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An exploration of the relationship between physical, social, and emotional resource access and the development of engineering identity and belonging

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Abstract

This research paper investigates the connections between engineering students' resource access and their development of engineering identity and belonging. Engineering identity and belonging are integral components of engineering student success. In fact, belonging is identified as the most important factor of student success and is tied to student outcomes such as academics, retention, and more. Engineering identity, one's perception that they are the "kind of person" who does engineering informs belonging development. Specifically, students who feel like they can do engineering and are engineers are more likely to feel like they belong in engineering itself. Literature has described the instrumental role that recognition from important others has in developing engineering identity and belonging. In our prior work, we identified that engineering student resource access may be connected to belonging development. Low-income student participants suggested that when they did not have access to certain resources, they questioned whether they belonged in the engineering spaces they were in. These connections were mostly identified as emotional, but some were also physical or social. We wondered whether these connections might exist across students of all backgrounds and, given connections between engineering identity and belonging, also wondered whether connections could be found across engineering identity development too. Using pre-existing data from a pilot study (n=56) regarding students' physical, social, and emotional resource access in engineering, as well as engineering identity and belonging measures, we explored connections between resource access and engineering identity development using linear regression. While specific resources were individually tied to identity development, we found that specific groupings of resources were tied to the specific development of belonging and engineering identity sub-constructs. Performance/Competence was not tied to any specific resource grouping in this study. Belonging and recognition, however, were predicted by access to basic physical needs, including access to a computer and heat, they were also predicted by access to discussions about personal and educational matters with family and teachers that were free of tension and ridicule. Finally, interest was predicted by support of academic matters related to things studied in class. These findings, and their implications, are discussed further in this paper.

Keywords: engineering identity, belonging, resource access, equity

Introduction

Participation and success in engineering programs remain a significant concern for educational institutions and the workforce. Engineering expertise is essential for addressing and solving pressing societal problems, from infrastructure development to technological innovation [1]. As such, ensuring that students enter and complete engineering programs is paramount.

Belonging and engineering identity are pivotal in supporting participation and success in engineering programs. Belonging refers to the fundamental human need to feel connected, accepted, and valued within a group or environment [2]. It involves one's perception of being an integral part of a social community where one's presence and contributions are recognized and appreciated [3]. Engineering identity is defined as the ways in which students describe themselves in relation to engineering as well as the way others perceive them [4]-[6].

Environments that support belonging and identity motivate students to engage actively in their studies, seeking support when needed and persisting through possible obstacles. These supportive environments enhance students' resilience and commitment to their educational journey, directly impacting their academic success and overall well-being [7].

However, research indicates that feelings of belonging and engineering identity are often lower among students with minoritized racial/ethnic identities compared to their dominant white peers [8]. This disparity raises concerns about potential underlying factors contributing to these differences. Qualitative research highlights that access to various resources plays a critical role in shaping student's experiences and outcomes in engineering programs [9]. Author's [9] research reveals that the lack of adequate resources–physical, social, and emotional–may undermine minoritized students' ability to develop a strong engineering identity and sense of belonging. We wanted to test such connections to see if engineering identity factors and belonging were indeed predicted by one's access to different physical, social, and emotional resources. This research thus investigates these connections by addressing the following research question (RQ): How are students' access to physical, social, and emotional resources connected to their perceptions of themselves as engineers?

Background

Engineering education is recognized for its rigorous curriculum, demanding coursework, and high academic expectations [10]. The complexity of the field demands not only academic excellence but also significant emotional resilience. Despite these needs, students' well-being outside of the classroom is often overlooked, leading to gaps in understanding how pre-college experiences affect their engineering journey.

Resources

Resources are crucial to students' success as they provide the necessary support for academic and personal development. This support can, in turn, influence students' academic performance and persistence [11]. Major's [9] qualitative investigation of their participant Samantha suggested that access to certain resources may also be predictive of engineering identity and belonging development. It is for these reasons that we test connections between resources, engineering identity, and belonging. Resources, which include both tangible items and conditions, fall into three categories as we use them in this work: physical, emotional, and educational resources. We describe these components further.

Physical resources at home encompass a range of tangible items necessary for academic success. These tangible items include textbooks, which provide essential learning materials; computers, which facilitate research, assignments, and online learning; and reliable internet access, which is vital for connecting with educational resources and participating in online coursework. The availability of these resources is deeply tied to the financial means or stability of a student's household. Adequate financial means are therefore important in enabling students to cover essential expenses as well as academic materials, which may contribute to a more conducive learning environment [12].

Similarly, physical conditions refer to the state of the student's living environment, such as cleanliness, temperature regulation, and access to basic necessities like water and electricity.

These conditions are also influenced by students' financial situation and social standing, as financial resources play a crucial role in maintaining an acceptable living environment. A clean environment with adequate temperature provides a healthy space for students, which may influence their physical and psychological well-being. Access to basic necessities is fundamental for daily activities as well as academic tasks. While physical resources may support academic activities, physical conditions significantly impact students' well-being and comfort, which in turn influences their academic focus and motivation [13].

