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Examination of Perceived Climate, Engineering Identity, and Belongingness among Undergraduate Women in Engineering

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Abstract: More women than men in the US graduate college, but women constitute only 16% of the engineering workforce [1]. Women frequently attribute their lack of persistence in engineering to a chilly academic climate [2]. Researchers have suggested that developing a robust engineering identity could moderate a climate effect and support improved retention and graduation of female engineers [2]. However, there is little empirical data on interrelationships among gender, perceived academic climate in engineering programs, engineering identity, and belonging to an engineering community.

We drew on social identity theory and extant literature to develop four research questions: 1) Are there any differences between men and women regarding perceived academic climate, sense of belonging, and engineering identity? 2) Does academic climate predict engineering identity in the same way for women and men? 3)Does sense of belonging mediate the relationship between perceived academic climate and engineering identity? 4) Do engineering students who are women demonstrate different relationships among perceived climate, engineering identity, and belongingness from men?

We used survey data from a multi-year NSF-funded project (Award # 1726268, #1726088, and #1725880/2033129) that incorporated experimental course-based interventions to build an inclusive curriculum. Surveys were administered at the beginning and end of the semester. We found that at the end of the semester women engineering undergraduates reported lower

engineering identity though the initial engineering identity, perceived academic climate, and sense of belonging were the same for both men and women engineering undergraduates. Multiple regression analyses with 601 first-year engineer majors (21% female) indicated perceived climate and gender accounted for 48% of engineering identity variability. The interaction between perceived climate and gender on engineering identity was not statistically significant. Mediation analysis revealed that sense of belonging (b=0.42, 95% CI [0.30, 0.53]) mediated the relationship between perceived climate and engineering identity for both males and females. Sense of belonging was critical in engineering identity. Moderated mediation analysis indicated gender did not moderate the indirect effect of perceived climate on engineering identity through a sense of belonging.

Keywords: Women in engineering, gender and engineering, engineering identity, perceived academic climate, sense of belonging

Introduction

Despite persistent efforts to promote diversity, equity, and inclusion with more women attending and graduating from college than men, women remain woefully underrepresented in engineering. Women are about half (52%) of the college-educated workforce but the percentages of female students in the engineering classrooms and the profession are less than expected [1]. Women comprised 22% of the bachelor's degrees conferred in engineering by the postsecondary institutions in the 2017-18 academic year [3], and only 16% of the engineering workforce [1]. Female undergraduate students switch majors and leave engineering during the first two academic years at higher rates than their male counterparts

[4]. Women frequently attribute their lack of persistence in engineering programs and the engineering workforce to a historically male-dominated climate in engineering [2].

This study is situated in a larger study directly targeting the chilly climate in engineering by addressing the issues head on through classroom-based intervention activities. Within this work, engineering identity is at the core of the constructs of interest. Identity as the central issue of retention and success in a program has rightly gotten much attention from engineering researchers and educators. However, interrelationships among how women perceive their academic climate, identify with the profession, and feel a part of the engineering community have not been well established in the extant published literature. Our primary focus was to study those interrelationships, and compare whether they differ between men and women engineering undergraduates. We narrowed our interest down especially on first-year female undergraduates in engineering because the attrition rate of female engineering first-year undergraduates is alarming [4].

Perceived academic climate and engineering identity

Usually, the academic climate is a social component of a learning environment that represents learners' perspectives of institutional policy, procedures and rules [5], [6]. Students' perception of academic climate is constructed with the interaction of organizational factors- like organizational fairness factor and diversity promotion and personal factors- like personal diversity value and comfort [7]. The personal factors are dependent on personal characteristics (like race, gender, ethnicity, and backgrounds). So, the perception of academic climate, an influential factor of students' learning, can be different depending on the individual's background as well as organizational factors. Academic climate perception often

shapes students 'sense of fit' in engineering field. Students' sense of fit in engineering is also called the engineering identity. For example, Rincón & George-Jackson found that women's perception of unsupportive academic climate is often tied to their lack of engineering identity [8] [9].

