rendered persistence identity-relevant.

The identity timing data provide quantitative grounding for this interpretation. No participant reported feeling like an engineer before or during their first year; instead, identity formation clustered around gateway-course milestones and applied experiences. Students who first identified as engineers during the gateway-course window (defined as response options 3–5 in Table 5, spanning sophomore foundational courses through junior-year specialization and the first internship) reported significantly higher current belonging than those who identified later or not yet ($d = 1.51$, $p = .004$), despite reporting similar current identity levels. This pattern is consistent with the possibility that gateway courses represent a developmentally relevant period for identity formation, though the cross-sectional design cannot rule out that current belonging shapes retrospective accounts of when identity formed.

Thermodynamics emerged as a particularly illustrative case. Students repeatedly referenced this course as a turning point where conceptual difficulty, peer collaboration, and eventual mastery intersected. Importantly, Thermodynamics is not presented here as unique or exemplary in itself, but as a concrete instantiation of broader mechanisms common to many gateway courses. Students' descriptions highlight how shared struggle fostered authentic connection, how eventual mastery provided validation of engineering competence, and how collaborative practices developed in response to difficulty transferred to later coursework. In this sense, Thermodynamics functions analytically as a window into how gateway courses can operate developmentally when challenge is embedded within supportive social contexts.

Crucially, these findings should not be interpreted as an argument that difficulty alone produces positive outcomes. Students did not describe challenge as inherently beneficial, nor did they suggest that all high-difficulty courses foster belonging or identity development. Rather, difficulty became developmental only when embedded within pedagogical and social conditions that normalized struggle, legitimized collaboration, and provided access to support (concrete examples of such conditions are discussed in the next subsection). In the absence of these conditions, similar levels of challenge may function exclusionarily rather than developmentally. This distinction is critical in interpreting gateway courses and aligns with critiques of rigor as a neutral or universally positive construct [8].

The Role of Intentional Pedagogical Practices

Participants' reflections also point to the importance of instructional practices that shape how difficulty is experienced. While students emphasized their own agency in forming study groups and seeking help, course structures created affordances that made these choices more likely and sustainable. Practices such as explicitly legitimizing collaboration, modeling recognition of students as emerging engineers, providing accessible support infrastructure, and calibrating difficulty to encourage productive struggle appeared to support the social processes students described.

These pedagogical choices did not guarantee community formation or identity development. Students still had to choose to engage, collaborate, and persist. However, they shaped the interpretive environment in which those choices were made. By framing struggle as expected and collaboration as normative, instructors influenced how students made meaning of difficulty and how they positioned themselves within the engineering community. Recent intervention research has demonstrated that deliberately normalizing academic challenge and encouraging help-seeking can improve belonging and retention in engineering [25]; the present findings suggest that similar processes can also emerge organically within well-structured gateway courses.

We acknowledge a substantial potential for bias arising from the researcher–participant relationship: the corresponding author taught Thermodynamics and administered the survey to former students. Several respondents named the researcher directly or addressed him in the second person within their open-ended responses, indicating clear awareness of the researcher's identity. This response context likely amplified Thermodynamics' prominence in participants' narratives and warrants particular caution in interpreting Thermodynamics-related themes; it is plausible that students wrote at least in part to acknowledge their instructor rather than to neutrally report their experience. The analytic focus here is on mechanisms common to gateway courses rather than course-specific evaluation, but replication across institutions and instructional contexts (and across investigators without an instructor relationship to participants) will be essential to assess the transferability of these patterns.

Limitations and Future Research Directions

Several limitations constrain interpretation of these findings. The focus on graduating seniors introduces survivor bias, as participants represent individuals who successfully persisted and may retrospectively interpret earlier challenges through the lens of later success. The retrospective design captures meaning-making rather than contemporaneous experience, and narratives may reflect reconstruction rather than direct recall. The modest sample size limits statistical power, and the low reliability of the belonging scale highlights ongoing measurement challenges. A subsequent cohort assessed with the full 18-item Psychological Sense of School Membership scale achieved strong reliability ($\alpha = 0.87$), suggesting that the low belonging reliability observed here reflects instrument brevity rather than instability of the construct.