Emotional resources include access to mental health services, counseling, and especially supportive networks that provide outside emotional support. Emotional conditions at home involve the support and care shown to students through intentional verbal or nonverbal communication from family members, friends, teachers, or even strangers. Examples of familial emotional conditions include feeling supported and encouraged by household members, experiencing regular discussions about future goals and academic planning with family, and having positive reinforcement from teachers and staff. Such supportive interactions with peers and mentors help students feel valued and understood, which significantly reduces stress and enhances their motivation and engagement in academic pursuits [14].

Educational resources involve the materials and services that support academic success. Today's educators are under great pressure to provide 21st-century students with a quality education based on 21st-century standards. Those standards include providing students with the technological and informational skills needed to compete in an ever-changing, technology-driven world [15].

Educational conditions refer to the broader educational environment and support structures that contribute to students' learning experiences. Educational conditions therefore include having access to things such as working computers or labs, which are crucial in facilitating learning and research [16]. Similarly, ensuring that students feel safe at school allows them to focus on their studies without fear or distraction.

Engineering Identity

Engineering identity is defined as the ways in which students describe themselves in relation to engineering as well as the way others perceive them [4]-[6]. Godwin et al. [5] break down engineering identity into three components: performance/competence, interest, and recognition. Each plays a pivotal role in supporting engineering students.

Performance/Competence refers to students' self-perception of their ability to understand and perform engineering tasks effectively [5]. Access to certain resources may enhance students' feelings of performance/competence such as access to working computers and textbooks, having guidance and support at home and at school. The resources can help students sharpen their skills while enabling the students to engage more effectively with their studies. When students believe in their capabilities, they are more likely to overcome obstacles in their academic journey, allowing them to build resilience. Academic resilience is significantly associated with enhanced performance and a greater likelihood of achieving educational goals, as resilient students are better able to overcome challenges and maintain motivation [17]. Research supports that self-efficacy, or belief in one's abilities, enhances motivation and engagement, which are crucial

for academic success [18]. Higher self-efficacy is associated with the use of deeper cognitive and metacognitive strategies, ultimately resulting in better academic outcomes [18].

Interest can be defined as the student's curiosity or enjoyment in the application of the principles of science and mathematics in order to create new products or solve global problems [5]. Interest drives students to engage deeply with their studies, fostering a passion for discovery and innovation. This enthusiasm can also lead to greater perseverance when facing difficult tasks, as motivated students are more likely to overcome challenges. Therefore, establishing extracurricular activities and ensuring that both the school and their household are equipped with the necessary materials to ensure the appropriate exposure may deepen students' passion and commitment to the field. When students find joy and curiosity in their studies, they are more likely to persist and excel [4]. Engineering can greatly enhance academic success and long-term commitment to the field.

Recognition is best described as students' beliefs that others see them as engineers or engineering students [5]. When students receive acknowledgement for their achievements and efforts, it reinforces their belief in their abilities and encourages them to continue striving for excellence. Godwin et al. [5] discuss how recognition from important people in their entourage can enhance students' commitment to their engineering studies by reinforcing their professional identity. Hence, having access to a supportive environment that allows students to openly discuss college plans with both family members and teachers may strengthen feelings of recognition.

Understanding these components of engineering identity is essential to our research as it allows us to explore how engineering students' access to resources influences their development of engineering identity [5]. We used these three elements of engineering identity as three of four predictive primary factors based on resources in our work.

Belonging

Belonging refers to the fundamental human need to feel connected, accepted, and valued within a group or environment. It involves the perception of being an integral part of a social community, where one's presence and contributions are recognized and appreciated [3]. In exploring the interplay between competence, interest, and recognition, it becomes evident how these components collectively foster a sense of belonging within the field of engineering [5]. Competence, or the belief in one's ability to effectively tackle engineering tasks, when individuals feel competent in their abilities, may reinforce one's connection to a group or community, as it affirms their role and contributions within that context [19]. Interest, when aligned with the group's goals or values, may foster engagement and a deeper sense of integration [5]. Recognition acknowledges and validates contributions, making individuals feel valued and integral to the collective [20]. Connections here show how engineering identity might be connected to belonging.

Belonging is an important factor to consider as it has the ability to impact students' mental health, an issue within the engineering culture [21]. Ensuring that emotional resources both at home and at school are healthy may create an environment in which students can have a safe space that allows them to share their needs and connect with others on different aspects. In that sense, a lack of belonging can negatively impact students' resilience and overall performance in

engineering programs [2]. Therefore, belonging is crucial to our research as it directly impacts engineering students' success and well-being. This study explores how access to resources influences the development of engineering identity and belonging, recognizing that these elements are integral to student outcomes such as academic performance and retention.

Methods

This particular study is part of a larger project investigating "chosen family" in engineering education [9],[22]. Authors [22] describe chosen family as "person[s] outside of the [student's] traditional family with individual or institutional power who genuinely and empathetically support and uplift [students] disrupting the [student's] place amongst the structure- agency dialectic, and in turn, instilling a strong sense of belonging" (p. 2-3). In short, chosen families are families students choose, who help the student enact agency in light of structures they might experience. Our study sought, in part, to understand what role resources play in these relationships. Particularly, we wondered whether the chosen family's assistance to students to access certain resources might support the growth of engineering identity and belonging. These particular investigations are beyond the scope of this paper, which specifically seeks to explore the connections between attitudes and resources.

