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Exploring Climate and Student Persistence in Engineering and Computer Science through Engineering Culture (Work in Progress)

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Abstract

This work in progress (WIP) paper describes the initial stages of a project to explore students' perceived climate and how that influences their persistence within engineering and computer science (ECS). Attrition of historically marginalized populations within ECS fields is often attributed to 'chilly climates'. We recognized the potential for such a chilly climate at our institution when analyzing the results of a retention study of the current undergraduate population within ECS. To address this, we conducted a mixed-method study to explore how climate (operationalized through sense of belonging, pedagogical experiences, and ECS culture) impacts student persistence. This survey was piloted with 100 undergraduate ECS students. Preliminary results of examining the ECS Culture Scale and associated qualitative survey question indicates that participants are aware of and have internalized ECS cultural values. Women and racial and ethnic minorities strongly identify with their majors and believe that working hard will lead to their success. At the same time, aspects of their values are in tension with the dominant culture (e.g., they strongly agree that an ability to help others is a central message of their major). These students have strong intentions to persist and use their isolated status and stereotypes associated with their identity to succeed in spite of outside perceptions of them. In contrast, those that believe that assumptions made about them do not impact their intention to persist (who are predominantly White and Asian men) do not recognize dominant cultural norms as strongly and are more ambivalent about their major being a big part of their identity. These results suggest that underrepresented students who intend to persist have internalized the dominant culture within ECS, which helps enable their success. For students who have not internalized that culture, the 'chilly climate' is likely all the chillier, which may influence their persistence.

1. Introduction

Undergraduate retention and persistence has been studied extensively in higher education and within engineering education [1]–[6]. In STEM fields like engineering, retaining students is important to building and growing a talented and qualified technical workforce to drive long term economic growth and help solve societal challenges. Despite decades of research, six-year graduation rates within U.S. engineering undergraduate programs remain about 60% [7]–[9]. This research suggests that engineering students do not leave solely because they are not performing well academically [4], [6], [10] and that historically marginalized populations in engineering leave at higher rates [11]–[13]. Geisinger and Raman found six broad factors that influence retention or attrition including: grades and conceptual understanding, student self-efficacy and confidence, interest and career goals, identity, and climate [3]. They found that over half of the studies they explored in their extensive literature review mentioned climate as a factor for students' leaving engineering programs.

Climate includes the attitudes, perceptions, and expectations associated with an institution and can be informed by interactions with individuals within that institution [14]. This climate can be influenced by historical legacy of exclusion, current diversity, and how institutional structures and personnel contribute to creating positive climates and organizational structures and practices [15]. A "chilly" climate is one where pervasive patterns of inequitable treatment can inhibit a student's confidence, self-esteem, and accomplishment [16] and has been linked to attrition [6], [10], [17]. This chilly climate impacts teaching and advising practices [6], [10], [18], creates a competitive or hostile environment [19], and increases students' sense of isolation [20]–[22]. There has been a well-documented chilly climate within engineering, especially for women and historically marginalized groups [23]. Students who experience a chilly climate perceive a lack of belonging. This perception can result from experiences such as being ignored, differential treatment, attribution of achievement to affirmative action policies, sexual harassment, microaggressions, lack of role models, stereotype threat, and limited interaction with faculty [6], [24]. The culture within engineering and academic institutions can also contribute to climate issues for students. For example, engineering education is competitive [6], [19], individualistic [6], [25], and rigorous [26]. This can lead to a "weed-out" culture, where some courses are structured to filter students out of engineering to preserve its rigor [6], [27].

In an effort to understand the retention issues specific to our large public research university, we engaged in a retention study using available institutional data and senior exit surveys. This analysis illuminated how factors such as student preparation (e.g., calculus readiness) and logistical issues (e.g., degree plan complexity, difficulty getting into classes) impact retention. While informative, this data only captured the experiences of the students who were successfully retained, emphasized the results of the dominant student population within engineering, and could only point to less easily measured factors such as social and pedagogical experiences. This combined with student reported dissatisfaction with the quality of teaching, qualitative responses citing a lack of social experiences, and a distinctive culture that prioritized hard work pointed towards the issue of a chilly climate within the school.

To explore this further, a sequential exploratory mixed-methods study was designed utilizing a survey collecting qualitative and quantitative responses which informs the second stage of the research (i.e., in-person interviews). While there are many contributors to a students' perceived climate, this study will specifically examine climate and its influence on student persistence through (a) Sense of Belonging; (b) Pedagogical Experiences; and (c) Engineering and Computer Science Culture. This work-in-progress (WIP) paper will describe the holistic approach used to develop the Climate and Student Persistence Survey (CASPS) and report preliminary survey results specific to ECS culture.