Perceived academic climate and sense of belonging

While academic climate refers to the perception of the learning environment, a sense of belonging is to what extent a student feels a part of their learning environment and academic community [10]. It was found that students from minority groups may view the academic climate as more uncomfortable and feel a lower sense of belonging [11], [12]. Women who are also underrepresented in the STEM field perceive their academic climate as more unwelcoming than their men peers that may affect a feeling of alienation [13].

Sense of belonging and engineering identity

The definition of students' sense of belonging and engineering identity sometimes overlaps because they have some similarities but there are also some distinctions between the two constructs. Students sense of belonging relates to their reflection on current experiences and greater affective components in their majors, like- how comfortable they feel in engineering classroom or college. It emerges from the self-reflection of the students' feelings when they compare themselves with their peers [10]. On the other hand, engineering identity is their broader sense of fit in the engineering discipline, like- the extent student sees themselves as a prospective engineer [14], [15].

In an engineering context, learning engineering content also requires becoming a member of the engineering community by increased participation and developing a sense of belonging. This theory of Lave and Wenger (1991) suggests an important role of sense of belonging in developing an academic identity [16].

Theoretical framework

Based on a multiple identity lens, identity is how we see and define ourselves and others [17], and therefore a central component of learning and development. We focus on understanding how different types of identity (gender, and academic identity) interact and are informed by the environment. Tate and Linn studied the experiences of women of color engineering students through the multiple identity lens. They found that students developed an academic identity, social identity, and intellectual identity, and the interactions between these three identities influenced the perception of their educational experiences [18].

We drew on social identity theory that connects two components of identity- social and personal. The personal component is individual traits and the social component is informed by group membership (ingroup vs outgroup). Group membership is formed by the perceived climate and underlies three mental processes: social categorization (by sorting similar characteristics, and can result in racism, sexism, etc.), social identification (modifying behavior, attitudes, and beliefs to match the group), and social comparison (compare in-group with other groups to affirm identity) [19]. This theory suggests that background characteristics and academic climate can be responsible for differences in feelings of belonging to a group and the development of social identity. In an engineering classroom,

students come from different backgrounds with an already established initial engineering identity that can be different for men and women [20]. Our work enhances current understandings of whether and how an intervened academic climate can mitigate those differences in belonging and identity.

Engineering identity is a kind of professional identity that lies under the umbrella of social identity, indicating how competent engineering students' view themselves and perceive how others see themselves in the engineering fields [15]. It has two components- personal, and social. Like other types of social identities (gender, religion, professional), engineering identity is also made up of experiences with others (peers, teachers, professionals, etc.). A student will have a stronger identification with the field if they think they match the professional demands. They will show higher interest, will see themselves as competent to perform academically or in engineering related tasks, and feel recognized by themselves and others as an engineer [21]. Women in engineering develop engineering identity through the interaction of four dimensions of identities, which include academic identities, institutional identities, gender identities, and role models in the field [22].

Social identity theory emphasizes heavily on group membership or feeling of belonging to a group that enhances stronger identity. Sense of belonging is an ongoing process of becoming a part of a group. The process of "becoming" a member of a group has been extensively studied by Lave and Wenger. Lave [16] showed how newcomers become recognized members of a community by participation and learn by the process of becoming. In an engineering context, learning engineering requires becoming a member of the engineering community through increased participation and development of a sense of belonging. Current

literature has not focused on the role of sense of belonging in perceived climate and identity in engineering contexts. However, from social identity theory, it can be hypothesized that sense of belonging will mediate the effect of perceived academic climate on engineering identity. As our context is engineering classroom, with an inclusive curriculum having classroom-based interventions, we will focus on organizational diversity promotion factor as an indicator of climate perception.

