Complete Work: Investigation of Sense of Belonging to Engineering in Introductory Level Pre-Engineering Classes

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Complete Research: Investigation of Sense of Belonging to Engineering in an Introductory Level Engineering Class

Abstract

This paper presents the complete research results of an evidence-based practice investigating students' sense of belonging in an introduction to engineering class. Studies have shown that student sense of belonging in the classroom, major, and institution can positively impact performance in future engineering classes and overall retention rates. Sense of belonging has been identified as particularly important to the retention of underrepresented minorities and females. This research project explores the effect of embedding small interventions designed to improve engineering pre-major students' sense of belonging into a first year introductory engineering class. In addition, this study investigates the effect of the interventions on student demographics such as gender and race. This study has the potential to benefit first-year engineering education pedagogies by exploring the effectiveness of small interventions that can be embedded into busy course curriculum without significantly detracting from classroom time available for content focused on meeting course outcomes. This paper describes the design and implementation of the three interventions that were embedded into multiple sections of an introduction to engineering class and presents the results of quantitative and qualitative data analysis. In addition, the authors discuss the challenges and limitations faced during the project including survey design limitations, inconsistency of survey interpretation, questions related to effectively measuring sense of belonging, and student ability to discern change in sense of belonging. The team shares the methods they used to overcome these challenges and presents the lessons learned with an emphasis on best-practices and future recommendations. All work was completed with IRB approval and student identity protection.

Introduction & Background

Sense of belonging generally relates to self-perceptions of fit within a given context including classrooms, campus community, and affinity groups [1, 2]. Increased sense of belonging among students leads to higher levels of motivation and engagement as well as increased retention rates and academic performance [3-5]. Research indicates that females and underrepresented students (URM) have a lack of sense of belonging in STEM departments and in engineering, specifically [6-9]. Studies suggest that students' sense of belonging can be positively impacted through interpersonal and academic validation which increases with positive classroom climate, appreciation of diversity, faculty connection, peer relationships, and growth mindset [10-12]. A work-in-progress paper has been previously published and includes a full literature review related to this research project [13].

This research study took place at Western Washington University (WWU), a public master's-granting institution with approximately 15,000 full-time undergraduate students. The Engineering and Design department at WWU offers four under-graduate only programs: Electrical Engineering, Plastics and Composites Engineering, Manufacturing Engineering, and Industrial Design. Students who are interested in majoring in Engineering and Design at WWU must formally apply to their program of choice after completing a series of prerequisite courses. Prior to being accepted into a program, students are considered "pre-majors." There are approximately 350 pre-majors and an additional 250 major level students enrolled in engineering and design at WWU. Recent institutional data has shown that number of female and URM students enrolled in engineering programs at WWU is far below the national average. In addition, the percentage of females in engineering has been declining since 2016 while the percentage of women nationally has been increasing. These trends are concerning and have been a focal point for recent departmental efforts related to improving equity and inclusion with a focus on increasing sense of belonging.

The research team created a series of three simple interventions, embedded them into an existing course, and studied the impact on the development of student sense of belonging. The interventions were added into a

first year, introductory engineering course (Introduction to Engineering & Design) with the aim of impacting as many students as possible early in their academic careers. The WWU Introduction to Engineering and Design (ENGR 104) course is a project based class that introduces students to the engineering design process and explores the role of creativity in design, team dynamics, 3D visualization, diversity of perspective, global impact of design, and ethics. All engineering and design students are required to take ENGR 104 as pre-majors, prior to applying to major. The majority of students take the course during their first year at WWU. The course is taught by a variety of instructors and has a class capacity of 50 students.

The three interventions embedded into the course were 1) a collaborative activity establishing classroom ***norms***, 2) a mid-quarter activity engaging students with the concept of ***growth mindset***, and 3) ***instructor connection*** through scheduled one-on-one meetings with the students or other forms of connections during office hours and lab work. These interventions are discussed in detail later in the paper, along with rationale related to the design and implementation of the interventions. Surveys were administered to students to gauge if the sense of belonging (SOB) of the students was affected by any or all these interventions.