2. Background

2.1 Institutional context

The University of Texas at Dallas is a large public research university in the Southwest region of the United States. The university was initially founded in the 1960s specifically as a graduate school and to supply a highly qualified engineering workforce for Texas Instruments. The university began accepting undergraduate students in the 1990s and has experienced rapid growth in undergraduate programs, particularly in computer science and engineering. In 2021, the School of Engineering and Computer Science (ECS) became the largest undergraduate school within the university making up over 30% of the undergraduate population. While enrollments have dropped at other institutions due to the ongoing COVID-19 pandemic [28],

[29], enrollment has increased at UTD compared to pre-pandemic levels. However, six-year graduation rates within ECS remain lower than the university's average and national undergraduate engineering program averages [9].

2.2 Exploration of institutional level data and senior exit surveys

ECS conducted a retention study in Fall 2020 in order to assess current and historical degree attainment trends and uncover factors that may be hindering students from making degree progress. This study has currently examined institutional student data (e.g., enrollment, degree attainment, math placement, GPA, grades) from 2011 to present and 2019-2020 Senior Exit Surveys. The results of this ongoing analysis indicate the potential for retention issues that are not directly or insufficiently measured by these datasets or surveys (e.g., chilly climates). Below is a list of relevant findings from this study we predict are related to issues of climate.

- Women transfer out of engineering at greater rates than men and predominantly choose other STEM majors similar to their original engineering major (e.g., Biological engineering will transfer to Biochemistry) similar to what was found in [6]
    - Women who transferred out of engineering had a higher GPA than men who transferred out of engineering
- African American and Hispanic/Lantino/a students have lower six-year graduation rates within ECS compared to all students
    - They have similar or higher graduation rates within certain majors (e.g., African American students graduate at higher rates in Electrical Engineering similar to what was found in [30]
- On Senior Exit Surveys, the number one reason students listed as why they could not complete their degree in four years was 'Personal Reasons'
- Senior Exit Survey data revealed that students were not satisfied with the quality of teaching
    - Qualitative survey comments confirmed this dissatisfaction describing several issues including: lecture-based teaching vs. active and project-based learning, perception that faculty do not care about students, disrespect towards students, student concerns are not listened to, inconsistent assessment, and perception that faculty evaluations have no impact
- Senior Exit Survey results also revealed a lack of social or college experience at the university and especially within ECS
    - Students described dissatisfaction with the quantity and quality of engineering or computer science clubs or organizations as well as a lack of college experiences such as football games
    - Students described how they only show up for class and leave without engaging with their peers
- Students directly described climate issues on the Senior Exit survey including weed-out classes and how isolated they felt as a woman, racial minority, or LGBTQIA+ student
- Results from both institutional datasets and Senior Exit Surveys varied by major, indicating there may be microclimates created within departments.

These results indicate the presence of broad climate issues related to belonging, their experience within the classroom, and the culture and microclimates within departments and ECS. To gain insight into these difficult to measure factors, we decided to survey our current undergraduate population about the climate within their programs and how that was influenced by sense of belonging, the culture (e.g., technically focused, individualistic) within their majors, and their respective pedagogical experiences.

2.3 Sense of belonging

Undergraduate student retention models include social integration into the institution as a critical component in retaining students [2], [31]–[33]. In essence, students require a level of social connection with peers, faculty, and advisors within a university setting to persist and complete their education [2], however some students may experience additional stressors such as prejudice and discrimination that impact their feelings of acceptance within an institution or their majors (i.e., sense of belonging) [34], [35]. For example, in a study of 487 first and second year undergraduate students they found that experiencing discrimination is associated with lower commitment to the institution for Latino students [36]. This lack of belonging can also impact whether students intend to stay in their majors. Women who reported a lower sense of belonging in STEM were more likely to switch out of their major [37]. Because sense of belonging is a measure of how students feel accepted and integrated into their institution and majors, a lack of sense of belonging may indicate an unfriendly or unwelcoming climate.

Climate is experienced differentially by underrepresented and historically marginalized students. Underrepresented and historically marginalized students in engineering and computer science encounter spaces which are dominated by White, male, Western, heterosexual, able-bodied, and neurotypical ways of thinking and being. As a result, students who do not embody these traits are often isolated [38]–[40], made to feel invisible [41], [42], tokenized [43], [44], experience stereotype threat [45]–[47], denigrated [48], and/or harassed [49]. They often lack faculty role models and mentors who share their experiences unique to their identities [6], [50]. As a result, they do not see themselves represented at higher levels such as faculty or graduate students. They also may have trouble finding community and creating social connections that help inoculate them against other challenging issues within engineering education.

Faculty play a critical role in influencing students' sense of belonging [31], [52], [53]. By being approachable and accessible, offering support and guidance, and providing professional development opportunities, faculty can influence how students identify with their discipline [53]. Research shows that students who experience more faculty interaction, have greater sense of community, and felt valued by professors more are more likely to be committed to engineering [51].

