Classroom Belonging and Student Performance in the Introductory Engineering Classroom

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The focus of Mark’s research can broadly be described as “pivot thinking,” the cognitive aptitudes and abilities that encourage innovation, and the tension between design engineering and business management cognitive styles. To encourage these thinking patterns in young engineers, Mark has developed a Scenario Based Learning curriculum that attempts to blend core engineering concepts with selected business ideas. Mark is also researches empathy and mindfulness and its impact on gender participation in engineering education. He is a Research Scientist and Lecturer in the School of Engineering at Stanford University and teaches the course ME310x Product Management and ME305 Statistics for Design Researchers.

Mark has extensive background in consumer products management, having managed more than 50 consumer driven businesses over a 25-year career with The Procter & Gamble Company. In 2005, he joined Intuit, Inc. as Senior Vice President and Chief Marketing Officer and initiated a number of consumer package goods marketing best practices, introduced the use of competitive response modeling and "on-the-fly" A/B testing program to qualify software improvements.

Mark is the Co-Founder and Managing Director of One Page Solutions, a consulting firm that uses the OGSP® process to help technology and branded product clients develop better strategic plans. Mark is a member of The Band of Angels, Silicon Valley’s oldest organization dedicated exclusively to funding seed stage start-ups. In addition, he serves on the board of several technology start-up companies.

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Sophia Pink is a sophomore studying engineering at Stanford University. She began conducting research in Dr. Sheri Sheppard’s Designing Education Lab in June 2016. Sophia’s academic interests include mechanical engineering, human-centered design and social science research.

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Adrian Piedra is pursuing an MS in Mechanical Engineering (ME) at Stanford University. He is a member of the graduate teaching assistants in the ME department at Stanford, and will be assisting with engineering design courses for the duration of his graduate studies. Adrian holds a BS (summa cum laude) in ME from the University of Florida. During his time at the University of Florida, he was a teaching assistant for engineering analysis courses.

Ms. Shivani Alexandra Torres, Stanford University

Shivani is pursuing her MS in Mechanical Engineering at Stanford University, as a first year Co-Terminal student, exploring intersection of biotechnology, product realization, smart product design, and design for manufacture. She holds B.S. in Bioengineering and a minor in Product Design, with an emphasis in medical device innovation and pre-medical studies. Her interests in education include increasing accessibility of engineering to students of all backgrounds, especially underrepresented minorities, investigating how to encourage young girls and women to get involved with manufacturing, and how mentorship and applications of engineering problem solving can influence identity. Specifically, I am particularly intrigued by the role closeness in academic setting can play on self-efficacy on proficiency.

In addition to my role as a student, I have also had a number of amazing opportunities to teach. This year (2015-2016) I have the privilege of being a Course Assistant for three classes at Stanford: (1) E14: Introduction to Solid Mechanics; (2) BIOE51: Anatomy for Bioengineers; (3) BIOE80: Introduction to Bioengineering and Engineering Living Matter. I also have pleasure of serving as the Safety and Operations Manager at the Volkswagen Automotive Innovation Laboratory, which includes managing the machine shop and teaching students how to use the machinery. In this role I am able to advise and educate students on design choices for their personal and research projects from ideation phases to functional products, with an emphasis on design and manufacturing techniques.
Mr. Kai Jun Chew, Stanford University

Kai Jun (KJ) Chew is a Research Data Analyst in the Mechanical Engineering department at Stanford University. He is currently working closely with Dr. Sheri Sheppard on two fronts: introducing reflective activities as part of the Consortium to Promote Reflection in Engineering Education (CPREE) and implementing the Continuous Improvement Program as part of the ABET evaluation. Born and raised in Malaysia, KJ received his Bachelor of Science in Mechanical Engineering at the University of Southern California (USC) and his Master of Science in the same field at Stanford University. He is currently exploring the field of data science as his potential career path.

Dr. Sheri Sheppard, Stanford University

Sheri D. Sheppard, Ph.D., P.E., is professor of Mechanical Engineering at Stanford University. Besides teaching both undergraduate and graduate design and education related classes at Stanford University, she conducts research on engineering education and work-practices, and applied finite element analysis. From 1999-2008 she served as a Senior Scholar at the Carnegie Foundation for the Advancement of Teaching, leading the Foundation’s engineering study (as reported in Educating Engineers: Designing for the Future of the Field). In addition, in 2011 Dr. Sheppard was named as co-PI of a national NSF innovation center (Epicenter), and leads an NSF program at Stanford on summer research experiences for high school teachers. Her industry experiences includes engineering positions at Detroit’s “Big Three:” Ford Motor Company, General Motors Corporation, and Chrysler Corporation.

At Stanford she has served a chair of the faculty senate, and recently served as Associate Vice Provost for Graduate Education.
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Abstract

This Complete Paper – Research describes a pilot study among post-secondary students involved in their first engineering-specific class and explores the concept of classroom belonging. The hypothetical premise of this research is that grade performance is, in part, determined by a student’s sense of belonging in a classroom. Further, “classroom belonging” is a function of several factors including social belonging, engineering self-efficacy, engineering identity and closeness to others in the classroom. This study revealed that a student’s sense of classroom belonging has a significant, positive impact on grade performance. The most important components of classroom belonging are the student’s sense of social belonging in the classroom and their engineering identity.

