

A Cross-Sectional Study of Belonging in Engineering Communities*

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Few research efforts in engineering education study the impact of affect on student experience. However, a substantial number of interventions, research centers, and similar organized efforts seek to improve the strength and cohesiveness of the community in which the student spends a substantial part of his or her time. Belonging and the related affective sense of connection to community are viewed implicitly in these efforts as a positive attribute of the intervention, yet rarely are these improvements explicitly measured. This work reports the results of the sense of belonging (and community) of students within a variety of engineering education venues, using measures that have been previously validated in K-12 educational venues and whose validity is confirmed for the higher education, engineering populations studied herein. Differences between the local (immediate) community and the larger community to which the engineering student or faculty belongs have been analyzed in conjunction with the sense of belonging experienced by engineers in five academic venues including conferences, classrooms, and retreats. Overall, the results show that an engineering sense of belonging is highest in local (immediate) venues in which community building is part of the venue mission (along with transformative goals for engineering research education), but lowest in undergraduate engineering classrooms. The sense of belonging in the larger community to which the engineer belongs tends to be highest for faculty, then graduate students, then undergraduate students. Sense of belonging is also highly correlated to the psychological sense of community (PSC), technical competence, and feelings of being socially at ease. Faculty-student relatedness, a major player in student fulfillment, is less correlated to belonging but still (moderately) related.

Keywords: belonging; psychological sense of community; affect; engagement; identity

1. INTRODUCTION

1.1 What is belonging?

BELONGING, BELONGINGNESS, psychological sense of community, and affiliation are all constructs that speak to the relational connections that people develop with others in the communities in which they live, work, and play. Of these constructs, belonging is the most fundamental and it is believed to be a basic human motivation [1]; belonging reflects the stable and consistent relational bonds that a person experiences in everyday life in proximate communities. All persons seek to satisfy the need to belong and a lack of belonging can lead to sub-optimal (compensating) behaviors and negative academic and social outcomes. Belonging can lay the foundation for a stronger sense of connection to other, surrounding communities, including the larger organizations in which someone participates and is affiliated. In this study, belonging is investigated in a cross-section of academic communities in higher education, ranging from research conferences to professional retreats to the classroom itself. Fundamental perceptions of belonging are studied relative to connections to the surrounding home

institution (i.e. the Psychological Sense of Community or PSC) for each study participant as well as other constructs that may mediate or influence belonging (e.g. faculty-student relatedness, social efficacy, and technical competence).

1.2 Why is belonging important in engineering education?

As a fundamental human motivation, belonging is important in any endeavor, whether academic, commercial, or otherwise. In engineering education, belonging may be especially important in the study of academic outcomes, because belonging and the psychological sense of community (PSC) are moderated by extraversion [2]; since engineering is dominated by introverts [3], particular emphasis toward the healthy development of belonging and PSC may be influential in the affective contribution associated with positive academic outcomes and engagement.

Working to improve personal interest and professional engagement in engineering education as well as aptitude enables not only an increase in students trained for the technical workforce but also a broadening of capability, beyond the purely technical, toward a social world view that will continue to dominate technical innovation in the 21st century [4]. The literature, gathered from

* Accepted 12 December 2009.

higher education, K-12, and organizational psychology clearly supports the importance of relational community in influencing engagement and cognitive outcomes and performance. Belonging and other connections to community are known and significant contributions to engagement in K-12 education [5–7]. A greater sense of connection to community, ranging from the immediate (belonging) to the broad (affiliation) level can also enhance retention, thereby delivering greater numbers of engineers to the technical workforce.

The explanatory power and programmatic utility of this theoretical construct is supported not only by the K-12 body of literature where belonging and membership in the school community are proven to influence drop out rates [8] but also by higher education research that cites lack of community (i.e. isolation) as a primary reason for women to leave engineering fields [9, 10] and connection to faculty community as a strong contributor to Hispanic student persistence in academic endeavors [11]. Improvements in retention resulting from increases in connection to community are also supported by the higher education model of social integration developed by Tinto, where student goals and commitments formed by pre-college attributes interact with their college experiences to indicate whether students are likely to complete an academic program [12, 13].

Belonging (consisting of the most local, social relational bonds in a community) is especially important because it is a “. . . powerful, fundamental, and extremely pervasive” motivation of humans to fulfill needs for attachment through social bonds ([1], p. 497). Sociocultural theories of human learning highlight the importance of negotiated individual identification with specific communities of practice (i.e. membership) and group-authorized roles for individuals to take on within community activities [14–16]. These dimensions of social participation are crucially contingent upon an individual sense of belonging within a given community and such activities serve to deepen our sense of belonging within particular communities over time.

Community also begets community; students who have not experienced a strong sense of community (and belonging) in their undergraduate experience would be less likely, in the long term, to take a critical community leadership role in industry. Moving from academia to the work place, a sense of belonging can result in increased feelings of security, stronger self-concept, self-respect, and coping abilities [2] and is cited in organizational behavior texts as part of the definition of an organization (e.g. [17]). Thus, from the perspective of the 21st century workforce, improved understanding of and ability to build community in engineering education venues links to essential needs in the technological workforce.