2.3 Pedagogical experiences

Experiences within the classroom and with faculty can also affect a student's perceived climate. Student interaction with faculty has a positive effect on student development, involvement and retention [54]. Informal contact between faculty and students both inside and outside the classroom increases first year persistence [33]. High attrition rates for undergraduate science and engineering students have been linked to inadequate faculty guidance and how unengaging the lecture model of teaching is [6]. Likewise, Marra and colleagues found that poor teaching and advising, the difficulty level of the engineering curriculum, and the lack of belonging in engineering influence engineering students' decision to leave [10]. Other research has also shown that students cite the inaccessible or unapproachable nature of faculty as a reason they leave engineering [55]. Faculty can influence student self-perception especially of their competence and correspondingly student performance and persistence [55]. Faculty are also key players in setting and sustaining disciplinary cultures.

2.4 Engineering and computer science culture

The perceived climate can be influenced by the culture within engineering and computer science and how a student identifies within that culture. Culture encompasses day to day behaviors and practices, values, and deeply held underlying beliefs and assumptions. Culture is taught to new members through the 'correct' way to perceive, think, and feel [56]. The disciplinary culture of engineering is highly technical, objective, individualistic, decontextualized, emotionless, rigorous, meritocratic, and depoliticized [26], [57], [58]. Engineering ways of thinking prioritize tangible, definable, measurable, and quantifiable reality where mathematics and visual diagrams act as an important means of communication [59]. Engineers see themselves as problem solvers, reducing complex real-life problems into logical, pragmatic solutions with a focus on cost, time, and efficiency [25], [60]. Within engineering, there is a strict adherence and valuation of 'rigor' where faculty have implicitly and explicitly taught courses in a way that filters out students who are 'unfit' for engineering through a fast curriculum pace, extensive workload, and fostering competition for grades [26], [59], [61]. This engineering culture simultaneously vaunts objectivity and being apolitical while reinforcing White, masculine, heterosexual, colonial, and Western ways of thinking. This culture and how it influences climate are often cited as possible explanation for the lack of persistence in engineering and computer science for unrepresented students [12], [50], [51], [62], [63].

3. Methods

3.1 Climate and student persistence survey (CASPS)

The Climate and student persistence survey (CASPS) was designed with three sections that inform student perception of climate: (1) Sense of Belonging (SB); (2) Pedagogical Experiences (PE); and (3) Engineering and Computer Science Culture (EC). A section of voluntary demographic information was also included to provide insight into whether students were experiencing climate differentially based upon identity factors. A brief summary of these sections is provided in Table 1. The survey contains both quantitative Likert scale questions where participants were asked to rate their agreement with a statements on a scale of 1-5, where 1 = Strongly Disagree, 2 = Somewhat Disagree, 3 = Neutral, 4 = Somewhat Agree, 5 = Strongly Agree. Qualitative questions were also included to give more context to student responses. At the end of the survey students were allowed to provide any additional comments or feedback and asked if they would like to be considered to participate in an interview as part of the larger mixed-method study.

3.1.1 Sense of belonging scale (SB)

The sense of belonging section was adapted from Lounsebury and DeNeui's Collegiate Psychological Sense of Community Scale [64] and included questions specific to persistence within their ECS majors. These items were then combined into a composite score to give each participant an overall SB score. Only one item in the scale was reverse coded [i.e., SB-10: I wish I had selected another major] to develop the composite SB score. We deliberately incorporated domain specific (i.e., major) belonging within the items as students' belonging to the institution may differ from their belonging within engineering and computer science [65].

Table 1. Summary of CASPS sections.

Survey Section	**Items**	**Description**	**Example Likert Question**	**Example Qualitative Question**
Sense of Belonging	11 Likert quantitative questions 2 qualitative free-response	Adapted from validated Sense of Belonging scale [64]. Measures the perceived sense of support and level of connection students feel with each other and within ECS.	I feel connected and supported by my peers within ECS	Describe an experience where someone within ECS (e.g., student, staff, faculty) made you feel like you belonged (or did not belong) in your major.
Pedagogical Experiences	11 Likert quantitative questions 2 qualitative free-response	Developed based on the results of the Senior Exit Surveys to assess how students' perception of climate manifests in the classroom through interactions with faculty and the curriculum.	I feel that grading and assessment within ECS classes is consistent and fair	Please describe an instance where an ECS professor helped or hindered you within or outside of the classroom. Why was it helpful (or not helpful)?
ECS Culture	12 Likert quantitative questions 1 qualitative free-response	Developed from a literature search and previous work. Assesses to what degree students recognize and ascribe to the dominant culture within ECS.	My major is a completely objective discipline	How have the assumptions that have been made about you as an ECS student affected your intention to persist (or not persist) in your ECS major?

3.1.2 Pedagogical experiences scale (PE)

The Pedagogical Experiences section was incorporated to assess how climate manifested within the classroom or curricular experiences with an emphasis on interactions with faculty. While climate can be informed by experiences outside the classroom (e.g., clubs, learning communities), our focus on the classroom was informed by the results of the Senior Exit Surveys. Our students described a culture of going to class and leaving immediately, feeling no impetus to stay on campus longer than they had to. Thus, we decided to narrow our focus to their experience within classroom. Like with the SB scale, the questions are asked from a positive perspective (e.g., I feel respected by ECS faculty within and outside the classroom) so that students could indicate their level of agreement with the statement. One item in the scale was reverse coded (i.e., PE-6: I feel like I have to teach myself the content within my ECS courses to be successful on homework and exams) to develop the composite PE score.