The survey-based quantitative data were complemented with qualitative interviews with underrepresented minority engineering students. These allowed us to explore their classroom belonging experiences and showed that classroom belonging is a familiar concept and a function of two separate sources of belonging: academic belonging and social belonging. Academic self-efficacy, curriculum content motivation and an ability to share academic struggles with others were important contributors to academic belonging. Social similarity, successful team experiences and a general sense of caring were also considered helpful to building social belonging in the classroom. Implications and ideas to build engineering classroom belonging from this research are discussed.

Key Concepts: social belonging, engineering identity, engineering task self-efficacy, closeness

1.0 Classroom Belonging

For this paper, we are conceptualizing that classroom belonging is defined as a relationship between a student’s sense of social belonging, their engineering identity, their engineering self-efficacy and their interpersonal closeness to the social elements that exist with a classroom – the professor, TAs and other students, as shown in Figure 1. We hypothesize that these factors contribute to a student’s sense of belonging in an engineering classroom.

The need for social belonging – seeing oneself as socially connected – is often considered a basic human need (Baumeister and Leary 1995). Social belonging has been linked to a range of positive, prosocial outcomes such a improved self-efficacy (Bong and Skaalvik 2003), better health outcomes (Bolger, Zuckerman, and Kessler 2000), improved team effectiveness (Mathieu et al. 2008) and better academic performance within the classroom (Goodenow 1993). Social belonging in the classroom or its reverse, belonging uncertainty (Walton and Cohen 2007), has proven to be a significant moderating variable for classroom performance particularly among less experienced students, such as first year students, and among minority and female students (Walton et al. 2012).
Engineering identity which, as defined by Tonso (2006; 2014), includes several factors: thinking about oneself as an engineer, the inner belief that one is performing as an engineer, and ultimately believing that one is thought of by others as an engineer. Engineering identity is an important contributor to both social belonging and classroom grade performance. Engineering self-efficacy, as defined by Mamaril et al. (2016), is the belief by the engineering student in their own ability to successfully achieve engineering tasks, and this in turn motivates them to act in ways that make their success within the engineering classroom more likely.

Finally, interpersonal closeness, as defined by Aron et al. (1991; 1997; 2013), is the desire to expand personal efficacy by developing interpersonal relationships that expand the “self” into “others.” The concept of closeness applies to the many social structures that exist within a classroom – for example, the student’s feeling of closeness to another student, a project team, the TAs and professor. For the purposes of this research we are considering interpersonal closeness and social belonging as interrelated but separate constructs. For example, we hypothesize that a student can feel classroom belonging without closeness to a specific person and conversely, a student can be close to another person in the classroom and still feel as if they did not belong.

Our a priori hypothesis is that classroom belonging is a latent construct defined by interrelationship of a student’s feelings of social belonging, a student’s sense of engineering self-efficacy and engineering identity, and their interpersonal closeness with the social structures within the engineering classroom. We further hypothesize that classroom belonging will have a direct and positive effect on grade performance.

2.0 Study Overview

This study is intended as a pilot study of the measures of social belonging in an engineering classroom. Data were collected from an introductory level solid mechanics class at a private university in the United States. Most student respondents were beginning their engineering
academic careers, mostly as sophomore students taking their first-ever engineering specific course. The instrument used to measure engineering self-efficacy was developed by our research team. The instruments used to measure social belonging, engineering identity and interpersonal closeness have strong research pedigrees but have never been used in this novel combination.

2.1 Measuring Social Belonging (SB)

The measurement of social belonging was accomplished using the Sense of Social and Academic Fit in STEM scale developed by Walton et al. (2015), as shown in Appendix A.1. This 10-item scale is a unitary construct of social belonging and measures a range of attitudes that define social belonging in the engineering classroom, including items such as I belong at [school name], I think in the same way as do people who do well in engineering at [school name] and Compared with most other engineering students at [school name], I am similar to the kind of people who succeed in engineering. Responses were collected within a 7 point “agreement” range\(^1\) and the items had good internal consistency (Cronbach \(\alpha = .83\)).

2.2 Measuring Engineering Identity (EI)

The measurement of engineering identity was accomplished using an adapted version of Godwin et al.’s (2016) measure of identity. Godwin et al. concludes that an engineering student’s engineering identity is a function of four attitudes relating to interest, performance, recognition and agency. Interest is the student’s innate attraction to the subject material surrounding engineering, such as math, science and physics. Performance is an academic self-efficacy construct measuring how much a student believes in their ability to positively perform in academically in engineering coursework. Recognition is how a student believes they are recognized as an engineer, particularly by meaningful others such as parents or professors. Finally, agency or as Godwin et al. define it, critical engineering agency, is defined as how students view the world through the value they place on being an engineer.

The scale used in this study is adapted from Godwin et al. (2016) using these four constructs. Godwin et al. focused on “math,” “physics” and “science” interests which were used to predict engineering career interest. For the current study, the Godwin et al. items were adapted by replacing “math,” “physics” and “science” with “engineering.” The resulting scale is 16-items, as shown in Appendix A.2. The four construct sub-scales had poor to questionable internal consistency (Cronbach \(\alpha\)’s ranging from .54 to .68); however, the entire 16-item scale had acceptable internal consistency (Cronbach \(\alpha = .79\)), so for this analysis engineering identity (EI) will be reported as a single, unitary construct. The modified Godwin et al. scale included two items measuring interest, five items measuring performance/competence beliefs, three items measuring recognition and six items measuring agency\(^2\) with responses collected within a 5-point “agreement” range.