Our proposed model based on the literature review is as follows:

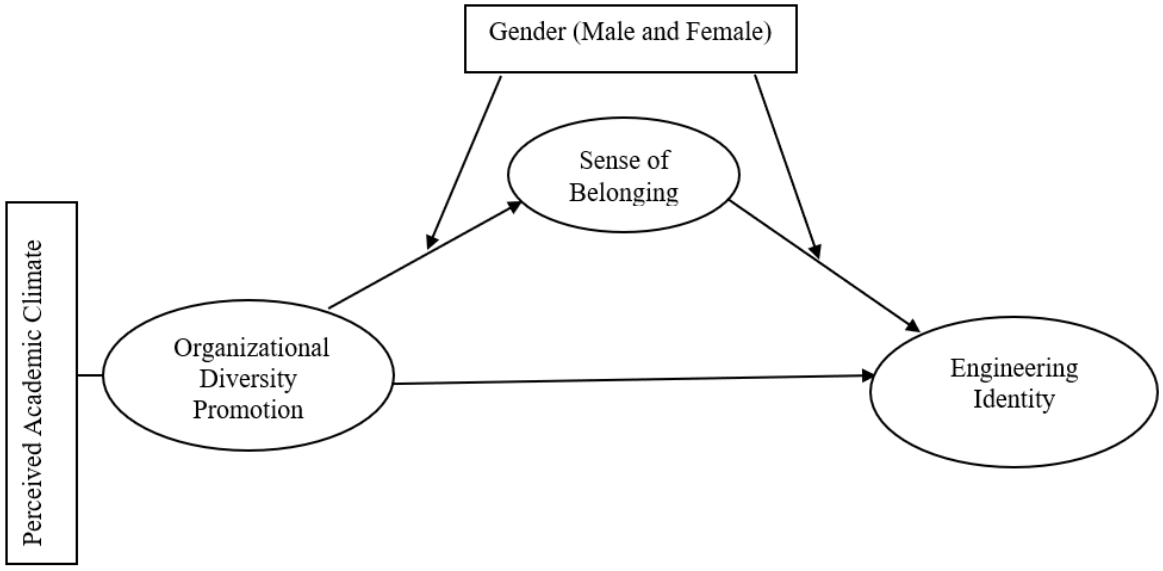

Figure1: Proposed Model (showing the relationship of Perceived climate, sense of belonging and engineering identity based on gender)

Current Study

This study sits within a larger study designed to help all engineering students develop an inclusive professional identity. In addition to having excellent technical skills, students with

an inclusive professional identity [23] seek out diversity in teams, leverage diversity to improve team dynamics and outcomes, and consider a wide range of potential consumers of their products or services. In this five year NSF funded initiative, we work with engineering and computer science instructors at four distinct campuses to incorporate course-based learning activities (for example- assignments, out of class experiences, learning modules, etc.) that promote at least one of elements of an inclusive professional identity. For this study, we examined whether an inclusive curriculum reduced discrepancies in perceived engineering climate, engineering identity, and sense of belonging between women and men engineering students.

We developed four research questions based on our review of extant literature. These are-

1. Are there any differences between men and women regarding perceived academic climate, sense of belonging, and engineering identity?
2. Does academic climate predict engineering identity in the same way for women and men?
3. Does sense of belonging mediate the relationship between perceived academic climate and engineering identity?
4. Do engineering students who are women demonstrate different relationships among perceived climate, engineering identity, and belongingness from men?

Methods

Participants

This study was conducted at a large R1 research university in the mid-Atlantic region. A total of 601 first-year engineering undergraduates (21.3% women, 78.7% men) with an average age of 18.19 years (*SD* = 0.88) participated. Of note, students were given multiple options for gender, but the students in this study only selected either men or women.

Procedure

This work was part of a larger multi-year NSF funded grant that incorporated experimental interventions to build an inclusive curriculum. Surveys were administered at the beginning and end of each semester as part of that project. The surveys included scales to measure perceived academic climate, sense of belonging in engineering classes, and engineering identity, as well as demographic questions such as gender and ethnicity.

Measures

In the larger NSF project, the surveys included demographic items, and measures of different psychological constructs. We used gender variable which was an open-ended question of students' self-reported gender. Later, we coded their responses. We have used the scales of perceived academic climate (organizational diversity promotion dimension), engineering identity and sense of belonging that included around 20 items. All scale items' responses were Likert type ranging from 0 (strongly disagree) to 6 (strongly agree).