3.1.3 Engineering and computer science culture Scale (EC)

The ECS culture section was incorporated to assess the degree students recognize and ascribe to the dominant culture within ECS. Undergraduate students have preconceptions of what engineering and computer science is before enrolling which are reinforced or in conflict with how faculty teach engineering and maintain the dominant culture within their field. This scale was designed to address dominant cultural messages of rigor [26], meritocracy [66], objectivity and the culture of disengagement [57], sociotechnical dualism [67], the value of efficiency [60], [68], innate intelligence and math and science ability [69], [70], individualism [71]–[73], the culture of hard work and difficulty [59], [74], and expectation of a lucrative career in industry [74]. Additional items were included to address the historical and persistent demographic underrepresentation of women, racial and ethnic minorities, LGBTQIA+ students, etc. (e.g., I have felt isolated within my ECS major) and how strongly they identify with their major (i.e., My major is a big part of who I am).

3.2 Research participation and collected data

Data collection for the pilot launch of the survey began in the Fall 2021 semester. After receiving IRB approval, the survey was sent out to all currently enrolled undergraduates on an email list-serv, advertised on official ECS social media (i.e., Facebook, Instagram, Twitter) accounts, and posted within ECS buildings on campus on flyers with a QR code linked to the survey. We received a total of 100 responses to this initial survey. All questions were voluntary with no forced answers resulting in participation dropping as participants progressed through the survey. Of these, 100 responded to the SB scale, 82 responded to the PE scale, and 76 to the EC scale. These scales will be considered separately for this preliminary work. Qualitative questions also had variable response rates from 59 to 74 responses.

A comparison of the demographics of the 100 survey respondents and the Fall 2021 enrolled undergraduate ECS population is provided in Table 2. Additionally, 23% of respondents identified as transfer students, 14% as first-generation students, 27% as part of the LGBTQIA+ community, and 17% as having a disability (e.g., learning, mental, or physical disability, chronic illness). Descriptive statistics for survey items were calculated (e.g., means, standard deviations). Significant differences between groups were not calculated due to small sample sizes. Qualitative questions were analyzed thematically to generate preliminary categories [75], [76] .

Table 2. Self-identified demographic information of CASPS respondents compared to Fall 2021 undergraduate population within ECS.

Factor	% of Survey Respondents	Fall 2021 ECS Demographics
Biomedical Engineering (BMEN)	6%	7%
Computer Engineering (CE)	3%	8%
Computer Science (CS)	57%	52%
Electrical Engineering (EE)	12%	9%
Mechanical Engineering (MECH)	16%	16%
Software Engineering (SE)	5%	8%
Man	65%	80%
Woman	21%	20%
Other or Not indicated	10%	0%
Asian	37%	40%
African American or Black	4%	5%
Hispanic or Latino/a	6%	16%
White	39%	27%
Two or More	11%	4%
Other or not indicated	3%	8%

3.3 Limitations and boundaries of inquiry

Cultures within institutions are highly contextual and therefore the results may only have limited transferability. This small pilot survey received 100 responses despite frequent advertising through multiple venues (email list servs, social media, flyers), indicating a general reluctance to participate among the undergraduate student population within ECS. In this pilot phase of the survey, no statistical significance tests were run between groups because of the low survey response rate. Therefore, described differences between groups could be exaggerated and based upon self-selection bias. It is likely that underrepresented minority (URM) responses were affected by this self-selection bias. URM who responded to this survey reported high sense of belonging and low levels of mistreatment by their peers and faculty while White and Asian students reported ambivalent or low sense of belonging and mistreatment. It is possible that URM who were secure in their current program felt safe enough to respond while the White and Asian student population responded despite their varied experiences.

4. Preliminary results

Initial results indicate that, overall, students are ambivalent about feeling connected and supported by their peers ($\text{SB-COMP}_{\text{ALL}}$=3.4), but indicated high intention to persist ($\text{SB-11}_{\text{ALL}}$=4.5) where 1= strongly disagree and 5=strongly agree [77]. Participants were also ambivalent about their pedagogical experiences ($\text{PE-COMP}_{\text{ALL}}$=3.3) including ambivalence about feeling respected by faculty and fairness and consistency in grading. Students felt they had to teach themselves to be successful (PE-6_{ALL}=4.2) and disagreed that class content resonated with their personal experiences (PE-9_{ALL}=2.8).