\(^1\) Responses were collected on 7-point scale, this was fit to a 5-point scale to align with the other measures.

\(^2\) Godwin has since simplified the Engineering Identity (EI) scale to three constructs and 11 items (A. Godwin 2016). A comparison of the EI scale used in this research and the newer version is shown in Appendix A.2.
### 2.3 Measuring Engineering Task Self-Efficacy

ETSE is designed to measure one’s confidence in their ability to perform integral technical engineering tasks such as “analyzing the operation or functional performance of a complete system.” The task of defining a small set of capabilities that can describe the whole engineering capability is challenging, to say the least, although several scholars have made headway in this area. For this study, we relied on Fouad and Singh’s (2011) work on engineering career outcomes, and were first deployed in the Pathways of Engineering Alumni Research Survey (Brunhaver et al. 2013).

The Fouad and Singh scale is composed of five items that were identified through factor analysis of a longer list of engineering task items. The items selected include: 1. Design a new product or project to meet specified requirements, 2. Conduct experiments, build prototypes, or construct mathematical models to develop or evaluate a design, 3. Develop and integrate component sub-systems to build a complete system or product, 4. Analyze the operation or functional performance of a complete system, and 5. Troubleshoot a failure of a technical component or system, as shown in Appendix A.3. Respondents rated confidence in their ability to perform these tasks on a scale of “not confident” (1) to “extremely confident” (5), and had good internal consistency (Cronbach $\alpha = .85$).

### 2.4 Measuring Interpersonal Closeness

Self-expansion is a behavioral psychology construct defined by two core principles: 1) individuals naturally seek to expand their individual potential efficacy or effectiveness, and 2) this expansion is typically achieved in relationship with other people (Aron and Aron 1996). Aron and Aron have developed the theory of self-expansion over the past 30 years through their work on “inclusion of the other in the self” (IOS) (Aron and Aron 1986; Aron and Aron 1996; Aron et al. 2013). Aron’s IOS model implies that individuals expand self-efficacy by developing close relationships with others, which in turn has the benefit of increasing material and social resources, perspectives and ultimately, self-efficacy. Aron has come to refer to this behavior of building self-efficacy through interaction with “others” as “closeness.” It has been shown that greater closeness to an individual, group or institution can lead to greater fairness, more sharing, openness to new ideas and reduced prejudicial attitudes (Arthur Aron et al. 1991; Crandall et al. 2004).

Aron and Aron have developed a novel instrument to measure IOS or closeness (A. Aron, Aron, and Smollan 1992). The instrument uses a series of Venn-like pictograms that show the relationship of the “self” to “other,” as shown Appendix A.4. Each pictogram is part of a range of choices, which can be projected onto a Likert scale ranging from, 1 to 5, where choice 1 would show the least closeness and choice 5 would show the most closeness. Closeness was measured for seven “other” social groups – professor, TAs, best friend in class, entire class, section group (20-22 students), Project 1 team (4 students per team) and Project 2 team (2 students per team). These measures of closeness had acceptable internal consistency (Cronbach $\alpha = .72$) so were averaged to form one measure of closeness.
3.0 Research Questions

This paper addresses three research questions:

**Research Question 1 (RQ1):** What are the contributing factors toward developing a sense of belonging in an engineering classroom?

**Research Question 2 (RQ2):** How does classroom belonging influence grade performance in an engineering classroom?

**Research Question 3 (RQ3):** How is classroom belonging defined or interpreted by students of different genders, underrepresented racial and ethnic minorities and first generation college students in an engineering classroom?

4.0 Methods and Sample Characteristics

This research was conducted at Western private university during Fall 2016. All participants in this research were engineering or prospective engineering students enrolled in an entry-level engineering course typically covering the general area of “statics”. Course content material was drawn from standard college-level solid mechanics textbooks. In-class labs were conducted in groups of 4-6 students and included hands-on, interactive experiences such as interpreting forces within stacked Jenga Blocks™ or calculating forces on a longboard. The course also included two major projects. Project 1 involved a four-person team building a 24 cm span model truss bridge which was then loaded to failure. Project 2 involved two person teams doing independent research on an engineering topic of their choice. Teams for both projects were self-selected by the participants.

Final course grades were collected and ranged from 66 to 96 out of 100 total possible points. A paper-based survey was used to collect respondent input on the various constructs during the last class session of the term. For this paper, differences in means were completed using both paired comparison and independent sample t-tests, and the significance threshold for all analysis is \( p < .05 \) using the R statistical package.

In total, 83 students\(^3\) received a grade for the course and this comprises the sample. Demographic data were collected including gender (52% female), underrepresented racial/ethnic minority (URM) status (28%) and first generation college\(^4\) (FGC) status (13%).