Demographics

Our survey was given to engineering students at a single Mid-Atlantic institution Fall 2022. The demographic of our survey collected comprehensive background information about students, including racial and ethnic identities, gender and sexual orientations, students' disability and military status, and education funding source. This information is crucial for understanding the diverse backgrounds of students and how these factors might influence their educational experiences and outcomes. By examining these demographic variables, the survey aims to provide a clearer picture of how different aspects of students' identities and circumstances impact their academic journey and support needs. A total of 56 participants completed the survey. The participants' demographics are shown below in Table 1.

Survey Questions

Our survey included questions addressing emotional, social, and physical aspects within two key contexts: students' home and school. Some items were created/adapted by Major [9] or adapted from the Educational Longitudinal Study of 2002 [16] or Gibson [23]. Others were created for the purposes of the larger research project addressing "chosen family." Items capture students' access or inaccess to certain resources. Many of these items were found to be connected to students' socioeconomic standing [9]. We also asked students about their engineering identity and sense of belonging using scales with strong validity evidence by [24]. The total list of relevant questions is provided in Appendix A. Some of these items are discussed further.

For physical resources and conditions, questions focused on the availability and condition of essential items. Some examples are whether the household had a computer, a television, or a heater, or whether a house was in disarray. While some questions were created by our team based on past work [9], others were taken from the Educational Longitudinal Survey of 2002 [16].

For the emotional aspects, questions focused on students' comfort in communicating with family members at home and their perceptions of treatment by teachers and staff at school. Some

examples of questions are whether students felt comfortable talking to household members and whether they experienced regular discussions about their future goals with their family. While some questions were created by our team based on past work [9], others were taken from the work of [23].

Table 1. Study Participant Demographics

Grouping	Count	%
Gender		
Women	24	42.9%
Men	34	60.7%
Transgender	≤ 5	< 8.9%
Non-Binary	≤ 5	< 8.9%
Did not disclose	1	1.8%
Race/Ethnicity		
American Indian	≤ 5	< 8.9%
Asian	7	12.5%
Black or African-American	≤ 5	< 8.9%
Hispanic, Latino, or Spanish origin	≤ 5	< 8.9%
Middle Eastern or North African	≤ 5	< 8.9%
White	44	78.6%
Did not disclose	1	1.8%
Intersectional Groupings		
Hispanic Women	≤ 5	< 8.9%
Hispanic Men	≤ 5	< 8.9%
Hispanic Non-binary	0	0.0%
Black Women	≤ 5	< 8.9%
Black Men	0	0.0%
Black Non-Binary	≤ 5	< 8.9%
Middle Eastern Women	≤ 5	< 8.9%
Middle Eastern Men	0	0.0%
American Indian or Alaskan Native Women	≤ 5	< 8.9%
American Indian or Alaskan Native Men	0	0.0%
American Indian or Alaskan Native Non-Binary	0	0.0%
White Women	25	44.6%
White Men	19	33.9%
White Non-Binary	≤ 5	< 8.9%
Asian Women	≤ 5	< 8.9%
Asian Men	≤ 5	< 8.9%
Asian Non-Binary	≤ 5	< 8.9%

NOTE: Sample sizes less than 5 (8.9%) have been redacted to protect our participants.

NOTE: Total sample sizes may not add up as students could choose more than one option for each demographic type.

The social aspect covered questions about support at home and involvement in extracurricular activities at school. This range of questions explores how social factors and engagement opportunities impact students' self-esteem and sense of community. While some questions were created by our team based on past work [9], others were taken from the Educational Longitudinal Survey of 2002 [16].

Finally, our questions about engineering identity and belonging focused on three factors described by [25]; performance-competence, interest, and recognition; and a single factor described by [26]. The entirety of our survey used a 7 point anchored Likert scale ranging from 1 representing “strongly disagree” to 7 representing “strongly agree” for each question. Questions come from Godwin et al. [5]. Again, the full list of items used can be found in Appendix A.

Linear Regression

Using the programming language R and the program Rstudio, we developed and backward-deleted linear regression models using primary and secondary factors. Our outcomes were engineering attitudes like belongingness, interest, recognition and performance/ competence. Our primary factors were different physical, emotional and educational resources and conditions such as those described in the section titled *Survey Questions*. The normality of the data obtained was tested by using skewness and kurtosis. We used intersectional demographics as secondary factors. Using backward-deletion, we removed insignificant factors ($\alpha = 0.05$ level for majority students; $\alpha = 0.10$ level for marginalized students [27]) to determine which factors were predominantly affecting the primary factors. After a parsimonious model was obtained, we analyzed raced and gendered effects, including intersectionality. Finally, we calculated effect sizes. Specifically, we sought small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$) effect sizes [28].

Results

Our final results are shown in Table 2. The table describes physical, social, and emotional resources in the home and school environments. We describe the results parsed out further.

Physical Resource at Home

We found that students who reported greater access to a computer or heating at home tended to experience a stronger sense of belonging as engineers ($\beta = 1.574$, $d = 1.32$; $\beta = 1.463$, $d = 0.84$; respectively). Conversely, those with more access to a TV were associated with lower levels of belonging ($\beta = -2.983$, $d = 2.16$). Students who identify as cisgender, when accounting for physical resource access, were more likely to express a higher sense of belonging ($\beta = 0.861$, $d = 0.27$), though the effects are small.