4.1 ECS culture

Participants showed strong agreement with ECS Culture statements, especially about weed-out classes (EC-1_{ALL}=4.1), working hard (EC-2_{ALL}=4.2), placing a high value on efficiency (EC-4_{ALL}=4.3), meritocracy (EC-9_{ALL}=4.2), and that their ECS degree will earn them a lucrative career ($\text{EC-11}_{\text{ALL}}$=3.9). A culture of individualism was also prevalent and students agreed with feeling isolated within their major (EC-7_{ALL}=3.8). The majority of participants did not feel mistreated by faculty or other students within their major (EC-8_{ALL}=2.3). Participants were ambivalent about being naturally gifted at math and science ($\text{EC-10}_{\text{ALL}}$=2.9), and their major being completely objective (EC-5_{ALL}=3.4). The means and standard deviations of these items are provided in Tables 3 and 4.

4.2 Culture within majors

There were only a few participants who responded from the smaller ECS majors (e.g., CE) so no statistical significance tests were performed. The ECS culture scale results by major (Table 3) suggests the presence of microclimates within specific majors. For example, Biomedical Engineering (BMEN) students strongly agree that their major contains weed-out classes ($\text{EC-1}_{\text{BMEN}}$=4.8 vs EC-1_{ALL}=4.1) and that they have to work harder than non-engineering and computer science majors ($\text{EC-2}_{\text{BMEN}}$=5.0 vs EC-2_{ALL}=4.2). While ECS students agree that they have to work harder, all BMEN participants selected 5=strongly agree. Additionally, BMEN agreed to the meritocratic statement that if they work hard enough they can be successful ($\text{EC-9}_{\text{BMEN}}$=4.7 vs EC-9_{ALL}=4.2). Mechanical engineering (MECH) students were also in higher agreement that they have to work harder than non ECS majors ($EC\text{-}2_{MECH}$=4.8). Unlike the general ECS participant population they were less ambivalent about having to be naturally good at math and science to be successful ($EC\text{-}10_{MECH}$=3.8 vs $EC\text{-}10_{ALL}$=2.9). There are also differences in how students perceive their field. BMEN students strongly agreed that a central message of their major is to help others ($EC\text{-}6_{BMEN}$=4.7 vs $EC\text{-}6_{ALL}$=3.2). CE, CS, and EE students disagreed that helping others was a central message of their field while MECH and SE students were more ambivalent about it. ECS students felt isolated ($EC\text{-}7_{ALL}$=3.8), but BMEN students are in greater agreement about feeling isolated ($EC\text{-}7_{BMEN}$=4.3).

4.3 ECS culture among groups

The starkest differences in agreement to ECS Culture items were with women and men. Women felt much stronger that certain classes were weed-out classes ($EC\text{-}1_{Women}$=4.4 vs $EC\text{-}1_{Men}$=4.0) and that they had to work harder than non-ECS students ($EC\text{-}2_{Women}$=4.7 vs $EC\text{-}2_{Men}$=4.1). Some of women's perceptions were in tension with dominant cultures in ECS. They were less likely to agree that their majors were a completely objective discipline ($EC\text{-}5_{Women}$=3.1 vs $EC\text{-}5_{Men}$=3.6) and more likely to agree that an ability to help others was a central message of their major ($EC\text{-}6_{Women}$=3.7 vs $EC\text{-}6_{Men}$=2.7). Additionally, they thought their majors were a big part of their identity compared to men ($EC\text{-}12_{Women}$=4.1 vs $EC\text{-}12_{Men}$=3.4).

There were a few differences in agreement to items based on race and ethnicity, particularly compared to White students. White and Hispanic/Latino/a students were less likely to agree that certain classes were weed-out classes ($EC\text{-}1_{White}$=3.8, $EC\text{-}1_{Hispanic}$=3.8) compared to Black ($EC\text{-}1_{Black}$=4.7) and Asian students ($EC\text{-}1_{Asian}$=4.3). White students were also less likely to agree that they had to work harder than non ECS students ($EC\text{-}2_{White}$=3.8), than Black ($EC\text{-}2_{Black}$=5.0) or Asian students ($EC\text{-}2_{Asian}$=4.4). Black students were in tension with the ECS culture statement that it is more important to have technical skills than people skills. They were in strong agreement that an ability to help others is a central message in their major ($EC\text{-}6_{Black}$=4.5), which was much higher than all students ($EC\text{-}6_{ALL}$=2.8). Black and Hispanic/Latino/a students ascribed highly to the meritocratic view if they worked hard enough they could be successful while being ambivalent or disagreeing with the view that students had to be naturally gifted at math and science to be successful. Asian students were slightly more likely to agree that their major is completely objective. White and Asian students were less likely to agree their major was a big part of their identity ($EC\text{-}12_{White}$=3.5, $EC\text{-}12_{Asian}$=3.2) than Black ($EC\text{-}12_{Black}$=4.3) or Hispanic/Latino/a ($EC\text{-}12_{Hispanic}$=4.5) students.