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\(^3\) The study sample of 83 respondents contained 95.6% complete data. It was determined that the missing data was missing completely at random (MCAR) and multivariate imputation by chained equations (MICE) was used with predictive mean matching (PMM) and 5-iterations to complete the data set. (Manly and Wells 2015; van Buuren and Groothuis-Oudshoorn 2011)

\(^4\) For the purposes of this study, underrepresented minority (URM) is defined as any respondent who indicated a Latino/a, African American, Native American or Pacific Islander race or ethnicity. First Generation College (FGC) is defined as any respondent whose parents(s)/guardian(s) had less post-secondary education than an Associate degree. There are many possible definitions of a first generation college student (Choy 2001; Auclair et al. 2008; Toutkoushian, Stollberg, and Slaton 2015) and this definition is regarded as more expansive.
5.0 Results

5.1 Research Question 1 (RQ1): *What are the contributing factors toward developing a sense of belonging in an engineering classroom?*

A sense of social belonging had a significant and positive correlation with grade performance ($r = .23$, $p < .05$), as shown in Table 1. There was no significant correlation between social belonging and closeness, suggesting that these are altogether different constructs.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\bar{x}$</th>
<th>$\sigma$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Belonging (SB)</td>
<td>3.53</td>
<td>.54</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Identity (EI)</td>
<td>4.20</td>
<td>.39</td>
<td>.59</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Task Self-Efficacy (ETSE)</td>
<td>3.28</td>
<td>.73</td>
<td>.17</td>
<td>.27</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Closeness (CL)</td>
<td>3.37</td>
<td>.56</td>
<td>.15</td>
<td>.25</td>
<td>-.06</td>
<td>--</td>
</tr>
<tr>
<td>Grade Performance (0-100)</td>
<td>87.61</td>
<td>6.81</td>
<td><strong>.23</strong></td>
<td><strong>.22</strong></td>
<td>-.11</td>
<td>.08</td>
</tr>
</tbody>
</table>

The strongest correlation among these variables is between social belonging and engineering identity ($r = .59$, $p < .00$), which suggests the engineering identity is interrelated with a student’s feeling of social belonging. This mechanism could work two ways - a strong “sense of self” as an engineer could be a helpful foundation for establishing social connections, or conversely strong social connections could lead to a stronger sense of engineering identity – and either pathway may lead to positive expectancy of performance within an engineering classroom.

The measure of engineering identity also had significant, positive correlations with engineering task self-efficacy ($r = .27$, $p < .01$), closeness ($r = .25$, $p < .02$) and grade performance ($r = .22$, $p < .05$). This positive interrelationship between engineering identity and other indicators like engineering self-efficacy and interpersonal closeness suggests these measures are may all be necessary in some capacity for successful classroom performance.

Over the term, student satisfaction with the various activities are routinely tracked and one activity in particular had a strong, positive relationship with the scores on the social belonging construct – Project 1, the four-person team, bridge building/testing activity. Student satisfaction with Project 1, which was measured in a post-class satisfaction survey, shows a strong and significant correlation with the social belonging measure ($r = .26$, $p < .02$), while no other activity satisfaction score had a significant correlation with social belonging. Project 1 is a two-week assignment where self-selected four-person teams design a model of a truss bridge to a set of specifications and then build it and test it to failure in the classroom. This activity is considered the highlight of the class and typically rates high in student satisfaction scores (4.12 on a satisfaction scale of 5 – “like a great deal” to 1 – “dislike a great deal” versus an average 3.66 score for all other activities). It is evident from observing these teams perform that these four person teams develop a strong interpersonal bond in the process of completing this assignment.
5.2 Research Question 2 (RQ2): *How does classroom belonging influence grade performance in an engineering classroom?*

Overall, social belonging as a standalone measure seems to have a positive but limited impact on grade performance. The square of a Pearson r correlation ($r^2$ – the coefficient of determination) indicates the proportion of variance in a dependent variable explained by the independent variable (Krathwohl 2009). In this case, from Table 1, the Pearson r correlation between grade performance (GP - dependent variable) and social belonging (SB – independent variable) is .23, meaning that of all the variation in grade performance, the social belonging measure explains just 5% ($r^2 = .053$), which is low predictive power by social science standards.

Structural equation modeling (SEM) can help identify the other influences on grade performance. The challenge with this approach in a pilot study is the low power of a limited sample size. It is has been suggested that SEM analysis requires at least 20 observations for each independent and dependent variable (Kline 2011). With four independent variables (SB, ETSE, EI and CL) and one dependent variable (Grade Performance) and relatively small effect sizes between them, a SEM analysis with a sample size of 83 is on the lower end of acceptable statistical power. With this caveat in mind, the SEM analysis begins to reveal important relationships highlighting the influences on grade performance.

Our *a priori* hypothesis of the factors that may comprise classroom belonging and then the relationship with grade performance (see Error! Reference source not found.) can be tested through confirmatory factor analysis (CFA) using SEM analytics. In the construction of the CFA model, observed variables such as social belonging, engineering self-efficacy, engineering identity and closeness measures are considered exogenous and causally independent from each other. These observed variables combine to define an endogenous, latent construct which we refer to as classroom belonging. In turn, classroom belonging then predicts grade performance, as shown in Figure 2.