Despite the fact that sense of community may be

harder to build among introverts, the fact that sense of belonging has been strongly linked to academic engagement makes it an important contributor (whether direct or mediating) to academic achievement. Thus, it is an important affective measure to be understood in assessing the success of any intervention but in particular those focused on enhancing and building community among engineering students. Of interest in this investigation are not only differences in belonging assessed in a cross-section of academic engineering communities, but also the extension of belonging to the surrounding community, the psychological sense of community or PSC to the home institution. These two levels of connection to community are influenced by and influence other relational and affective constructs including relatedness, social comfort, and perceptions of technical competence. Thus, this study begins with the most basic question:

- What types of communities exhibit significant differences in participant belonging?

We then move on to address the ripple effect of belonging to surrounding or advanced communities:

- Does belonging increase as participation in a community advances from peripheral (e.g. undergraduate) to central (e.g. research in a Research I institution)?
- Does a strong sense of belonging extend to other related and larger communities (and associated psychological sense of community)?

This study also seeks to identify potential mediators and contributors to sense of belonging and PSC:

- How are belonging and PSC related to other aspects of the community in which the student participates?

This study lays a foundation for defining the qualities of engineering communities that are likely to successfully support belonging and to enable strategies that will increase belonging and sense of community in intensely technical environments. We advance the argument that increasing belonging ultimately increases engagement, which enables a broader set of active instructional strategies to be effectively implemented and practiced in the engineering educational arena.

1.3 Methods

This study has adapted items from instruments used to assess belonging in previous studies; all items were validated in the higher education contexts under investigation before being aggregated and used to understand belonging in all the study populations. All populations were self-selected (i.e. voluntary) and contained different combinations of faculty, undergraduate, and graduate student populations.

1.4 Survey

Respondents were asked to evaluate their sense of belonging in the immediate context (i.e. the event/location in which the survey is administered) and their related sense of community in the surrounding context of the home institution (PSC). Most items were previously validated items from the Anderson-Butcher belonging scale [18] used to assess sense of community in prior research. A complete list of survey items (used to assess belonging and PSC) and validation status is listed in Table 1 for clarity. The list consists of a subset of Anderson-Butcher belonging scale items that are particularly relevant to higher education settings. As a whole, these items are selected from a subset of survey items selected from (a) the entire set of Anderson-Butcher belonging items and (b) additional items considered for their validity in the higher education setting. Validity analyses were used to reduce the original set of survey items to a smaller subset that was clearly related to belonging (and PSC) in the higher education settings evaluated in this study. All items were assessed on a 5-point Likert scale.

Some items have been aggregated for the immediate context; for example, it is not practical to assess respondents' comfort with other students in a community (item 2) in which they only participate for a short period of time, such as in the case of a conference. Therefore, items "I feel comfortable with faculty" and "I feel comfortable with students" are replaced with the more appropriate, single aggregate item "I feel comfortable in the classroom" in the immediate context (conference/retreat/class). Belonging is then assessed using a total of four items in the immediate context (conference/retreat/class) and, as PSC, using a total of seven items in the surrounding context

(at the home institution). All study participants were asked to assess belonging and PSC while participating in the conference/retreat/class.

Items that were either not a part of the Anderson-Butcher survey items or did not load heavily into the belonging factor in the validity analysis are listed in Table 2. In exploratory factor analysis, four of these items loaded heavily onto one another and were aggregated into an additional construct: faculty-student relatedness. The remaining items were assessed individually as single factors and are not necessarily representative of a particular construct.

It is noteworthy that the feelings of acceptance (Item 11b) expressed by survey participants were validated as a representation of belonging in the original study (on which this survey was validated) but not in this higher education study. Feelings of acceptance were disconnected from sense of belonging in this study (while the same is not true for younger adolescent populations assessed in previous investigations using these items).

The remaining items (outside the Anderson-Butcher belonging items) used in this study were included for a number of reasons. Those items representing relationships between faculty and students (Items 8, 9, 10, 11b) were included because faculty-student relationships have been shown to have a strong influence on student affect and fulfillment among undergraduates in previous engineering education studies [19, 20]. Feelings of being socially at ease (Items 12a and 12b) are important because they relate to the mediating effect of extraversion on the ability of college students to develop a strong sense of community [2]. Since engineering students are predominantly introverted [3], it may be that a sense of belonging is more difficult to develop for

Table 1. Survey items used to assess belonging and PSC

Item #	Previously Validated	Belonging: Immediate Context	PSC: Surrounding Context
1	Yes	I feel comfortable in the conference/retreat/class.	I feel comfortable with faculty at my home institution.
2	Yes		I feel comfortable with students at my home institution.
3	Yes	I feel part of the conference/retreat/class.	I feel part of my home institution.
4	Yes	I feel supported at the conference/retreat/class.	I feel supported by faculty at my home institution.
5	Yes		I feel supported by students at my home institution.
6	Yes	I feel committed to the conference/retreat/class.	I feel committed to faculty at my home institution.
7	Yes		I feel committed to students at my home institution.