Students' perceived academic climate measure was borrowed from the work of Mor Barak, et al [7]. We used the organizational diversity promotion factor containing 5 items as an indicator of academic climate perception. Sample items include, "I think my campus climate is positive in terms of issues concerning diversity.", "I think there are numerous efforts to increase diversity on campus". Higher scores on the scale indicates positive perception of the academic climate. This measure had acceptable internal consistency (α = 0.90).

University sense of belonging of the students was measured using a 11-item scale, adapted from the work of Slaten [24] and Goodenow [25]. The sense of belonging scale contained items such as, "I see myself as part of the community in [this university's Engineering] College.", "I feel like I fit in [this university's Engineering] College.". We reversed coded two items. Higher scores on this scale indicated a higher sense of belonging. The sense of belonging measure had a good internal consistency (α = 0.89).

Engineering identity was measured using 4 items such as, "In general, being an engineer is an important part of my self-image.", "I have come to think of myself as 'an engineer' ", developed from Chemers' science identity survey [14], [26]. Higher scores were associated with stronger engineering identity. The engineering identity scale had good internal consistency (α = .93).

Results

Research Question 1. Are there any differences between men and women regarding perceived academic climate, sense of belonging, and engineering identity?

We investigated our first research question by applying an independent sample *t*-test. The differences between women and men undergraduates' initial engineering identity [$t_{(595)}$ = 0.68, $p > 0.05$], perceived academic climate [$t_{(394)} = 1.05$, $p > 0.05$], and sense of belonging [$t_{(394)} = 1.07$, $p > 0.05$] were not statistically significant. But compared to male undergraduates ($M = 4.38$, $SD = 1.41$, $N = 302$), female undergraduates ($M = 4.02$, $SD = 1.43$, $N = 94$) reported statistically significant lower engineering identity [$t_{(394)} = 2.14$, $p < 0.05$], at the end of the semester.

Research Question 2. Does academic climate predict engineering identity in the same way for women and men?

We did a multiple regression analysis to see whether perceived academic climate and gender predicted engineering identity after controlling the initial identity. The overall model accounted for a substantial amount of variance in engineering identity, R^2=0.47 [F (4, 388) = 85.01, p <.05]. Perceived academic climate was found to significantly predict undergraduates' engineering identity $F(1, 392) = 34.47$, $p < .05$. We did not find any effect of gender (coded as 0=male, and 1=female) in predicting engineering identity, F (1, 392) = 0.12, $p > .05$. The interaction of perceived climate and gender on engineering identity was also not significant, $F(1, 392) = 0.00$, $p > .05$.

For female undergraduates, the perceived climate was a predictor of engineering identity, B=0.34, t=3.39, p< .05, 95% CI: [0.14, 0.54], with a small effect size, η_p^2 = 0.03. The

perceived climate was also a predictor of engineering identity for male undergraduates, B=0.35, t=6.07, p<.05, 95% CI: [0.23, 0.46], with a medium effect size, η_p^2 = 0.09.

Research Question 3. Does sense of belonging mediate the relationship between perceived academic climate and engineering identity?

To answer our third research question, we did a mediation analysis. We examined any indirect effect of students' perceived climate scores on their engineering identity through their sense of belonging. The analysis was conducted using the PROCESS macro in SPSS. The significance of the indirect effect was tested through calculation of a bootstrap confidence interval using 5,000 bootstrap samples. Initial evaluation of the model revealed that perceived climate score was a significant predictor of students' sense of belonging (X to M), b=0.45, t=10.75, p<.05. Further, sense of belonging predicted students' engineering identity (M to Y), b=0.92, t=16.10, p< .05. Combined with perceived climate, sense of belonging accounted for approximately 48% of the variance in engineering identity (R^2=0.48). The direct effect of perceived climate on engineering identity was not statistically significant, b= 0.07, 95% CI [-0.03, 0.18]. Finally, the indirect effect of perceived climate on engineering identity through sense of belonging was statistically significant, b=0.42, 95% CI [0.30, 0.53], indicating that students' sense of belonging completely mediated the relation between their perceived climate and their engineering identity.