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5 This analysis was conducted with the lavaan package in R (Rosseel 2012) using standardized data (centered and scaled) and 1,000 simulations to compensate for the low power of this sample.
The latent construct of classroom belonging shows a strong and significant prediction of grade performance ($\beta = .37, p < .05$). For model fit, the root mean square error of approximation (RMSEA = .047) and comparative fit index (CFI = .981) are considered “good” and “acceptable,” respectively. For the RMSEA, values less than 0.05 indicate a good fit (Schreiber et al. 2006). For CFI, values greater than 0.9 indicate an acceptable fit (Hu and Bentler 1999).

The exogenous effect factors of classroom belonging show that social belonging and engineering identity are the most important contributing factors. The effect indicators have been indexed to the social belonging measure which serves as the scaling constant (see Kline 2011, p113). This shows that engineering identity has 1.60 times the effect of social belonging in the definition of the classroom belonging, while engineering self-efficacy and closeness have a lesser effect of .45 and .43 times the effect of social belonging.

The classroom belonging measure of social belonging had the strongest individual correlation with grade performance, followed closely by engineering identity. Both variables had a strong and significant correlation with each other (see Table 1). The question then is how these variables interact to predict grade performance. A mediation analysis confirms the significant partial mediating impact of engineering identity on the relationship between social belonging and grade performance, as shown in Error! Reference source not found.. In this analysis, a positive and significant direct effect relationship exists between the social belonging measure and grade performance ($c \beta = .16, p < .05$). If this relationship is partially mediated by engineering identity ($a \beta = .59$ and $b \beta = .17$), this results in a positive and significant total effect relationship ($c' \beta = .23, p < .05$). This data suggests that improvements in student grade performance require several contributing factors – including a sense of social belonging in the classroom, enhanced by strengthening individual engineering identity.

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6 This analysis was completed with the mediation package in R (Tingley et al. 2014) using standardized data (centered and scaled) and 1,000 simulations to compensate for the low power of this sample.
5.3 Research Question 3 (RQ3): How is classroom belonging defined or interpreted by students of different genders, underrepresented racial and ethnic minorities and first generation college students in an engineering classroom?

To better understand the implication of social belonging in the engineering classroom, we conducted in-depth qualitative interviews with four underrepresented minority engineering students, two women and two men. These students were more academically experienced than the students surveyed in this study (third, fourth and fifth year engineering students) so that we could learn from students who had dealt with social belonging in a variety of engineering classroom environments.

In the quantitative data, we had expected to see differences in social belonging scores by gender, URM status and first generation college (FGC) status. While there were differences, none were statically significant, as shown in Table 2. The mean of social belonging scores among women (3.45) were lower than among men (3.63), however the difference was not statistically significant ($\Delta = +.18, t = 1.52, p < .13$). A similar pattern emerged among URM and FGC students, with lower mean scores than their counterparts but none of these differences were statistically significant. These lower scores are consistent with previous research on social belonging among female, URM and FGC students (Walton et al. 2015) and the lack of statistical significance may be a result of the small sample size or the unique cultural aspects of this one testing site.

<table>
<thead>
<tr>
<th>Scale/Variable</th>
<th>Male</th>
<th>Female</th>
<th>$\Delta$</th>
<th>$p$</th>
<th>URM</th>
<th>#URM</th>
<th>$\Delta$</th>
<th>$p$</th>
<th>FGC</th>
<th>#FGC</th>
<th>$\Delta$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Belonging</td>
<td>40</td>
<td>43</td>
<td>.18</td>
<td>.13</td>
<td>23</td>
<td>60</td>
<td>-.19</td>
<td>.30</td>
<td>3.35</td>
<td>3.56</td>
<td>-.21</td>
<td>.41</td>
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<tr>
<td>Engineering Identity</td>
<td>4.29</td>
<td>4.12</td>
<td>.17</td>
<td>.05</td>
<td>4.07</td>
<td>4.25</td>
<td>-.18</td>
<td>.09</td>
<td>4.25</td>
<td>4.19</td>
<td>.06</td>
<td>.67</td>
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<tr>
<td>Engineering Task SE</td>
<td>3.29</td>
<td>3.27</td>
<td>.02</td>
<td>.92</td>
<td>3.21</td>
<td>3.31</td>
<td>-.10</td>
<td>.63</td>
<td>2.96</td>
<td>3.33</td>
<td>-.37</td>
<td>.14</td>
</tr>
<tr>
<td>Closeness</td>
<td>3.39</td>
<td>3.35</td>
<td>.04</td>
<td>.79</td>
<td>3.42</td>
<td>3.35</td>
<td>-.07</td>
<td>.60</td>
<td>3.66</td>
<td>3.32</td>
<td>.34</td>
<td>.08</td>
</tr>
<tr>
<td>Grade Performance</td>
<td>87.4</td>
<td>87.8</td>
<td>-.4</td>
<td>.75</td>
<td>84.1</td>
<td>89.0</td>
<td>-4.9</td>
<td>.03</td>
<td>84.6</td>
<td>88.1</td>
<td>-3.5</td>
<td>.20</td>
</tr>
</tbody>
</table>

$\Delta =$ difference; $p =$ t-test $p$ value; Bold – $p < .05$
Engineering identity appears to be an important discriminant factor among female, with statistically lower scores (\(-.17, p < .05\)) than their male counterparts. This aligns with previous research on engineering identity and gender that shows that while female students academically perform as well as men (Geisinger and Raman 2013), their self-perception of performance and engineering skill self-efficacy are typically lower than those of male students (Cech et al. 2011). As Godwin et al. (2016) states “often, women face the double burden of authoring their identity as engineers while also combatting the traditional stereotypes about engineering as a masculine field” (p 313). Other research has shown that this is also true for URM students who typically begin their engineering academic careers with lower academic self-efficacy than their non-URM counterparts and struggle to achieve parity over their educational career (MacPhee, Farro, and Canetto 2013).