Table 2. Additional survey items

Item #	Context	Item	Construct Measured
8	Surrounding	I feel faculty and students trust each other at my home institution	Faculty-Student Relatedness (at the home institution)
9	Surrounding	I feel welcome to ask questions at my home institution.	
10	Surrounding	I feel faculty treat students with respect at my home institution.	
11b	Surrounding	I feel accepted by faculty at my home institution.	
12a	Surrounding	I feel socially at ease at my home institution.	Single Factor (Unknown Construct)
12b	Immediate	I feel socially at ease in the conference/retreat/classroom.	Single Factor (Unknown Construct)
13a	Surrounding	I feel technically competent at my home institution.	Single Factor (Unknown Construct)
13b	Immediate	I feel technically competent in the conference/retreat/classroom.	Single Factor (Unknown Construct)

engineers at the undergraduate, graduate, and faculty level. Finally, feelings of technical competence were considered especially relevant to the environments (engineering) under study because so much of the value of the education and the engineering identity revolves around technical content (and knowledge). These salient aspects of the engineering education environment may well affect the sense of belonging for students and faculty throughout their career.

1.5 Sample size and selection

The belonging survey has been administered to six different populations consisting of various combinations of faculty, graduate students, and undergraduate students. No participants were part of more than one of the six populations (i.e. the populations are non-overlapping). The six populations, the number of participants in the survey n and the total possible number of participants N (estimated) in each location are:

- Education Research Conference (EdConf): a venue for faculty and graduate students to present research results in engineering education. Engineering faculty are the majority of the conference population but graduate students are also present. Survey participants are self-selected from randomly chosen sessions in the conference ($n = 101$; $N = 1000$).
- Engineering Research Conference (EngConf): a venue for faculty and graduate students to present research results in sensors research. Graduate students are the majority of the conference population but faculty are also present. Survey participants are self-selected from randomly chosen sessions ($n = 29$; $N = 4000$).
- Engineering Research Center Retreat (Retreat 1): a venue for faculty and graduate students participating in NSF-sponsored research centers with a topical focus in an important, contemporary aspect of engineering research. Graduate students are the majority of the retreat population, but faculty and undergraduate students are also present. All participants are affiliated with one of several highly focused engineering research centers around the country. Survey participants are self-selected from a student-only, professional development workshop at the retreat ($n = 32$; $N = 200$).
- Science and Technology Center Retreat (Retreat 2): a venue for faculty and graduate students

participating in NSF-sponsored research centers with a topical focus on an important, contemporary aspect of scientific research. Graduate students are the majority of the retreat population, but faculty and undergraduate students are also present. All participants are affiliated with a representative science and technology center (which includes four participating higher education institutions). Survey participants are self-selected from a student-only, professional development workshop at the retreat ($n = 51$; $N = 200$).

- R1 sophomore classroom (R1 Sophomore): an introductory class for undergraduate students in electrical engineering at a major Research 1 university. Survey participants are self-selected from the class ($n = 42$; $N = 42$).
- R1 junior classroom (R1 Junior): a junior level core class for undergraduate students in electrical engineering from the same Research 1 university as R1 sophomore. Survey participants are self-selected from the randomly chosen core class ($n = 36$; $N = 55$).

Each participant completes the survey instrument containing two sets of survey items:

- one evaluating sense of belonging in the immediate context; for example, at the Engineering Research Center Retreat;
- evaluating sense of belonging in the broader context, at the home institution. These two contexts (for each population) are summarized in Table 3.

1.6 Survey validity

The core of the survey used for this investigation is a group of items taken directly from the validated form of a survey designed for and administered to younger adolescent populations in previous research (Anderson-Butcher & Conroy, 2002). Because of significant differences between the original population used for validation and this new (higher education) setting, the external validity of the Anderson-Butcher items needs to be established. To address external validity, an exploratory factor analysis ($n = 139$) was first conducted on all survey items. The items shown in Table 1 strongly loaded onto the first factor of the three factor analysis. To confirm the use of these items in representing student belonging, an informal face validity survey ($n = 11$) was also conducted among randomly selected graduate

Table 3. Context in study source populations

Source Population	Immediate Context	Surrounding Context
Ed Conf Eng Conf	Belonging at the Conference	PSC (Psychological Sense of Community) at the Home Institution
Retreat 1 Retreat 2	Belonging at the Retreat	
R1 Sophomore R1 Junior	Belonging in the Classroom	

students in engineering, staff (various non-STEM backgrounds), and graduate students in education. The face validity analysis confirmed that these items (a total of four in the immediate context and seven in the broader context) represented the construct of belonging in the different contexts (Table 2) studied herein. In summary, the validity analysis of the items taken from the Anderson-Butcher survey clearly produced a subset of items that represent the construct of belonging in the engineering education setting, thereby allowing the results of this study to be compared with results from other studies (in higher education, K-12, and elsewhere) on belonging and sense of community.