Participants that identified as First Generation also expressed some tension between dominant culture values. They were more ambivalent that their majors were completely objective ($EC\text{-}5_{FirstGen}$=3.1 vs $EC\text{-}5_{ALL}$=3.4). However, they were more likely to agree that it is more important to have technical skills over people skills ($EC\text{-}3_{FirstGen}$=4.0 vs $EC\text{-}3_{ALL}$=3.7) and they aligned with the full participant population with their disagreement that an ability to help others was a central message of their major ($EC\text{-}6_{FirstGen}$=2.8 vs $EC\text{-}6_{ALL}$=2.8). LGBTQIA+ identifying students and students who have a disability also showed this internal tension, being ambivalent about their majors being completely objective and disagreeing that an ability to help others was a central message of their major.

Table 3. Means and standard deviations (in brackets) from the Engineering and Computer Science (ECS) scale by major. Questions asked students to agree with a statement on a scale of 1-5 where 1=strongly disagree and 5=strongly agree.

Question key	Short Description	All Students n=76	BMEN n=6	CE n=2	CS n=42	EE n=10	MECH n=14	SE n=2
EC-1	Weed-out Classes	4.1 (1.2)	4.8 (0.4)	3.5 (0.7)	4.0 (1.1)	3.9 (1.1)	4.1 (1.4)	3.0 (2.8)
EC-2	Work harder than others	4.2 (1.1)	5.0 (0.0)	4.0 (1.4)	4.0 (1.2)	4.0 (1.2)	4.8 (0.6)	3.0 (2.8)
EC-3	Technical skills vs. people skills	3.7 (1.2)	3.2 (1.2)	3.5 (0.7)	3.6 (1.3)	4.0 (1.1)	3.8 (1.1)	2.5 (0.7)
EC-4	Value efficiency	4.3 (0.9)	4.8 (0.4)	3.5 (0.7)	4.3 (1.0)	4.3 (1.1)	4.2 (0.7)	4.0 (1.4)
EC-5	Completely objective major	3.4 (1.2)	3.3 (1.5)	3.5 (0.7)	3.3 (1.1)	3.5 (1.3)	3.5 (1.4)	4.0 (1.4)
EC-6	Ability to help others is important within major	2.8 (1.4)	4.7 (0.8)	2.5 (0.7)	2.5 (1.3)	2.4 (0.9)	3.2 (1.5)	3.5 (0.7)
EC-7	Felt isolated within major	3.8 (1.3)	4.3 (1.2)	2.5 (2.1)	3.8 (1.2)	4.0 (1.2)	3.7 (1.2)	3.0 (2.8)
EC-8	Felt mistreated by others	2.3 (1.1)	2.2 (1.2)	1.5 (0.7)	2.4 (1.3)	1.8 (1.0)	2.7 (1.5)	3.0 (2.8)
EC-9	Working hard= successful	4.2 (1.1)	4.7 (0.5)	4.5 (0.7)	4.1 (1.3)	4.3 (0.8)	4.1 (1.1)	5.0 (0.0)
EC-10	Naturally gifted at math/science	2.9 (1.3)	3.0 (1.5)	2.5 (0.7)	2.8 (1.3)	2.9 (1.4)	3.7 (1.2)	3.5 (0.7)
EC-11	Lucrative career	3.9 (0.9)	3.8 (1.2)	3.5 (0.7)	4.0 (1.0)	3.6 (0.7)	4.1 (0.6)	3.5 (0.7)
EC-12	Major is part of identity	3.6 (1.4)	3.8 (1.6)	2.5 (0.7)	3.6 (1.4)	3.0 (1.1)	3.9 (1.3)	3.0 (2.8)

Table 4. Means and standard deviations from the Engineering and Computer Science (ECS) scale by identity factor. Questions asked students to agree with a statement on a scale of 1-5 where 1=strongly disagree and 5=strongly agree.