The qualitative interviews were structured to reflect the hypothesized theory (see Eisenhardt 1989) of social belonging as presented in Error! Reference source not found.. The researchers conducting the interviews were all graduates of the engineering class in this study and had served as a teaching assistant for this course at some time in the previous years. An interview questionnaire was developed to reflect the social belonging framework and to align with the qualitative research principles outlined by Corbin and Strauss (2008). A pre-interview review was conducted among all interviewers to answer questions and align expectation and post-interview debriefs occurred among the interviewers to share learning and perspective.

One participant was selected by each interviewer for an in-depth qualitative interview usually lasting 30-45 minutes. Each interview participant was asked to think of the classroom experience where they felt “they most belonged” and the interviewers used this one exemplar experience as a reference point to structure their questions. The interviews were not recorded, rather interviewers captured notes and quotations as each conversation progressed. The qualitative interview subjects are described in Table 3.

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Description</th>
<th>Classroom Exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td>“AB”</td>
<td>Female, 21 years old, BSME, MSME (in process), East Asian heritage</td>
<td>Graduate Lecture and Project class</td>
</tr>
<tr>
<td>“CD”</td>
<td>Male, 23 years old, BSME, MSME (in process), Caribbean heritage</td>
<td>Study abroad experience</td>
</tr>
<tr>
<td>“EF”</td>
<td>Male, 23 years old, BSME, MSME (in process), African American heritage</td>
<td>Undergraduate Lecture and Project class</td>
</tr>
<tr>
<td>“GH”</td>
<td>Female, 21 years old, BSME (in process), East Asian heritage</td>
<td>Undergraduate Lecture Class</td>
</tr>
</tbody>
</table>

Following the participant interviews, analysis began with interviewers summarized their notes and developed a concept map outlining the conversation. The interviewers were trained in ontological concept map development using the method described by Turns, Atman and Adams (2000) and later adapted by Besterfield-Sacre et al. (2004). This method typically places the core, central concept in the center of the page and then connects related concepts, sometimes using “action words” to describe the nature of the connection. The interviewers assembled in a
room and drew their individual concept maps on a whiteboard, simultaneously explaining the findings to the other interviewers. Once all maps had been displayed and discussed the researchers summarized the findings and then developed a “consensus concept map” that contained the key concepts and relationships, as shown in Error! Reference source not found..

The first overall observation is that the notion of classroom belonging was easily understood by all participants. They could readily identify a classroom experience where they felt like they belonged and distinguish this experience from other classroom experiences where they felt like they did not belong. This seemed to indicate that the feeling of classroom belonging (or not) is present in many, if not all, classroom experiences and this implies that classroom belonging can be an influential experience in the learning process.

The consensus of the participants is that classroom belonging is a function of two forms of belonging – academic and social belonging. Academic belonging is the sense that you, as a student, have the academic capability to satisfy the requirements of the course, while social belonging deals with the feeling of social fit with the other students in the classroom. Academic and social belonging are interconnected and reinforcing in both a positive and negative sense. For example, if a student feels out of place and disconnected socially from other students, this can have a negative impact on academic performance. In a positive sense, if a student feels academically confident in a class it may be easier to connect with other students and establish social connections, as expressed by participant “GH”:

> At first, I felt a bit intimidated by the other students in the class, like they all knew a lot more than did about statics. But as I got to know some of them through labs or office hours, I realized that they were just as lost and confused as I was. That sort of brought us together. By the end of the class I felt like I was at where most people were, which reinforced a sense of community.
The foundation of academic belonging was a sense of academic self-efficacy, or the internal belief that the student had the capability to do the work required by the class. This was enhanced if the student was motivated to learn the specific content of the class. The role of the professor was also critical to academic self-efficacy; a professor that was approachable and expressed a genuine interest in the students aided academic self-efficacy. Participants expressed the view that academic self-efficacy was often reinforced by feedback on academic performance, as described by “CD”:

*Initially, I was not confident [in my ability to learn the course material]. It was only after I did the first midterm that I realized I could do well in the course. The other students were complaining about it being difficult and sought me for help. I began explaining the material to others, which helped build my confidence.*

The feeling of social belonging often began with a sense of social similarity, where a student had the sense that others in the classroom were like them in terms of grade level, academic experience and interests, demographics or even situation. For example, “CD” expressed a high level of social similarity in his study abroad experience because even though there were many differences between the students, “they were all in this foreign country together.” Social belonging is also a function of something we define as “social-technical standing,” meaning that if an engineering student was perceived as having a high level of technical competency it was easier to make friends in the classroom and they were a more attractive as a team member.