The engineering education conference results came from a preliminary study that did not use these validated survey items. In order to incorporate the results of the engineering education conference (Ed Conf) study in this belonging analysis, we use a simple, single level multilinear equation to structurally model the ability to predict sense of belonging from these three initial items. The three initial items:

- I feel welcome to ask questions;
- I feel technically competent;
- I feel socially at ease.

were evaluated in all six settings in this study. In the five settings that contained both these three initial items and the validated belonging items (Table 1), a simple multilinear model was used to evaluate the capability of the three initial items taken in the immediate context to predict belonging in the immediate context, and an additional three initial items taken in the surrounding context

to predict belonging, in the immediate and the surrounding context.

After multilinear regression was used to compute the coefficients for this multilinear model, the model was clearly able to predict belonging in the immediate and surrounding context for the Ed Conf data.

2. RESULTS

Belonging (in the immediate context) and PSC (belonging in the surrounding context) in all six populations have been aggregated in Table 4. The Ed Conf population (primarily faculty in engineering) demonstrated the highest combined connection to community while the R1 classrooms demonstrated the lowest connections to community (combined PSC and belonging). Significant differences were found in belonging between Retreat 1 and Retreat 2 ($p = 0.0305$; $F = 4.85$) and between Retreat 1 and the R1 Junior Classroom ($p = 0.0065$ and $F = 7.9$). The R1 Junior and R1 Sophomore populations were so similar in their responses that additional assessments of the classroom populations were made only for the R1 Junior population.

The additional survey items outlined in Table 2 were assessed for the four student-based populations that showed significant differences in belonging and PSC scores (Table 5). Significant differences in faculty-student relatedness were evident between the R1 Junior population (class) and all other student populations outside the classroom, including the research conference EngConf

Table 4. Belonging and PSC results in study populations

Population Information			Measures		
Type	Population Size	Sample Size	Context	Mean (μ)	Standard Dev (σ)
Ed Conf	1000	101	Immediate	4.45	0.74
			Surrounding (PSC)	4.32	0.81
Eng Conf	4000	29	Immediate	3.88	0.56
			Surrounding (PSC)	4.35	0.54
Retreat 1	200	32	Immediate	4.14	0.68
			Surrounding (PSC)	4.32	0.81
Retreat 2	200	51	Immediate	4.32	0.81
			Surrounding (PSC)	3.73	0.85
R1 Sophomore	42	42	Immediate	3.4	0.72
			Surrounding (PSC)	3.49	0.72
R1 Junior	55	36	Immediate	3.67	0.69
			Surrounding (PSC)	3.44	0.73

Table 5. Additional results in study populations

Item/Construct	Eng Conf		Retreat 1		Retreat 2		R1 Junior	
	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev
Faculty/Student Relatedness	4.18	0.67	4.25	0.68	3.98	0.91	3.68	0.73
Social Ease (12a): Immediate	3.97	0.68	4.16	0.81	n/a	n/a	3.78	0.87
Social Ease (12b): Surrounding	4.52	0.63	4.41	0.87	n/a	n/a	3.53	1.06
Technical Competence (13a): Immediate	4.0	0.71	4.41	0.8	3.64	0.95	3.61	0.87
Technical Competence (13b): Surrounding	4.41	0.68	4.16	0.72	3.88	0.91	3.56	0.94

($p = 0.0061$; $F = 8.06$), Retreat 1 ($p = 0.0022$; $F = 10.15$), and Retreat 2 ($p = 0.0523$ and $F = 3.87$). No significant differences in faculty-student relatedness among the non-classroom populations studied was demonstrated. Likewise, the classroom population (R1 Junior) reflected significant differences in feelings of being socially at ease in the class itself compared to student perceptions at the EngConf ($p = 0$; $F = 10.15$) and at the Retreat 1 ($p = 0$; $F = 19.73$). At the home institution, however, the EngConf population felt similarly uneasy in a social sense as the R1 Junior population; the Retreat 1 students, however, continued to demonstrate high levels of social ease even at the home institution when compared to the R1 Junior classroom ($p = 0$; $F = 13.76$) and other populations.

Technical competence played a surprising role at the conferences, retreats, and classrooms under study as well as in the home institution. Only the EngConf students showed high self perceptions of technical competence compared to the remaining populations (for example, $p = 0.0029$; $F = 9.6$ compared to R1 Junior) at their corresponding home institutions. In contrast, at the event (immediate context) itself, perceptions of technical competence varied widely, coming in lowest at the EngConf and in the R1 classroom, while being much higher at Retreat 2 ($p = 0.0002$; $F = 15.28$) followed by Retreat 1 at levels significantly higher than Retreat 2 ($p = 0.0079$; $F = 7.41$).