We also found that students with greater access to air conditioning were more likely to express increased interest in engineering ($\beta = 0.320$, $d = 0.29$). Students who identified as American Indian or Alaskan Native, when accounting for physical resource access, are more likely to report lower levels of interest in engineering ($\beta = -2.385$, $d = 0.30$).

Physical Condition at Home

We found that students who reported that their house had problems with mold showed a higher sense of belonging as engineers ($\beta = 0.246$, $d = 0.28$), though the effect size is small. Shared

experiences of adversity may strengthen community bonds, helping these students feel more recognized and validated as engineers. Moreover, students who reported their household having more access to healthcare professionals were more inclined to express interest in engineering (β = 0.198, *d* = 0.37). Students who identified as Black, when accounting for the physical conditions of their pre-college home, were more likely to report reduced interest in engineering (β = -1.057, *d* = 0.25).

Emotional Resource at Home

Our analysis of emotional conditions in students' pre-college home reveals that those students who felt comfortable discussing issues with family members were more likely to report a stronger sense of belonging as engineers (β = 0.314, *d* = 0.48). However, male students reported lower levels of belonging under similar emotional conditions (β = -0.943, *d* = 0.38). Similarly, students who felt that household members took their concerns seriously and that their homes were understanding, were more likely to report a higher feeling of recognition as an engineer (β = 0.332, *d* = 0.68; β = 0.276, *d* = 0.51; respectively). On the other hand, students from households where yelling was frequent tended to feel less recognized as engineers (β = -0.344, *d* = 0.77). When accounting for the emotional conditions of a student's pre-college home, students who identified as American Indian or Alaskan Native were more likely to report a higher feeling of recognition as an engineer (β = 1.622, *d* = 0.28).

Interestingly, students who reported feeling comfortable talking to family members were more likely to report higher levels of performance/competence (β = 0.212, *d* = 0.38). Also, when accounting for emotional conditions, students who identified as Hispanic were more likely to report higher levels of performance/competence (β = 1.128, *d* = 0.31).

Educational Resource at Home

Students who frequently had their homework checked by family members or discussed friends with them showed a higher sense of belonging as engineers (β = .220, *d* = 0.40; β = 0.387, *d* = 0.64; respectively) while students whose family members frequently discussed grades or college planning with them reported lower levels of belonging as engineers. Furthermore, while accounting for educational resources, we found that students who identified as male reported lower levels of belonging.

In contrast, discussions about class topics or college planning with family members were associated with higher feelings of recognition as engineers (β = 0.506, *d* = 1.09; β = 0.368, *d* = 0.70; respectively). However, students who engaged in discussions about courses or friends were more likely to feel less recognized as engineers (β = -0.541, *d* = 1.12; β = -0.278, *d* = 0.55; respectively). When considering educational resources, students who identified as female were more likely to report a higher feeling of recognition as an engineer. (β = 0.568, *d* = 0.28).

Additionally, students who frequently discussed college planning with family members were more likely to report lower levels of perceived performance/competence (β = -0.515, *d* = 0.93) while those who discussed friends and future goals reported higher levels of perceived performance/competence (β = 0.263, d = 0.49; β = 0.274, d = 0.54, respectively).

Physical Resource of High-School
Students who reported their pre-college school having more access to working computers were more likely to report higher levels of interest in engineering (β = 0.299, *d* = 0.27). In contrast, students who reported higher feelings that their pre-college school made them feel safe were more likely to report lower levels of interest in engineering (β = -0.187, *d* = 0.20). Lastly, when accounting for physical conditions of a student's pre-college school, students who identified as American Indian or Native Alaskan were more likely to report lower levels of interest in engineering(β = -2.198, *d* = 0.28).

Emotional Resource of High-School
Students who frequently engaged in discussions about current events with teachers and staff were more likely to feel a sense of belonging as engineers (β = 0.281, *d* = 0.40). However, those who felt that teachers and staff treated them differently reported lower levels of interest in engineering (β = -0.168, *d* = 0.18), although the effect size is small. When accounting for emotional conditions of a student's pre-college school, students who identified as American Indian or Native Alaskan reported lower levels of interest in engineering(β = -1.934, *d* = 0.25).

In terms of recognition, students who discussed their future goals with teachers and staff reported a higher sense of recognition as engineers (β = 0.316, *d* = 0.51). Lastly, when accounting for the emotional conditions of a student's pre-college school, students who identified as Black were more likely to report a lower feeling of recognition as an engineer (β = -1.906, *d* = 0.46).

Discussion
We sought to understand how students' access to resources impacts their belonging and engineering identity. Our discussions on these topics, based on our research presented here, and discussed.

Belonging
Our results indicate that emotional resources strongly impact students' sense of belonging. Our results, shown in Table 2, specifies that students who received consistent emotional support from their entourage, encompassing both family members, classmates, teachers and staff members, reported higher levels of belonging. This result aligns with Samanta's experience from Author's original work [9]. Particularly, Samantha's feelings of belonging were improved when her friends offered her emotional support by being understanding and empathetic of her situation [9]. Although receiving emotional support positively impacted her feelings of belonging, her financial difficulties exacerbated her feelings of isolation and inadequacy which impacted her educational experience. Our results also highlight that physical resources which are directly related to her financial standing, can impact students' feeling of belonging. According to Godwin & Kirn [28], a sense of belonging is critical for academic engagement and persistence. Thus, our results confirm that emotional resources play a pivotal role in fostering a strong sense of belonging among engineering students.