Q Key	**Short description**	**All Students n=76**	**F n=17**	**M n=48**	**Asian n=39**	**Black n=3**	**Hispanic n=9**	**White n=45**	**LGBT+ n=22**	**First-Gen n=12**	**Has Disability n=14**
EC-1	Weed-out Classes	4.1 (1.2)	4.4 (0.9)	4.0 (1.2)	4.3 (0.9)	4.7 (0.6)	3.8 (1.5)	3.9 (1.3)	4.1 (1.1)	3.7 (1.0)	4.4 (0.9)
EC-2	Work harder than others	4.2 (1.1)	4.7 (0.7)	4.1 (1.2)	4.4 (1.0)	5.0 (0.0)	4.0 (1.4)	3.8 (1.2)	3.8 (1.4)	3.9 (1.2)	3.9 (1.4)
EC-3	Technical skills vs. people skills	3.7 (1.2)	3.5 (1.2)	3.7 (1.2)	3.7 (1.2)	3.0 (1.0)	3.8 (1.3)	3.5 (1.4)	3.2 (1.4)	4.0 (1.1)	3.9 (1.4)
EC-4	Value efficiency	4.3 (0.9)	4.5 (0.7)	4.3 (0.9)	4.4 (0.7)	5.0 (0.0)	4.5 (1.0)	4.2 (1.1)	4.3 (0.8)	4.3 (1.1)	4.6 (0.6)
EC-5	Completely objective major	3.4 (1.2)	3.1 (1.5)	3.6 (1.1)	3.6 (1.1)	3.3 (2.1)	3.0 (1.4)	3.3 (1.1)	3.0 (1.1)	3.1 (1.1)	3.4 (1.2)
EC-6	Ability to help others is important within major	2.8 (1.4)	3.7 (1.4)	2.7 (1.3)	2.9 (1.5)	4.5 (0.7)	2.5 (1.3)	2.7 (1.3)	2.4 (1.4)	2.8 (1.6)	2.5 (1.5)
EC-7	Felt isolated within major	3.8 (1.3)	4.0 (1.2)	3.7 (1.3)	3.9 (1.2)	3.7 (1.2)	3.8 (1.9)	3.8 (1.3)	3.8 (1.2)	3.7 (1.1)	4.1 (0.9)
EC-8	Felt mistreated by others	2.3 (1.1)	2.4 (1.5)	2.3 (1.3)	2.3 (1.2)	1.3 (0.6)	1.5 (0.6)	2.5 (1.5)	2.3 (1.2)	2.3 (1.3)	2.6 (1.4)
EC-9	Working hard= successful	4.2 (1.1)	4.4 (0.7)	4.2 (1.2)	4.3 (0.9)	4.7 (0.6)	4.8 (0.5)	4.2 (1.3)	4.2 (1.1)	4.2 (1.2)	3.9 (1.3)
EC-10	Naturally gifted at math/science	2.9 (1.3)	3.1 (1.4)	2.9 (1.4)	3.0 (1.3)	3.0 (2.0)	2.0 (0.8)	2.9 (1.4)	2.9 (1.3)	3.3 (1.2)	2.8 (1.3)
EC-11	Lucrative career	3.9 (0.9)	4.3 (0.7)	3.9 (0.9)	3.8 (1.0)	4.7 (0.6)	4.5 (0.6)	4.0 (0.8)	4.3 (0.8)	3.7 (1.0)	4.2 (0.8)
EC-12	Major is part of identity	3.6 (1.4)	4.1 (1.1)	3.4 (1.4)	3.2 (1.5)	4.3 (1.2)	4.5 (0.6)	3.5 (1.3)	3.5 (1.5)	3.8 (1.0)	3.8 (1.5)

4.4 Qualitative survey results

Several qualitative questions were included in the survey that were geared towards the three sections (i.e., Sense of Belonging, Pedagogical Experience, ECS Culture). The ECS culture qualitative question asked participants: *How have the assumptions that have been made about you as an ECS student affected your intention to persist (or not persist) in your ECS major*? There was a wide range of responses from a denial that assumptions made about them had any impact on their persistence intentions to feeling so isolated that assumptions did not impact them at all. Some students described being invigorated by the challenge and difficulty of ECS majors or that they wanted to persist in spite of challenges. Others took pride in the assumption that they were intelligent and skilled while some were negatively impacted by assumptions about math and science skill when they struggled with those subjects.

4.4.1 Assumptions do not impact persistence

There were many responses, predominantly expressed by White and Asian men, that indicated that they did not feel that assumptions made about them did not impact their persistence at all. Only 2 out of 23 of these responses were expressed by women and 4 out of 23 of these responses were by races or ethnicities other than White or Asian. Some even questioned the existence of assumptions altogether. For example, one student stated:

> *The assumptions that have been made about me as an ECS student have not affected my intention to persist (or not persist) in my ECS major. Although to be fair, I don't know what these assumptions are, who is making these assumptions, nor if these so-called "assumptions" even exist at all* (SE, White, Man).

4.4.2 Persisting in spite of challenges

There were many participants who expressed that they were aware of assumptions of ECS majors being difficult or that they would be a minority within their field but that motivated them to persist. For example, one participant stated, “It is somewhat motivating to be a woman in ECS. My desire to succeed in a male dominated field has caused me to persist” (MECH, Hispanic/Latino/a, Woman). Another was inspired by the challenge of the difficult major. He stated, “Assumptions over ECS majors being hard have made me persist within the major since I like the challenge. I enjoy the thought of me graduating from a major to be considered one of the more difficult within the university” (EE, Black, Man). Another felt they had to prove stereotypes wrong. She stated:

> *The assumption that I will be less successful due to my gender has greatly affected my intention to persist. I feel that it is my duty to prove stereotypes about women in STEM wrong, and that my success reflects not only my efforts, but the efforts of my support network* (MECH, White, Woman).

4.4.3 Difficulty as a double-edged sword (pride vs. demoralization)

The assumption that ECS majors were difficult was both motivating and demotivating for students to persist. Some participants took pride in being a major that was considered difficult. This pride acted an inoculant despite experiencing difficulty. For example, one participant said:

> *When people tell me the assumptions they make about MECH majors including myself, it gives me a kind of pride to know that I am associated with this group of individuals. It makes me want to continue to pursue this Major* (MECH, White, Male).