3. ANALYSIS AND DISCUSSION

3.1 What types of communities exhibit significant differences in belonging?

Several significant differences in belonging occur for the various communities studied in this effort (Fig. 1). At some level, all of these communities seek

transformational change whether through a conference, a classroom, or a research center; this emphasis on transformational change is clearly reflected in the mission or over-arching top-level description of each community. For example, the first research center evaluated (Retreat 1) was institutionally framed to engage in “. . . transformational engineered systems research in order to advance technology and produce engineering graduates who will be creative innovators in a global economy.” [21]. Similarly, the second research center (Retreat 2) is framed to conduct “. . . world-class research in partnerships . . . to create new and meaningful knowledge of significant benefit to society” [22]. Despite the emphasis on community, profound change, and the link between the two, belonging indicators in these two groups are significantly different (4.14 vs. 3.77 on a 5 point Likert scale for the Retreat 1 and Retreat 2 populations respectively; $p = 0.03$); this difference indicates a substantial difference in the relational fabric of the community, likely heavily influenced by leadership and management strategy. In fact, the Retreat 2 scores are comparable to the classroom (R1 sophomore and R1 junior) scores, indicating that community building (initiated by the research center as compared to the classroom itself) has likely not permeated Retreat 2 sufficiently to impact belonging. To understand the importance of this result, it is helpful to first understand where belonging fits in the social contribution to transformational change. Maton [23] describes a relevant multi-disciplinary and multi-level framework to understand the role of belonging in this kind of context. Maton’s framework for transformational change requires four cornerstones in:

- (1) the instrumental environment by building capacity;

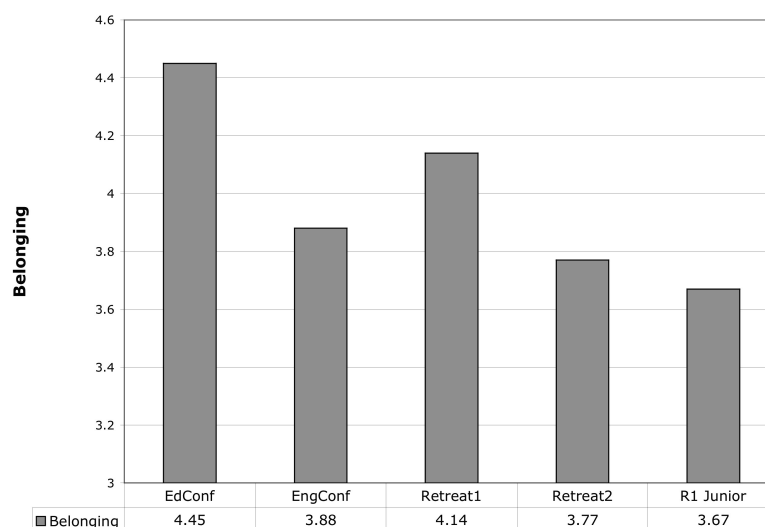


Fig. 1. Summary of belonging. (Sense of belonging is highest among faculty within communities of research (Ed Conf). Students demonstrate a high sense of belonging in some communities (Retreat 1) that specifically target community building, but not in other like communities (Retreat 2). In fact, improvements in belonging in the Retreat 2 community are negligible compared to the baseline provided by the R1 Junior classroom).

- (2) the structural environment via group empowerment;
- (3) the cultural environment through cultural challenge;
- (4) the relational environment via community building.

The first cornerstone, the instrumental environment, is well supported in both research centers (corresponding to the Retreat 1 and Retreat 2 populations); the NSF funding and corresponding organizational (institutional) commitment to a research center builds the human and technical capacity to do transformational research. Extensive review by NSF and internal/external review boards also ensures the structural environment where the distribution of resources (budget, equipment, etc) across groups enables opportunities for all groups (invested in the center) to contribute to the research goals of the center. In contrast, advances in the cultural environment may be difficult given the inherent individualism and strong careerism inherent in academic life. By far, the most challenging aspect of transformational center life lies in the successful support of the relational environment. It is in this environment, that belonging, and its related constructs (support, cohesion, cooperation, and trust) are essential to engaging a strong and sustainable community building effort, that in turn, becomes one of the fundamental cornerstones to engaging transformational change at the center level. Both belonging and sense of community (PSC) in Retreat 2 are lower than that expressed in the Retreat 1 population, suggesting a deficit in the relational environment that may be pervasive enough to thwart transformational change.

The deficit in belonging and trust expressed in Retreat 2 may well be a result of the lack of humanizing processes in the Retreat 2 community

that have been demonstrated to benefit the relational environment [23]. For example, at Retreat 2, diversity is discussed as a clinical and separate concept in passive lecture-based settings, a format that does not necessarily influence the everyday life of graduate students in individual laboratories. Concrete examples whereby the benefit of diversity in ideas and problem solving capacity of research groups are not provided; hence diversity, while valued, is not humanized and made relevant within the context of the everyday research life for graduate students. Much of the evaluation techniques of the center are similarly separate rather than participatory and localized. Surveys are sent out via e-mail to understand student experiences rather than focus groups and interviews conducted on a more face-to-face basis. Thus, the Retreat 2 community likely lacks some of the key components demonstrated to improve the relational environment, resulting in a lower sense of belonging and trust that the Retreat 1 community.

Similar differences are captured in the classroom environments (R1 sophomore and R1 junior), where the predominating passive (i.e. non-interactive) instructional style [24] severely limits opportunities for developing and building the relational environment within the classroom. Classroom belonging and the corresponding sense of community (PSC) at the home institution are both comparable and lowest among all populations studied.