Team performance also seemed to be a sort of litmus test of social belonging. If forming a team was difficult, if the team struggled and the overall team experience was negative, it tended to dampen the feeling of social belonging. If a student was easily assimilated into team and if that team was successful, then there was a good chance that the student had a favorable sense of social belonging, as described by “EF”:

*I had lots of good friends in the class. It made things comfortable. We were able to form teams easily, collaborate on PSETs easily, and collaborate between teams easily. It made the class more enjoyable.*

Finally, there was a consensus that many of the contributing factors to academic and social belonging were interrelated (as represented by the dotted lines in Error! Reference source not found.). For example, social similarity probably aligns with academic content motivation and this makes it easier to form effective classroom teams. A classroom where students find a sense of caring about their personal journey makes it easier to share classroom struggles with others, including the professors and teaching assistants, as described by “AB”:

*The professor went above and beyond what was required in terms of staying late in the lab, helping students, and generally being very welcoming and nice. In fact, I felt so comfortable with him that I did research in has lab the following quarter, which I had never done before.*

It was also the sense of the student interviewees that not every contributing factor mentioned in Error! Reference source not found. needed to be in place to have a sense of classroom
belonging, but the more factors evident the greater the likelihood that a student would experience the feeling of classroom belonging.

5.5 Limitations

This study suffers from many of the drawbacks of pilot work. The sample size was small, meaning that effect sizes had to be quite large to register as statistically significant. This can be remedied through expansion to a broader base of students and additional institutions. These students were from only a handful of majors (mostly mechanical and civil engineering) and results might differ significantly through inclusion of other majors.

The engineering identity measure (EI) is new and adapted from Godwin et al.’s (2016) definitional work and has not been qualified as a valid and reliable measurement scale. This would require more study with larger samples, perhaps lead to a focus on selected items in the scale that have greater impact and less scale items overall.

The engineering task self-efficacy results (showing a negative, though not statistically significant correlation with grade performance) are puzzling and contrary to a large body of research positively connecting self-efficacy with academic performance. Perhaps in this research, the students are so early in their academic engineering career that ETSE is measuring capabilities that they are in the process of obtaining and do not yet have confidence. It also is possible that within this very limited sampling of students at one university we have a group of very confident engineering students who may be disconnected with their own capabilities and level of performance. It should be noted that this self-efficacy measure was conducted late in the course term but before the final exam or final grade was awarded for the course.

This research was also conducted in an entry-level class, with many in-class activities and significant group work, including the important Project 1. This style of teaching might lead to a greater sense of closeness and social belonging than what is found in more advanced engineering classes with less group work. This research is a one-time snapshot of how these students feel about belonging and may not be representative of the totality of their engineering academic experiences. The qualitative findings represent the input of just four students and while it has provided a working theory of how social belonging develops in an engineering classroom, the results would need to be confirmed in a larger, broader sample.

6.0 Conclusion and Implications

One of the most important questions engineering students ask themselves at the very beginning of their academic careers is “Do I belong in engineering?” This question is revisited many times throughout their academic careers and their answer is often influenced by the experiences and relationships they have over time. As engineering educators, we should be mindful that our students are asking themselves this question and we need to do what is possible to present engineering as a broad field that is better served by a diverse population of professionals.

This pilot research shows that social belonging in an engineering classroom has a positive and significant relationship with a student’s engineering identity, their engineering task self-efficacy and their closeness to other social structures in the classroom such as the professor, TAs and
other students. Among these variables, engineering identity, defined as the belief by the engineering student in their own ability to successfully achieve engineering tasks, and a feeling of social belonging seem most related to classroom belonging. While this study did not uncover a strong relationship between social belonging and grade performance (as in work by Walton et al.) it did show that the latent construct of classroom belonging as combination of social belonging and strong engineering identity had a significant impact on grade performance.

In many ways, the qualitative results added perspective to the quantitative results and will shape the future direction of this research effort. The qualitative definition of classroom belonging as a function of academic and social belonging that emerged from the interviews closely aligns with the quantitative findings. We recognize that Godwin et al.’s engineering identity construct seeks to be more than simply academic self-efficacy, capturing interest (perhaps as a version of academic content motivation), performance (perhaps as a proxy for academic self-efficacy), recognition (which has social belonging aspects) and agency (perhaps as overall engineering as a career self-efficacy). As a next step, the focus of engineering classroom belonging research should turn to understanding the interaction between social belonging in the classroom and an individual’s engineering identity.

The quantitative and qualitative data in this study also point the challenge faced by minorities – women, racial and ethnic minorities, and first generation college students – stemming from belonging uncertainty in the engineering classroom and the corrosive impact it can have on performance. Through our qualitative study, we found that social belonging among minority students can be positively affected by activities that already occur in most engineering classrooms – successful group projects, where the relationships established in the classroom extend to life outside the classroom.

Interventions that might address greater social belonging in the classroom range from considerable to trivial. On the more difficult end of the spectrum is increasing the presence of more women, minorities and first generation college students in the seats of an engineering classroom – a knotty, vexing, and involved problem from many perspectives – but perhaps the most meaningful solution long-term. The presence of more women, minorities and first generation college students in engineering classrooms should help to redefine the meaning of social belonging, closeness and engineering identity for all students, reducing implicit barriers of performance while strengthening the relationship between academic and social belonging.