Table 2. Regression output.

Regressions	**Est.**	**Err.**	***t***	***p***	**Sig.**	**d**
Physical Resources at Home						
Belonging ~						
My household had a computer/laptop.	1.517	0.628	2.417	0.021	*	**1.28**
My household owned a television.	-2.773	0.943	-2.940	0.006	**	**2.01**
My household owned a heater.	1.340	0.588	2.281	0.029	*	**0.77**
Female or Non-Binary	0.658	0.366	1.796	0.082	.	**0.27**
Physical Conditions at Home						
Belonging ~						
My home had problems with mold.	0.220	0.136	1.620	0.114		**0.25**
Female or Non-Binary	0.700	0.385	1.819	0.078	.	**0.28**
Emotional Conditions at Home						
Performance-Competence ~						
I felt comfortable talking to members of my household.	0.212	0.091	2.327	0.027	*	**0.38**
Recognition ~						
Engineering Identity: Performance/Competence	0.463	0.129	3.587	< 0.001	**	**0.49**
Yelling was a regular occurrence in my household.	-0.307	0.116	-2.635	0.013	*	**0.69**
My household felt tense.	0.311	0.133	2.338	0.026	*	**0.64**
Members of my household took my concerns seriously.	0.294	0.079	3.705	< 0.001	**	**0.54**
Belonging ~						
I felt comfortable talking to members of my household.	0.314	0.092	3.400	0.002	**	**0.48**
Female or Non-Binary	0.943	0.348	2.712	0.010	*	**0.38**
Emotional Support at Home						
Performance-Competence ~						
Members of my household discussed college planning with me.	-0.583	0.119	-4.888	< 0.001	***	**1.05**
Members of my household discussed college planning with me.	0.328	0.111	2.952	0.006	**	**0.62**
Members of my household had discussions with me about my future goals.	0.283	0.105	2.702	0.011	*	**0.55**
Underrepresented Racially	-0.673	0.394	-1.707	0.098	.	**0.25**

Interest ~						
Engineering Identity: Performance/Competence	1.012	0.112	9.025	< 0.001	***	**0.78**
Members of my household helped with my homework.	-0.287	0.089	-3.229	0.003	**	**0.41**
Members of my household discussed things studied in class with me.	0.401	0.101	3.955	< 0.001	***	**0.63**
Members of my household discussed preparation for the ACT/SAT with me.	-0.195	0.087	-2.233	0.034	*	**0.31**
Members of my household had discussions with me about things that were troubling to me.	-0.172	0.068	-2.538	0.017	*	**0.25**
Members of my household helped me figure out how to navigate my transition to college.	0.299	0.073	4.092	< 0.001	***	**0.46**
Recognition ~						
Engineering Identity: Performance/Competence	0.337	0.151	2.229	0.035	*	**0.36**
Members of my household discussed my school courses with me.	-0.679	0.157	-4.318	< 0.001	***	**1.4**
Members of my household discussed things studied in class with me.	0.631	0.151	4.181	< 0.001	***	**1.35**
Members of my household discussed college planning with me.	0.227	0.109	2.082	0.047	*	**0.43**
Members of my household discussed college planning with me.	-0.139	0.116	-1.199	0.241		**0.27**
Underrepresented Racially	-1.010	0.361	-2.798	0.010	**	**0.39**
Female or Non-Binary	0.774	0.296	2.613	0.015	*	**0.38**
Belonging ~						
Members of my household checked my homework.	0.195	0.089	2.184	0.037	*	**0.36**
Members of my household discussed grades with me.	-0.327	0.109	-2.990	0.005	**	**0.54**
Members of my household discussed college planning with me.	-0.401	0.114	-3.516	< 0.001	**	**0.65**
Members of my household discussed college planning with me.	0.516	0.124	4.154	< 0.001	***	**0.85**
Underrepresented Racially	-1.184	0.411	-2.883	0.007	**	**0.39**
Female or Non-Binary	0.954	0.322	2.966	0.006	**	**0.39**
Physical Conditions of High School						
Interest ~						
Engineering Identity: Performance/Competence	1.028	0.127	8.090	< 0.001	***	**0.80**
My school had accessible access to working computers.	0.290	0.122	2.385	0.024	*	**0.26**
My school made me feel safe.	-0.220	0.102	-2.154	0.039	*	**0.24**
Emotional Conditions of High School						
Interest ~						

Engineering Identity: Performance/Competence	1.026	0.129	7.980	< 0.001	***	**0.80**
Teachers and staff at my school treated me differently than other students.	-0.218	0.095	-2.301	0.028	*	**0.23**
Recognition ~						
Engineering Identity: Performance/Competence	0.434	0.113	3.842	< 0.001	***	**0.46**
Teachers and staff at my school had discussions with me about my future goals.	0.367	0.079	4.639	< 0.001	***	**0.59**
Underrepresented Racially	-1.316	0.326	-4.037	< 0.001	***	**0.51**
Belonging ~						
Teachers and staff at my school discussed current local/national/global events with me.	0.281	0.109	2.586	0.014	*	**0.40**

Legend: Estimate = "Est."; Error = "Err."; *t*-value = "*t*", p-value = "*p*", Significance (see below) = "Sig."; *d* = Cohen's *d*.