These limitations point toward important future research directions. Longitudinal studies tracking students through gateway courses in real time are needed to examine how belonging, identity, and self-efficacy develop dynamically. Comparative studies including students who leave engineering would illuminate differential trajectories and missing supports. Intervention studies could test whether deliberate modifications to gateway course design produce measurable changes in tool acquisition and persistence. Finally, refined measurement of belonging that distinguishes social, academic, and institutional dimensions may better capture the relational processes described here.

Connection to a Broader Research Program

This study represents the first phase of a three-study research program examining how motivation, belonging, and identity intersect within gateway-course contexts. The patterns identified here generate testable hypotheses for subsequent work, including longitudinal tracking of students across gateway sequences and comparative analyses of persisters and leavers.

Exploratory cross-sectional path analysis provides preliminary support for the directionality suggested by the qualitative themes: belonging was a significant predictor of identity ($b = 0.55$, $p = .028$, unstandardized), and identity in turn was marginally associated with GPA ($b = 0.32$, $p = .081$). The full indirect effect (belonging $\rightarrow$ identity $\rightarrow$ GPA) did not reach significance in the present sample (bootstrap 95% CI $[-0.06, 0.49]$), consistent with the limited statistical power available at this sample size. These preliminary patterns motivate the larger longitudinal and comparative investigations that follow.

The long-term goal is to develop evidence-based approaches to designing mechanical engineering curricula that function as tool-building environments, supporting all students (particularly those from historically underrepresented groups) in acquiring the capacities needed for persistence and success.

Conclusion

This exploratory mixed-methods study examined how graduating mechanical engineering students retrospectively interpret the role of gateway courses in shaping their persistence, motivation, belonging, and engineering identity. Across qualitative narratives and contextual quantitative patterns, students consistently described their success as learned rather than innate, emphasizing socially situated experiences through which they acquired tools for navigating academic challenge.

This study contributes to engineering education research by reframing gateway courses not as passive filters of student ability, but as formative environments in which students acquire cognitive, relational, and identity-relevant tools that support persistence. Rather than attributing persistence primarily to individual traits such as grit or preparation, participants described developing collaborative practices, help-seeking norms, generalized self-efficacy, and validated engineering identities through participation in demanding coursework embedded within supportive social contexts.

Qualitative findings indicate that shared academic struggle played a central role in this process. When difficulty was experienced as collective and expected, students reported reduced isolation, strengthened peer connections, and shifts in how they interpreted challenge. Gateway courses, particularly those characterized by high conceptual demand, functioned as threshold experiences where students learned not only disciplinary content but also how to engage with others, seek support, and see themselves as legitimate members of the engineering community. These processes help explain why academic challenge sometimes functions developmentally rather than exclusionarily.

At the same time, these findings should not be interpreted as an argument that difficulty itself produces positive outcomes. Students did not describe challenge as inherently beneficial. Instead, difficulty became developmental only when embedded within pedagogical and social environments that normalized struggle, legitimized collaboration, and provided access to support. In the absence of these conditions, similar levels of challenge may undermine belonging and persistence. This distinction is critical for ongoing debates about rigor and inclusion in engineering education.

Several limitations constrain interpretation, including the retrospective design, survivor bias inherent in studying only persisters, modest sample size, low reliability of the belonging measure, and potential response bias arising from the corresponding author's role as Thermodynamics instructor and respondents' clear awareness of the researcher's identity. These limitations underscore the need for longitudinal and comparative research that captures students' experiences in real time and includes those who leave engineering pathways.

Despite these limitations, the convergent patterns identified here suggest that persistence in engineering may be best understood not as a function of enduring individual characteristics, but as an outcome of access to environments that help students learn how to belong, collaborate, and persist through difficulty. From this perspective, a central question for engineering educators is not whether gateway courses are challenging, but whether they are designed in ways that enable students to acquire the tools needed to navigate challenge productively and remain engaged in engineering pathways. This study establishes a foundation for future longitudinal work aimed at answering that question and informing the design of gateway courses as inclusive, tool-building environments.

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