Prior work:

This research began as a collaborative study involving a university (WWU), community college (Whatcom Community College), and technical college (Bellingham Technical College) [13]. The rationale behind involving the three institutions was to allow for the involvement of students with differing demographics, backgrounds, educational goals, and character. This approach would allow the research team to investigate the impact of the same interventions on different student populations at different institutions. However, as summarized in the previous paper, the authors faced multiple challenges that impeded progress and complicated the study. Due to the different class requirements at each institution, various teaching styles among the instructors at each institution, and the challenges in collecting and interpreting the data per institution, it was determined it would be beneficial to focus the study on one institution. This would allow the team to simplify the study, gather and analyze additional data, and then determine whether or not to extend the study to additional institutions based on the initial results. Readers are encouraged to review the work-in-progress paper for a discussion of prior work including literature review, survey development, and discussion of initial results.

Interventions: Design & Implementation:

The interventions were chosen and designed specifically to encourage students to connect with other students in their classes, engage in self-reflective processes, and utilize available institutional resources. The researchers designed simple interventions to maximize the potential impact on students while minimizing the time required to administer the interventions. As is true with most engineering curriculum, course content is focused on course outcomes and, as such, there is often little unstructured time in which to integrate new content in an effective manner. The total class time required for all three interventions ranges from 1-2 hours which equates, on the higher end, to one class session per quarter. The researchers and instructors of the course agreed that the number of interventions and required time is reasonable without interfering with the core class material. These interventions are hypothesized to improve engineering students' sense of belonging and self-efficacy in their majors [14, 15].

After considering course assignments and scheduling, the researchers chose a selection of ENGR 104 courses in which to embed the interventions: Fall 17, Spring 18, and Fall 19. Each course was taught by a different instructor however, the content of the interventions was consistent for each offering of the course. Two of the sections were taught by a member of the research team and a third section was taught by a faculty member who worked closely with the research team. An additional class section (Fall 19) participated in this study as a control group (no interventions were embedded but students were asked to complete the surveys). It is important to note that the interventions were not embedded into all available sections of the 104 course during the research period due to inconsistency in staffing which resulted in slight variations of the course. In

additional, not all faculty members who were scheduled to teach the course were interested in embedding the interventions into their course.

Classroom norms activity

The goal of this activity is to promote a respectful and encouraging learning environment in and out of the classroom. By establishing expectations of classroom behavior, students gain a sense of ownership over the classroom environment and feel they are active members of the classroom community rather than passive observers. Instructors involved in this research had implemented this activity in the past and received feedback through anonymous student evaluations that this activity had created an inclusive environment in the classroom. On the first day of class, students were asked to individually reflect on their experience being a student and were asked to write down classroom norms that they think are important to achieve a respectful and encouraging learning environment. Then the students were asked to form groups of four members and discuss the individual norms developed individually. Together, the groups agreed upon two norms to be discussed with the class. A representative from each group presented the two norms developed with their group, and the instructor-facilitated a class discussion related to each norm. After a thorough discussion on all the presented norms, the instructor combined and modified the norms based on the student discussion to reflect the final decisions of the whole group. The class norms were recorded and shared with the class in a place visible and accessible to all students.

Growth mindset activity

The goal of this activity is to foster the growth mindset practice that was originally developed by Dr. Dweck [16]. According to Dweck, students who engaged in growth mindset thinking patterns report feeling a significantly higher sense of belonging as compared to students who engaged in fixed mindset thinking patterns. Female and URM students, in particular, can be most at risk to feel as though they don't belong due to stereotypes and cultural differences [17].

This activity was designed to help students to develop a growth mindset which in turn would help them to feel a greater sense of belonging in the larger classroom environment. The activity started with an in-class showing of the Ted Talk Video by Eduardo Briceño, the Co-Founder and CEO of Mindset Works (link to the YouTube video: https://youtu.be/pN34FNbOKXc). In this video, Mr. Briceño articulates how the understanding of intelligence and abilities among students is a key when it comes to being successful academically and in life. This video was followed by a class discussion relating to the question: "What kind of situations trigger your fixed mindset." To facilitate this discussion, the students were arranged into groups where they each shared stories relating to experience with their own fixed mindset. This was followed by sharing strategies that they believed would help to develop a growth mindset. As a concluding activity, the whole class worked together to identify what particular classroom situations might trigger the fixed mindset and how classmates, teaching assistants, and/or instructors can work together to encourage the growth mindset.