However, this difficulty came at a cost when considering math and science skills. If students were struggling with math or science, they felt that was a reflection of their ability to be successful in or persist in their majors. For example, one participant stated, "[Assumptions] have made me doubt my ability in my math and science skills. And made me feel [like I] sucked since there's not a lot of people like me" (MECH, Black, Other/Not Indicated). Another denied that expectations affected his intention to persist but that they were emotionally difficult. He stated:

> *I don't think [assumptions] had much of an effect on my intent to persist, because I've always been fairly determined to be a CS major. However, the assumptions that ECS students are all great at math and algorithms has made it harder to feel okay about myself when I'm struggling with a topic* (CS, White, Other/Not Indicated).

5. Discussion

Women and other underrepresented students often find their identities in tension with the dominant culture within engineering and computer science [25], [26], [57]. These students do not see themselves both physically in these spaces (i.e., lack of faculty and professional role models that share their identity) and in the curriculum (e.g., lack of culturally relevant examples that build upon their funds of knowledge). For example, women encounter cues that convey that engineering and computer science are masculine [78], [79]. In our survey, women had a stronger perception of dominant cultures within ECS such as the presence of weed-out classes than the surveyed men did. Additionally, they were in stronger agreement than men that they had to work harder than non ECS students, and that their majors were a large part of their identity. However, some of these dominant discourses in engineering were in tension with their perceptions (i.e., an ability to help others being a central message of their major). Black students also showed this tension specific to an ability to help others. Some students select technical fields like engineering not only for personal empowerment but as a way to help others and their community [80]–[82]. For example, Canney and Bielefeldt found that female engineering students had more positive social responsibility attitudes than male engineering students [82]. However, social responsibility attitudes decrease over time [83] as these students are socialized into a culture of disengagement that prioritizes the technical over the social aspects of engineering [57], [67].

These culture tensions are also differential by major, specifically for Biomedical Engineering (BMEN). BMEN participants strongly agreed that there were weed-out classes, they had to work harder than non-ECS majors, efficiency was highly valued, and if they worked hard enough they can be successful. However, unlike other ECS majors, BMEN participants strongly agreed that an ability to help others is a central message in their major. This is likely because BMEN is a newer discipline within engineering, is one of the newer majors established at our institution in 2010, and it attracts more women than other engineering majors [84]. While BMEN participants agreed that helping others was important to their major, they were ambivalent about technical skills being more important than people skills. In this way, they are expressing the sociotechnical dualism where social and technical skills are not mutually exclusive but rather exist in tension with an implied hierarchy [67]. Just as social responsibility attitudes can decrease over time for other majors [83], it is possible that BMEN and ECS students become more ambivalent about the importance of helping others within their major over the course of their undergraduate career.

Women, Black, and Hispanic/Latino/a participants expressed a stronger belief in working hard leading to success (i.e., meritocracy) than White or men participants. In the qualitative responses they also expressed working hard to overcome assumptions made about them. These responses to using the challenges associated with being undervalued or stereotyped to persist within their major are reminiscent of the ‘prove them wrong syndrome’ [85]. In one study, Black students in engineering described the need to disprove negative stereotypes about them even at Historically Black Colleges and Universities [81].These results suggest that persistence may come at a price. This could be through psychological distress as was suggested by their emotional reactions to not doing well in math and science or shouldering the burden of being an example to look up to for others who share their identity. There is also the price of conforming to or resisting the dominant engineering and computer science culture. Participants recognized assumptions made about them and used that to motivate their persistence by working harder to spite the perception that those within their identity group are not successful in these majors. Students who represent the majority population (i.e., White and Asian males) did not have to do this same underlying work and expressed not being affected by assumptions or doubting that they exist.

6. Implications

Participants recognized aspects of the dominant culture within ECS and assumptions made about them and used that to motivate their persistence by being proud of overcoming difficulty and to spite the perception that their identity group are not successful in these majors. On the other hand, students who represent the majority population (i.e., White and Asian males) expressed not being affected by assumptions or doubting that they exist. These results suggest that the URM students who took this survey are persisting because they identify with the dominant ECS culture. In fact, the surveyed women and underrepresented minority participants more strongly agreed that their major was a big part of their identity than White, Asian, and male students. However, students who may be more interested in the social aspects of engineering and computer science (e.g., helping others) may feel the necessity to forego or dampen these social responsibility attitudes over time. Even when students think that using their disciplinary field to help others is important, technical and economic aspects will likely take precedence over social considerations in their coursework and as they enter the workforce. While these students are likely to persist in ECS, the dominant culture that creates chilly climates that lead to attrition for other students is also likely to persist as well. This may help explain why despite extensive efforts to recruit and retain underrepresented students within engineering, the field remains predominantly White and male [6], [84]. Future work will examine semi-structured interview data and consider how this culture, students’ pedagogical experiences, and sense of belonging interact to form a climate that inhibits or fosters persistence.

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