Significance: p < 0.10 ".", p < 0.05 "*", p < 0.01 "", and p < 0.001 "***"**

Performance/Competence

Emotional resources significantly impact students' perceived performance and competence in engineering. Our results reveal that students who were comfortable discussing college and planning future goals with family members felt more competent and capable in their academic endeavors. This finding is also consistent with Samantha's case [9], where improved emotional support enhanced her confidence and academic performance. However, the opposite is also true for Samantha as her ongoing stress and conflict at home led to diminished self-confidence and self-efficacy, resulting in lower academic performance and confidence in her engineering skills. Additionally, Godwin et al.'s [5] research supports the idea that emotional backing contributes to a stronger sense of personal efficacy. Our data, as shown in Table 2, reinforces that emotional resources are crucial for enhancing students' self-perceived competence and performance.

Interest

Students' interest in engineering is also greatly impacted by emotional resources. Those students' who experienced encouraging interactions both at home and at school were more likely to develop and sustain an interest in the field. Samantha's improved engagement with engineering, following emotional support, reflects this trend. Godwin et al. [5] also emphasizes the importance of early encouragement in sustaining academic interest. Our findings, highlighted in Table 2, show that emotional resources significantly contribute to fostering and maintaining interest in engineering. Similarly, the physical conditions of the school environment–associated with financial conditions–also influences the level of interest in students. Particularly, having access to computers makes it possible for students' exposure to real world applications..

Recognition

Emotional resources have the strongest influence on students' sense of recognition in engineering. Our results demonstrate that students who felt supported both at home and school were more likely to report high levels of recognition. The opposite is also true for students who reported a tense environment such as recurrent yelling in their household. Particularly, students with more tumultuous households showed a lower level of recognition. Samantha's story illustrates this perfectly as increased support in her household led to greater recognition of her academic achievements while the stress and conflict within her home contributed to her struggles with self-esteem and her sense of achievement [9]. According to Godwin et al. [29], recognition is often tied to the support systems that validate students' efforts and achievements. The results, especially those in Table 2, confirm that emotional resources are crucial for enhancing students' perceptions of recognition in engineering.

The purpose of this study was to investigate how students' access to the resources are connected to their perceptions of themselves as engineers, particularly one's sense of belonging and engineering identity. Our research question (RQ) explored how students' access to physical, social, and emotional resources connected to their perceptions of themselves as engineers. We find that the validation and motivation obtained from students' peers amplifies their feeling of self as an engineer while also developing interpersonal relationships with them which creates a sense of belongingness. Therefore, it is possible to say that a student's perception of themselves as an engineer is most heavily impacted by emotional and educational resources. Socioeconomic resources seem to have little effect, and physical resources seem to affect a student's feeling of

belonging but does not seem to affect their perceived performance. These effects are overwhelmed by the impact of emotional resources nonetheless.

Implications

We found that both emotional and physical resources are important in shaping students' sense of belonging. Emotional resources, whether from home or school, not only foster a stronger sense of belonging but also significantly influence students' development of an engineering identity. On the other hand, physical resources primarily affect students' feelings of belonging, without directly impacting their engineering identity. This distinction highlights the broader role emotional support plays in both creating a connection to the field and helping students see themselves as engineers.

We believe that our results can help improve the attitudes and experiences of engineering students by using them as guidance to develop targeted interventions to address these issues. If staff members and teachers understand the impact that providing certain educational resources can have on a student's engineering experience, they could implement systems for students who aspire to pursue engineering. Schools could organize workshops or put in place clubs or competitions that encourage hands-on experience and practical experience in order to equip these students with technical skills that are valuable both at a college level and in the workforce. Similarly, creating mentorship programs that allow them to connect with engineering professionals can benefit them by obtaining valuable guidance. This approach would therefore contribute to creating an environment that provides the comprehensive support they need to achieve their goals.

As we previously discussed, it seems that students are most affected by the emotional conditions of their pre-college home. We cannot directly change the support that a student receives at home. However, it could benefit students if parents become more engaged with their school activities and discuss their future plans with them. If no plans have been considered yet, parents might explore their children's interests in school subjects and seek opportunities to expose them to these areas. This involvement can help students feel supported, recognized, and encourage open communication, making them feel comfortable being transparent about their uncertainties. Since parents might be unsure how to approach or address certain issues, we believe schools can act as a bridge to facilitate communication and inform parents about available opportunities while creating a supportive network for both students and families. Therefore, there may be opportunities to create organizations or systems to provide information and support for students and parents such as parent-teacher associations, after-school programs or mentorship programs and even parent support groups.

Conclusions, Limitations, & Future work

Our research aimed to uncover connections between access to resources and engineering students' sense of belonging and engineering identity, both of which are critical components of student success. Our study builds on prior research that suggested a lack of resource access, particularly among low-income students, could lead to doubts about belonging and low levels of engineering identity in engineering spaces. We therefore investigated these connections across students from diverse backgrounds, focusing on physical, social, and emotional resources in relation to engineering identity and belonging. Our results highlight the critical role of both

emotional and physical resources in shaping engineering students' experiences and their self-perceptions as engineers. These results provide valuable insights into how educational institutions can better support students from high school through higher education by ensuring that students' interests and resources are focused on and understood. Ultimately, addressing these factors can improve students' engagement, performance, and persistence in engineering, paving the way for a more successful and fulfilling academic and professional journey.