Research Question 4. Do engineering students who are women demonstrate different relationships among perceived climate, engineering identity, and belongingness from men?

To investigate our fourth research question, we conducted a moderated mediation analysis to determine whether gender moderated the indirect effect of climate on engineering identity through sense of belonging. The significance of the difference between conditional indirect effects was tested through calculation of a bootstrap confidence interval using 5,000 bootstrap samples. Initially, the interaction between perceived academic climate and gender was not statistically significant, b= -0.04, SE=0.10, t= -0.37, p>.05, and accounted for no additional variances in undergraduates' sense of belonging, ΔR^2=0.00. The interaction between sense of belonging and gender was not statistically significant, b=0.15, SE=0.12, t=1.23, p>.05, and accounted for no additional variances in undergraduates' engineering identity, ΔR^2=0.00. The difference between conditional indirect effects was not statistically significant, moderated mediation index= -0.03, Bootstrapped SE= 0.12, 95% CI [-0.23, 0.27]. That means the indirect effect of perceived climate on engineering identity through sense of belonging was not moderated by gender.

Discussion

We examined three constructs to understand undergraduate women's experience as compared to their male peers in an inclusive curriculum intervention: perceived academic climate, university sense of belonging, and engineering identity. The results of our first research question showed that at the end of the semester female undergraduates had lower engineering identity than male undergraduates. This was true even though their initial engineering identity, overall perceived academic climate, and sense of belonging were the same.

Previous studies on engineering identity framed the learning environment or campus climate as the influential factor in determining engineering identity. Thus, our second research question was shaped. We did a multiple regression analysis to examine whether perceived climate predicted engineering identity in the same way for female and male undergraduates. We found that perceived climate was a positive predictor of engineering identity. That is, positive perception of engineering climate was associated with stronger engineering identity. The interaction of perceived climate and gender was not significant. That means the perception of climate predicts engineering identity similarly across genders.

We next inspected the role of sense of belonging that prior research showed to be important in learning and development [16]. While students' positive climate perception significantly predicted stronger engineer identity, this relationship was completely mediated by sense of belonging. So, it appears that interventions expected to strengthen engineering identity by changing engineering classroom climate do so by strengthening students' sense of belonging.

Our last research question investigated whether the relationship among climate perception, sense of belonging, and engineering identity established in analysis of the third research question varied across genders. Our moderated mediation analysis did not find any effect of moderation by gender. We assumed that the classroom interventions might minimize the effect of gender. However, comparing the results of this study with a control group can be more informative.

We contribute to literature on the relationship among three important constructs in engineering education focusing on women in engineering. We considered the context of inclusive curriculum and showed the importance of a sense of belonging in developing engineering identity. Sense of belonging is a salient factor that enhances in-group feelings that confirm group membership and help develop stronger identity with the group [19]. While planning and designing an intervention for empowering women in engineering classrooms, it should be kept in mind whether the intervention is able to foster a sense of belonging in a way that women feel they are a part of the engineering community. Strengthening group dynamics can help minimize climate effects. So, interventions should be designed around increasing women students' belongingness in an engineering group. Increasing participation and meaningful interaction among engineering students can be helpful.

Limitations

Two limitations should be considered to contextualize our findings. First, we excluded a small number of non-binary respondents and retained only those self-selecting either male or female gender. We acknowledge that gender is a socially constructed non-binary phenomena. Second, we utilized a composite score for perceived academic climate although this scale has subscales on which male and female respondents may differ.

Future scope

Future studies should focus on all the students of different gender identities with focused efforts to obtain sufficient numbers of respondents across that continuum. An in-depth analysis of perceived academic climate subscales by gender might be useful. While we found

no interaction with gender, at the end of the semester women engineering students engineering identity was lower. Future research should incorporate other methodologies to explore what causes such decreases in women undergraduates' engineering identity. A qualitative analysis could include female undergraduates to have more information and better understanding of how their engineering identity is shaped in an inclusive curriculum.

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