3.2 Does a strong sense of belonging extend to other larger communities?

The results of this study strongly indicate that a sense of belonging at the local (immediate) context transfers to a greater sense of community (PSC) in a surrounding context, at the home institution

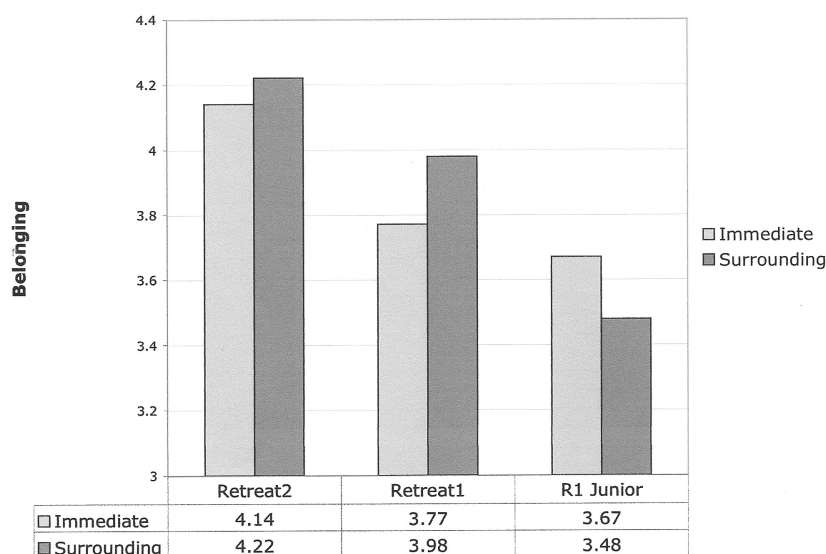


Fig. 2. Belonging and PSC (When students experience a strong sense of belonging in the immediate community (the class, conference, or retreat), they also tend to experience a strong sense of connection to the surrounding community, the home institution. This broader connection (the psychological sense of community or PSC) is less fundamental than belonging to human survival).

(Fig. 2). Belonging has been demonstrated, in a comprehensive examination by Baumeister and Leary [1], to be a fundamental human motivation, a basic need without which other social connections (and other psychological needs) cannot be attained. This framework suggests anyone who experiences strong relational connection to the immediate (proximal) community will likely have the fundamental attachments necessary to develop a greater sense of connection to larger communities in which the individual participates or is affiliated. Where the sense of belonging in the classroom, conference, retreat is high, so the sense of belonging (connection to the home institution community) is also high. This relationship is demonstrated in the Ed Conf population (belonging of 4.45 at the conference and 4.33 at the home institution) and the Retreat 1 population (belonging of 4.14 at the retreat and 4.32 at the home institution). However, the reverse is not necessarily true. When belonging (sense of connection to the home institution) is high, it does not universally translate to a strong sense of belonging in the conference, retreat, or classroom. For example, the sense of belonging for the R1 sophomore population in the classroom is moderate (3.7) while the corresponding sense of connection to the home institution (broader context of belonging) is low (3.49). In contrast, the Eng Conf population demonstrated a moderate sense of belonging at the conference itself (3.88) but a much higher sense of connection and belongingness to the home institution (suggesting that the need to belong is being met in some other way than through the research conference). In summary, the results of this study indicate that belonging correlates to PSC, thereby strengthening the likelihood that belonging, as the Baumeister and Leary analysis concludes, is a fundamental human need.

3.3 Does belonging increase as participation in the community advances from peripheral to central?

Belonging increases with level of expertise and participation in the academic community, a result which can be readily integrated into the situated learning model suggested by Lave and Wenger [15]. The situated learning model emphasizes the whole person, giving emphasis to the social and cultural processes associated with learning and the development of expertise—hence, creating a gateway for relational constructs such as belonging to be influential in the situated learning framework. As the learner becomes more able to do and less absorbed in absorbing, he moves from the legitimate, acknowledged periphery of a community of practice to a more central position in the community (see Fig. 3). This concept of apprenticeship training is often integrated into professional learning models (e.g. graduate school), whereby the learner increasingly moves from the abstract to the concrete, from being a novice to becoming an expert; these models predict an increasing level of engagement and complexity for the individual's role in a learning environment (or community of practice).

As the learner advances in apprenticeship, we would expect belonging to improve hand-in-hand with engagement (as the advancement in knowledge makes the learner feel more of a part of the group). This basic premise of apprenticeship as reformulated by Lave and Wenger into a higher level learning model plays out in this work. As the learner advances, from undergraduate (peripheral participation) to graduate to faculty (central or master participation), belonging also advances; increasingly central roles in the activities and practices of a community are likely to provide the social mechanisms necessary for cultivating belonging. The undergraduates in this study