Future work will include expanding the sample size and diversity. The work presented here was only a pilot and is limited in its explainability. Expansion of the sample would provide a better understanding of how resources impact students from various backgrounds, providing better generalizability. Other work can further investigate the role of emotional resources and conditions in recognition. Parallel work by Panuganti et al., [30] has begun to investigate this component qualitatively and has found that students' emotional resources help them develop a feeling of "authenticity," particularly that they can be themselves. These feelings may be contributing to students' feelings of recognition, and thus overall engineering identity and belonging. Further investigation is needed to verify this connection.

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Appendix A

Q3 – Resources

Q3a = To what extent do you agree or disagree with the following statements as they pertain to your pre-college experiences?

Q3a_1 = My household had a computer/laptop.
Q3a_2 = My household had internet access.
Q3a_3 = My household owned a DVD player.
Q3a_4 = My household owned an electric dishwasher.
Q3a_5 = My household owned a clothes dryer.
Q3a_6 = My household owned 50 or more books.
Q3a_7 = I had my own room in my household.
Q3a_8 = I owned a cell phone.
Q3a_ 9 = My household had access to a reliable vehicle.
Q3a_10 = My household owned a phone.
Q3a_ 11 = My household owned a television.
Q3a_ 12 = My household owned an air conditioner.
Q3a_ 13 = My household owned a heater.
Q3a_ 14 = My household owned a gaming console.
Q3a_ 15 = I owned one or more pets.
Q3a_ 16 = I owned name-brand clothes.
VALUES: 1 through 7 (rating scale); 1 = "Strongly Disagree", 7 = "Strongly Agree", = missing

Q3b = To what extent do you agree or disagree with the following statements as they pertain to the socioeconomic conditions of your pre-college home?

Q3b_1 = My household regularly could not pay one or more bills.
Q3b_2 = It was common for utilities to be disconnected in my household.
Q3b_3 = My household regularly sold personal possessions to make ends meet.
Q3b_4 = My household could not afford many of the things I wanted.
Q3b_5 = I typically wore clothing that was older than that of my peers.
Q3b_6 = My household experienced difficulties paying for my school supplies.
Q3b_7 = My household experienced difficulties paying for groceries.
Q3b_8 = My household experienced difficulties paying the mortgage/rent.
Q3b_ 9 = My household experienced difficulties paying for transportation needs (e.g., gas maintenance, repairs).
Q3b_10 = My household did not go out to eat very much.
Q3b_ 11 = I received very little beyond the basics of what I needed.
Q3b_ 12 = My household took regular vacations.
VALUES: 1 through 7 (rating scale); 1 = "Strongly Disagree", 7 = "Strongly Agree", = missing

Q3c = To what extent do you agree or disagree with the following statements as they pertain to the physical conditions of your pre-college home?

Q3c_1 = My household felt crowded with people.
Q3c _2 = My home was regularly cluttered or dirty.
Q3c_3 = The temperature of my home was often too hot or cold.
Q3c_4 = The greenery surrounding my home was overgrown.
Q3c_5 = Members of my household hoarded items.

Q3c_6 = Members of my household were regularly ill.
Q3c_7 = Internal and external features of my home were regularly in disrepair.
Q3c _8 = My home regularly had an issue with pests (e.g., insects, mice).
Q3c _9 = My home regularly had clean running water.
Q3c_10 = My home had problems with mold.
Q3c_11 = Members of my household could visit healthcare professionals when they needed to.
Q3c_12 = My household could easily access a grocery store.
Q3c_13 = My household shopped at stores with a large variety of options.
VALUES: 1 through 7 (rating scale); 1 = "Strongly Disagree", 7 = "Strongly Agree", = missing

Q3d = To what extent do you agree or disagree with the following statements as they pertain to the emotional conditions of your pre-college home?
Q3d_1 = Yelling was a regular occurrence in my household.
Q3d _2 = It was common for physical altercations to take place in my household.
Q3d_3 = My household felt tense.
Q3d_4 = I commonly felt I was "walking on eggshells" in my household.
Q3d_5 = I felt comfortable talking to members of my household.
Q3d_6 = Members of my household took my concerns seriously.
Q3d_7 = Members of my household took my mental health seriously.
Q3d _8 = Members of my household were often irritated by individual differences or different points of view.
Q3d _9 = When I was growing up, members of my household used me as a confidant but were not a confidant for me.
Q3d_10 = Members of my household often said and did things without thinking about the feelings of others.
Q3d_11 = I rarely received attention from members of my household.
Q3d_12 = The mood of specific members of my household impacted everyone else.
Q3d_13 = I feel like I could never do enough to make members of my household happy.
Q3d_14 = Open, honest communication with members of my household was difficult or impossible.
Q3d_15 = I ran or hid when something happened in my household.
VALUES: 1 through 7 (rating scale); 1 = "Strongly Disagree", 7 = "Strongly Agree", = missing

Q3e = To what extent do you agree or disagree with the following statements as they pertain to educational support in your pre-college home?
Q3e_1 = Members of my household checked my homework.
Q3e _2 = Members of my household helped with my homework.
Q3e_3 = Members of my household discussed my school courses with me.
Q3e_4 = Members of my household discussed things studied in class with me.
Q3e_5 = Members of my household discussed school activities with me.
Q3e_6 = Members of my household discussed grades with me.
Q3e_7 = Members of my household discussed preparation for the ACT/SAT with me.
Q3e _8 = Members of my household discussed college planning with me.
Q3e _9 = Members of my household discussed current local/national/global events with me.
Q3e _10 = Members of my household had discussions with me about things that were troubling to me.