Instructor connection

The third intervention involves having each student meet individually with the course instructor. As part of a graded course assignment, students were required to schedule an individual meeting time with the instructor no later than the end of the second week of the quarter. Through individual meetings with students, instructors could relate more personally with students and help them to become less hesitant to ask for assistance when they need it. During these meetings between students and instructors, students were essentially "practicing" engaging with their available resources. The researchers' hypothesized that students would develop an informal relationship with the instructor and would be less hesitant to ask for help when

the need arose. The overall goal of these meetings was to help develop positive, supportive relationships between student and faculty while allowing an opportunity for faculty to provide information related to college and university resources to the pre-major students. This intervention has the potential to have a significant impact on student belonging since connection with faculty and access to support resources play a crucial role in improving students feeling of belonging to their field of study [10, 11]

The researchers constructed a list of guidelines that were provided to course instructors outlining suggestions for how to structure the individual student meeting. The instructors were encouraged to keep the conversation informal and to allow time for additional and unexpected conversational topics. Potential conversation topics included course related topics (outcomes, project specifics, teamwork, etc.), sharing of personal and/or education background, and discussion of department and college support resources. Faculty met with each student individually for up to 20 minutes in their office during the first two weeks of the quarter.

Research Design, Data Collection & Analysis

The two research questions assessed through this research were:

> RQ 1: How effective will small in-class interventions be on increasing the sense of belonging among engineering students?
>
> RQ 2: Is there a difference between the effect of interventions on different student groups, specifically females and URM?

It is worth noting that due to the small sample sizes and to protect student identity, the researchers did not include a separate category for URM females. Students who fell into this category were included in both data sets (female and URM). The researchers are interested in this intersection of these identities and hope to conduct follow-up research investigating the sense of belonging of this particular student group.

To collect data for the assessment of these research questions, pre-and-post sense of belonging surveys were developed and given to students at the beginning and end of the quarter for formative assessment. The survey questions were based on validated belongingness surveys found in the literature [5]. To ensure a high response rate, the surveys were administered as graded assignments. All enrolled students were required to respond to both surveys as part of their class assignments, but only the data of those who agreed to participate in the research by signing a consent form for identity protection are used for analysis. On average, 56% of students enrolled in the class completed both surveys and agreed to participate in the study.

To be able to statistically measure the effectiveness of interventions, a set of ten survey questions were asked in the same way on both the pre and post-survey using a 5 point Likert scale. Identifiers (student name and ID number) were included in both surveys. On the pre-survey, additional questions to gather demographic information were included. And on the post-survey, additional reflective questions related to student perception of their change in the sense of belonging were added.

Survey Questions (both pre and post survey):

1. I feel the institution resources are useful in supporting my learning
2. I feel connected and supported by my peers and the institution community
3. I feel comfortable reaching out to my professors with questions and concerns
4. I feel comfortable working with my peers on class-projects inside the classroom
5. I feel comfortable working with my peers on class-projects outside the classroom
6. I feel supported in this class

7. I feel that I am part of this class
8. I really enjoy going to school here
9. I feel that there is a real sense of community at this school
10. I feel that I will continue to pursue an engineering major.

The post-survey included the ten questions from the pre-survey along with additional questions related to the interventions. The goal was to compare the impact of the interventions on course activities and assignments on the development of student sense of belonging. The post survey intervention question asked was "*How much did the following course activities impact your sense of belonging in the course, at the college, and/or in your major."* This was followed by a checklist of course activities that included the interventions (establishing classroom norms during the first week of class; growth mindset video and activity; interaction with the instructor).

In addition to completing the surveys, students in the Fall 2019 sections of the class (including the control group) were required to complete an open-ended reflective writing assignment on their experience in the class. This assignment was added to the class by the researchers in order to gather additional qualitative data to help verify the survey results.