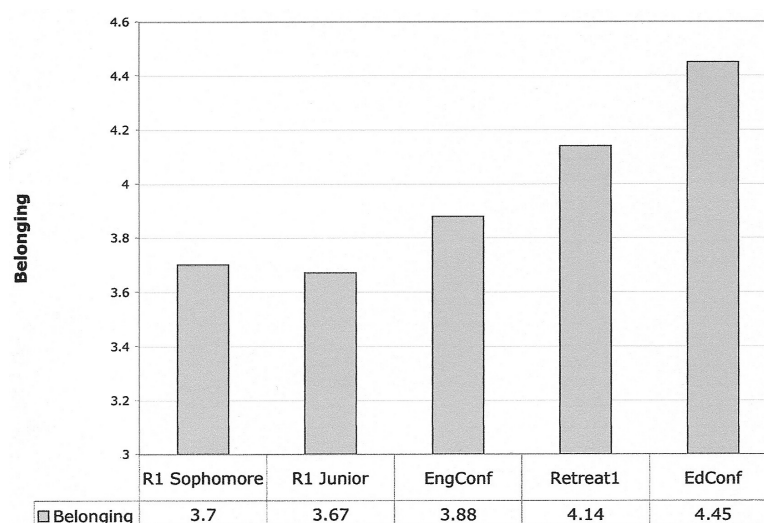


Fig. 3. Growth in belonging (At the undergraduate level, participation in the academic is peripheral and belonging is correspondingly low. As students advance in their mastery of the skills of engineering, their participation in the situated community of academic research increases, as does their belonging. The master of research, the faculty member, is at the center of the community and demonstrates a correspondingly high sense of belonging).

demonstrate the lowest sense of belonging (3.7 in the classroom or immediate context for both R1 sophomore and R1 junior populations), graduate students at the Retreat 1 much higher sense of belonging (4.14) and faculty at the Ed Conf the highest sense of belonging (4.45) of all the populations. It is noteworthy that the cycle of apprenticeship and the positive effects of belonging can be influenced by other factors including a potentially poor relational environment (suggested in Retreat 2 population) or a depersonalized (i.e. overly large) conference population (suggested in the Eng Conf population). Thus, even as a student's participation in a particular community advances to become more central, the anticipated increases in sense of belonging can be thwarted by depersonalizing effects common in large populations. Likewise, even when a student's participation in a community of practice is more peripheral (as with the undergraduate experience), belonging can be nevertheless advanced by emphasizing the development of frequent, local relational bonds within extra-curricular support networks. Seymour and Hewitt have clearly shown these support systems to play a critical role in determining whether students remain in or depart from science fields at the undergraduate level [25]. Specific emphasis on developing close and local relational

bonds within these support networks can enhance belonging and offset the detrimental effects of peripheral participation in the community of practice characteristics of the student in his or her undergraduate years.

3.4 How is belonging related to other aspects of the community to which the student participates?

From this survey, three additional salient points arise from the belonging survey:

- (1) Feeling socially at ease goes hand in hand with belonging for students in class, at conferences, and at retreats.
- (2) Perceptions of technical competence at all levels correlate highly to belonging for all engineering students.
- (3) Faculty-student relatedness is also a correlated to belonging for students, both undergraduate and graduate.

The fact that most students who feel as they belong also feel socially at ease is consistent with Baumeister & Leary's analysis [1] that concludes belonging to be a fundamental human motivation. As a basic need, belonging is characterized by stable, positive, and consistent relational bonds with others in a person's local sphere of influence. A person who possesses these solid relational bonds

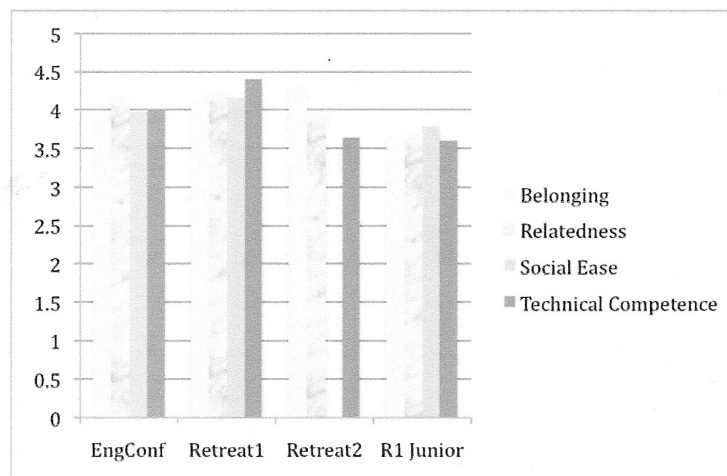


Fig. 4. Other factors. (Belonging is only one affective or relational construct and we expect relational and affect constructs to be heavily inter-related via the complexity of the human psyche. Belonging is highly correlated to social ease in the immediate context (the conference/retreat/class) as well as technical competence both in the immediate context and at the home institution. It is less likely to be correlated with social ease at home and with faculty-student relatedness).

Table 6. Correlation and likelihood of no correlation among belonging and other constructs correlation (p-value)

Construct	#1	#2	#3	#4	#5	#6	#7
#1: Belonging (Conf/Retreat/Class)	1.0 (0)						
#2: Belonging (Home Institution)	0.28 (0)	1.0 (0)					
#3: Faculty-Student Relatedness	0.21 (0.04)	0.67 (0)	1.0 (0)				
#4: Social Ease at Home Institution	0.15 (0)	0.63 (0)	0.62 (0)	1.0 (0)			
#5: Tech Competence at Home Institution	0.27 (.01)	0.57 (0)	0.63 (0)	0.62 (0)	1.0 (0)		
#6: Social Ease at Conf/Retreat/Class	0.72 (0)	0.2 (0.05)	0.2 (0.06)	0.24 (0.02)	0.27 (0.01)	1.0 (0)	
#7: Tech Competence at Conf/Retreat/Class	0.63 (0)	0.36 (0)	0.36 (0)	0.26 (0)	0.46 (0)	0.41 (0)	1.0 (0)

in a community is clearly more likely to feel socially at ease than one who is operating in the absence of these bonds.