Q3e_11 = Members of my household helped me fill out college forms (e.g., applications, financial aid).
Q3e_12 = Members of my household helped me figure out how to navigate my transition to college.
Q3e_13 = Members of my household had discussions about my friends with me.
Q3e_14 = Members of my household had discussions with me about things that interested me.
Q3e_15 = Members of my household had discussions with me about my future goals.
VALUES: 1 through 7 (rating scale); 1 = "Strongly Disagree", 7 = "Strongly Agree", = missing

Q3f = To what extent do you agree or disagree with the following statements as they pertain to your pre-college school's conditions in high school?
Q3f_1 = The structure of my school was falling apart.
Q3f _2 = My school had poor heating or cooling.
Q3f_3 = The science labs in my school were in working condition.
Q3f_4 = My school was well-maintained.
Q3f_5 = My school was crowded.
Q3f_6 = My school's library felt like it was well-funded.
Q3f_7 = My school had adequate access to textbooks and supplies.
Q3f _8 = My school had accessible access to working computers.
Q3f_9 = My school had accessible access to other forms of multi-media (e.g., movies, projectors, etc.)
Q3f_10 = My school made me feel safe.
Q3f_11 = My school had most of the things that students needed to succeed.
VALUES: 1 through 7 (rating scale); 1 = "Strongly Disagree", 7 = "Strongly Agree", = missing

Q3g = To what extent do you agree or disagree with the following statements as they pertain to the emotional conditions of your pre-college high school?
Q3g_1 = Teachers and staff at my school treated me differently than other students.
Q3g _2 = Teachers and staff at my school discussed preparation for the ACT/SAT with me.
Q3g_3 = Teachers and staff at my school discussed college planning with me.
Q3g_4 = Teachers and staff at my school discussed current local/national/global events with me.
Q3g_5 = Teachers and staff at my school helped me fill out college forms (e.g., applications, financial aid).
Q3g_6 = Teachers and staff at my school had discussions with me about things that interested me.
Q3g_7 = Teachers and staff at my school had discussions with me about my future goals.
Q3g _8 = Teachers and staff at my school talked about my home life with me.
VALUES: 1 through 7 (rating scale); 1 = "Strongly Disagree", 7 = "Strongly Agree", = missing

Q3h = To what extent do you agree or disagree with the following statements as they pertain to your pre-college school experiences in high school?
Q3h_1 = It was easy to get involved in extracurricular activities.
Q3h _2 = My high school had a lot of cliques.
Q3h_3 = My teachers/staff were there when we needed them.
Q3h_4 = Other students were there when we needed them.
Q3h_5 = My high school was a community.

Q3h_6 = My high school was welcoming to newcomers.
Q3h_7 = It was easy to get lost in the shuffle in my high school.
Q3h _8 = My high school was "tight knit."
Q3h _9 = Everyone knew each other at my high school.
Q3h_10 = I felt like I belonged in my high school.
VALUES: 1 through 7 (rating scale); 1 = “Strongly Disagree”, 7 = “Strongly Agree”, = missing

Q9 - Faculty Caring and Belonging
Q9b = We would like to know about how you feel that you fit in engineering and belong in your engineering community.
Q9b_1 = I feel comfortable in engineering.
Q9b_2 = I feel I belong in engineering.
Q9b_3 = I enjoy being in engineering.
Q9b_4 = I feel comfortable in my engineering classes.
Q9b_5 = I feel supported in my engineering classes.
Q9b_6 = I feel that I am part of my engineering classes.
Q9b_7 = I feel that my engineering classes are large.
VALUES: 1 through 7 (rating scale); 1 = “Not at all”, 7 = “Very much so”, = missing

Q12 – ID, Motivation, & Agency
Q12a = To what extent do you agree or disagree with the following statements:
Q12a_1 = I see myself as a physics person
Q12a_2 = I see myself as a math person
Q12a_3 = I feel like an engineer now
Q12a_4 = I will feel like an engineer in the future
Q12a_5 = I see myself as an engineer
Q12a_6 = My parents see me as an engineer
Q12a_7 = My instructors see me as an engineer
Q12a_8 = My peers see me as an engineer
Q12a_9 = I have had experiences in which I was recognized as an engineer
Q12a_10 = I am interested in learning more about engineering
Q12a_11 = I enjoy learning engineering
Q12a_12 = I find fulfillment in doing engineering
Q12a_13 = I am confident that I can understand engineering in class
Q12a_14 = If you are reading this statement select two
Q12a_15 = I am confident that I can understand engineering outside of class
Q12a_16 = I can do well on exams in engineering
Q12a_17 = I understand concepts I have studied in engineering
Q12a_18 = Others ask me for help in engineering
Q12a_19 = I can overcome setbacks in engineering
VALUES: 1-7 (rating scale); 1 = “Strongly Disagree”, 7 = “Strongly Agree”, = missing