As we work on the greater goal of broader inclusion, there are many smaller, easier to execute ideas that could have significant impact. Walton et al. (2012) terms this “mere belonging” and it involves “small cues of social connectedness to another person or social group.” Among the more intriguing “small cues” is simple reinforcement of what Walton et al. calls a “social-belonging intervention” (2015). This is often a simple communication vehicle, such as a hand out or video, designed to reinforce students’ sense of belonging in engineering by providing a nonthreatening narrative with which to interpret instances of adversity. The communication can take the form of statistics (“X% of first year students worry about completing engineering assignments”) or quotes from former students (“When I got here, honestly, I thought professors were scary … and then I learned that even when they were critical of me they weren’t looking...”) or...
down on me. It made me a better engineer.”) It is not hard to imagine these relatively simple interventions being tailored to a specific engineering school or even a specific engineering discipline within a school.

At these very early stages of an engineering student’s academic career it seems essential to address feelings of social marginalization and reinforce a sense of social belonging. It is our hope that this study, in some small way, motivates other engineering educators to further investigate and facilitate social belonging among all types of engineering students.
7.0 Acknowledgements

The work is part of the Epicenter, an academic/non-profit partnership that offers faculty, students, researchers and academic leaders engaging ways to support entrepreneurship and innovation learning in undergraduate engineering education. Epicenter was funded by the National Science Foundation (Grant No. 1125457) and managed by Stanford University and VentureWell, formerly the National Collegiate Inventors and Innovators Alliance (NCIIA).

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References


Appendix

A.1 Social Belonging (SB)

Please answer the following questions about what engineering at [school name] is like for you. Indicate the extent to which you agree or disagree with each statement using the scales below. Please use the whole range of the scale.

<table>
<thead>
<tr>
<th>Strongly Agree (7)</th>
<th>Agree (6)</th>
<th>Somewhat Agree (5)</th>
<th>Neither Agree nor Disagree (4)</th>
<th>Somewhat Disagree (3)</th>
<th>Disagree (2)</th>
<th>Strongly Disagree (1)</th>
</tr>
</thead>
</table>

I belong in engineering at [school name]
I feel comfortable in engineering at [school name]
Other people understand more than I do about what is going in engineering at [school name] (reverse scored)
I think in the same way as do people who do well in engineering at [school name]
It is a mystery to me how engineering at [school name] works (reverse scored)
I feel alienated from engineering at [school name] (reverse scored)
I fit in well in engineering at [school name]
Compared with most other engineering students at [school name], I am similar to the kind of people who succeed in engineering
Compared with most other students at [school name], I know how to do well in engineering
Compared with most other engineering students at [school name], I get along well with people in engineering

A.2 Engineering Identity (EI)

Please rate how strongly you agree or disagree with the following statements:

<table>
<thead>
<tr>
<th>Strongly Agree (5)</th>
<th>Somewhat Agree (4)</th>
<th>Neither Agree nor Disagree (3)</th>
<th>Somewhat Disagree (2)</th>
<th>Strongly Disagree (1)</th>
</tr>
</thead>
</table>

Adapted Godwin et al. 2016 Items used in this research

**Interest**
- I enjoy learning engineering
- I am interested in learning more about engineering

**Performance**
- I am confident that I can understand engineering in class
- I am confident I can understand engineering outside of class
- I can do well on exams in engineering
- I understand concepts I have studied in engineering
- Others ask me for help in engineering

**Recognition**
- I see myself as an engineer
- My engineering professor sees me as an engineering person
- My parents/relatives/friends see me as an engineering person

**Agency**
- I can overcome setbacks in engineering
- Learning engineering will improve my career prospects
- Engineering is helpful in my everyday life
- Engineering has helped me to see opportunities for positive change
- Engineering has taught me to take care of my health
- Learning engineering has made me more critical in general

Revised Godwin 2016 Items recommended for future research

**Interest**
- I enjoy learning engineering
- I am interested in learning more about engineering
- I find fulfillment in doing engineering

**Performance/Competence**
- I am confident that I can understand engineering in class
- I am confident that I can understand engineering outside of class
- I can do well on exams in engineering
- I understand concepts I have studied in engineering
- Others ask me for help in this subject

**Recognition**
- My peers see me as an engineer
- My instructors see me as an engineer
- My parents see me as an engineer
A.3 Engineering Task Self-Efficacy (ETSE)

How confident are you in your ability to do each of the following at this time?

<table>
<thead>
<tr>
<th>Not Confident (1)</th>
<th>Slightly Confident (2)</th>
<th>Moderately Confident (3)</th>
<th>Very Confident (4)</th>
<th>Extremely Confident (5)</th>
</tr>
</thead>
</table>

Design a new product or project to meet specified requirements
Conduct experiments, build prototypes, or construct mathematical models to develop or evaluate a design
Develop and integrate component sub-systems to build a complete system or product
Analyze the operation or functional performance of a complete system
Troubleshoot a failure of a technical component or system

A.4 Closeness (CL)

We are interested in how you would describe your relationship with other people in the ENGR-14 class. We know that it is early in the class, but answer this as best you can.

Please choose the picture below which best describes your relationship to [Other].

Coded as:

1  2  3  4  5

This figure was repeated with [Other] replaced by:
Professor, Teaching Assistant, Best Friend in Class, Entire Class, Project 1 Team, Project 2 Teammate