The relationship between technical competence and belonging, however, is more specific to the engineering community and is not addressed in more general frameworks of belonging, such as the analysis posed by Baumeister and Leary. To understand this relationship, we must consider both the possibility that belonging supports perceptions of technical competence, and that feelings of technical competence engage a greater sense of belonging. It is not possible to conclude (within the results of this study) to what degree, each of these directions of influence supports the results. However, it is possible to frame both directions of influence in underlying educational psychology. First, we consider whether strong perceptions of technical competence support a greater sense of belonging by looking to identity theory. Engineers define their identities based on four primary principles [26]: Technical Competence, Interpersonal Skills, Work Ethic, and Moral Standards. A student with a strong engineering identity will feel greater connections at all levels to engineering; the sense of belonging is simply the most local (or immediate) connection to community, the day-to-day relational bonds experienced by the student that support belonging. Since technical competence is a cornerstone of identity formation, we would expect that high perceptions of technical competence are related to belonging through the development of strong engineering identity.

Stronger relational bonds (and a greater sense of belonging), however, also have been shown to support increased perceptions of self, including technical competence in programs such as those based on the Treisman model [27] which show increased self-evaluation with greater sense of community incurred by a positive collaborative learning experiences [28]. Depressed self-evaluations of competence in the field, which tend to be common in engineering education, are moderated by peer-to-peer contact, especially that which occurs on an everyday basis. In the lens posed by the Treisman model, then, belonging strengthens perceptions of technical competence rather than vice versa. Thus, the research not only supports the influence of belonging on self-assessed technical competence [27] but also a potential contribution of technical competence on belonging. The relative degrees by which one factor influences the other is a subject of future investigation.

An interesting observation from this study is our last salient result: that belonging and faculty-student relatedness are highly correlated. In Astin's comprehensive assessment of what matters in college [29], faculty-student interactions and student/faculty ratios play an important role in student satisfaction, leading to greater levels of dissatisfaction in larger, more research-dominated institutions; interestingly, in Astin's important

study, peer-to-peer relationships, however, were far more influential on academic growth and affective development than faculty-student relationships; in this study, however, faculty-student relationships dominate over peer-to-peer relationships in their influence in belonging.

Previous studies [19, 20] have confirmed this significance of the faculty-student relationship on student fulfillment in engineering programs; the reasons why this particular set of relationships mean more to engineering students than peer-to-peer relationships, however, remain relatively unexplored. It is likely that, since engineering instruction remains dominated by passive lectures [24], the students naturally value the instructor/faculty relationship more because he remains the primary authority figure and point of contact in the classroom learning process. In this traditional hierarchical instruction scheme, students will tend to place greater value in relationships with those who have more power, in contrast to a more active or cooperative learning environment, where a relatively flat balance of power enables the student to value and engage in a broader set of relationships to be successful academically. Indeed, cooperative learning not only increases the value of peer-to-peer relationships but, as Felder has observed in practice, also increases sense of community as students study together, party together, and complain with unusual unanimity when they are unhappy about something in the curriculum [30].

4. CONCLUDING REMARKS

In a substantial number of studies in K-12 learning contexts, belonging has proven to be an important contributor to academic achievement and engagement. However, in higher education, belonging has not been studied, except in a broader sense, as a connection to the student's primary institution (i.e., psychological sense of community). This study has established a baseline for belonging in a cross section of engineering education communities ranging from undergraduate classes to graduate retreats/conferences to faculty-dominated conferences. Belonging and PSC increase as an engineering becomes more central and less peripheral to the community, as perceptions of technical competence increase, and as feelings of being socially at ease increase. The role of technical competence is hardly surprising considering its strong role in forming engineering identity. Students also appear to respond to community building efforts, by showing a corresponding increase in belonging. Thus, despite the fact that relatedness, belongingness, and connection to community are counter-moderated by introversion, belonging can still be improved in introvert dominated engineering community via external instructional and community building effort.

The benefits of increased belonging already evident in K-12 are likely achievable in the engineering education community. Future work in understanding the role of belonging in engineering and other technical environments in higher education should seek to identify this likely link, among belonging, engagement, and ultimately academic achievement and persistence.

Furthermore, additional study of support networks, whether inside the classroom or in extracurricular organizations, should seek to identify the qualities of these support networks most likely to support increases in belonging. Greater

understanding of support networks and how they induce greater sense of belonging will serve a critical role in enabling “handicapped” larger, research oriented institutions (which inherently produce lower rates of satisfaction among students) to produce micro-culture environments that impart sense of belonging at levels comparable to smaller institutions; such interventions can ultimately increase student satisfaction and performance at these larger institutions, a much needed component of both short-term and long-term persistence in engineering fields, especially for under-represented populations.

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