I would like each of you to write a short paper responding to the following two questions:

1. *Considering all you have learned and experienced this quarter, what will you take with you into the future?*
2. *What (if any) particular aspects of this class do you think will be the most beneficial to your future as a student?*

Survey Analysis

The survey instrument adopted in this study is based on validated questions that are commonly used by researches to measure sense of belonging among participants [18]. The breakdown of the number of students who consented to participate in this study per class and the demographic data is shown in Table 1. It is important to note that the percent female and URM students who participated in this study is not indicative of the percentages of those student in the classes. In all 4 classes, the percent female student ranged from 8.8% to 37.5% while the percent URM ranged for 12.5% to 29.2%.

Table 1: Study participants and demographics (*total n = 108*)

	n	*%Female*	*%URM*
Fall 17- study group	29	6.9%	13.8%
Spring 18- study group	25	20.0%	32.0%
Fall 19- study group	28	35.7%	17.9%
Fall 19- control group	26	46.2%	23.1%

We compared the four classes mean scores on composite survey factors between the pre and post-survey results related to SOB using independent samples T-tests [19]. Though some small differences in group means were evident, none of those were statistically significant. Table 2 summarizes the statistics for the composite survey factors related to SOB for the four classes.

Table 2: Pre and post-survey results of SOB composite survey factors

Results of all students	*mean*		*SD*		*p-value (95% CI)*
	pre	*post*	*pre*	*post*	
Fall 17- study group	3.43	3.15	0.66	0.61	0.21
Spring 18- study group	4.13	3.95	0.67	1.04	0.49
Fall 19- study group	3.98	3.82	0.56	0.53	0.28
Fall 19- control group	3.88	3.77	0.65	0.54	0.51

Based in the data shown in Table 2, the direct answer to our first research question "RQ1: How effective will small in-class interventions be on increasing the sense of belonging among engineering students?" is that **no significant difference between the classes that administrated the interventions and the control group** was observed.

It is important to note that in all 4 cases, sense of belonging actually *decreases* from the pre-test to the post-test. Although this is not a statistically significant result, it was of interest to the researchers. This was a very interesting finding to the researchers since the additional essay portion of the post-survey showed that many students think that these interventions helped improved their SOB, as will be discussed in the next section.

Results of the composite survey factors per gender and race were also consistent with the results above in terms of **no significant difference between the study groups and the control groups**. Thus, there are no significant findings related to RQ2: Is there a difference between the effect of interventions on different student groups, specifically females and URM? However, it is worth noting that the study groups scored slightly higher than the control group in terms of averages as shown in Table 3. In addition, in most cases, the sense of belonging from the pre to the post increases. The researchers would like to investigate this finding future to examine if these particular interventions may positively impact underrepresented students more than their peers.

Table 3: Pre and post-survey results of sense of belonging composite survey factors by gender and race.

Results of Female students	*mean*		*SD*		*p-value (95% CI)*
	pre	*post*	*pre*	*post*	
Fall 17- study group	4.53	4.21	0.41	0.64	0.59
Spring 18- study group	4.24	4.28	0.65	0.38	0.90
Fall 19- study group	3.73	4.09	0.49	0.42	0.09
Fall 19- control group	3.73	3.96	0.74	0.59	0.41

Results of URM students	*mean*		*SD*		*p-value (95% CI)*
	pre	*post*	*pre*	*post*	
Fall 17- study group	4.62	4.52	1.25	1.23	0.90
Spring 18- study group	4.22	4.26	0.45	0.53	0.88
Fall 19- study group	3.70	4.24	0.41	0.46	0.08
Fall 19- control group	3.81	3.83	0.56	0.46	0.95

Analysis of the individual items level for the survey did not show any items that were significantly different in scores if compared to the composite scores between the study groups and the control groups. However, as

mentioned, it was noticed that some of the scores slightly decreased from the pre to post test results. The researchers believe that this might be influenced by when these surveys are administrated. The post surveys are administered during the last week of the quarter when deadlines are looming, stress levels are high, and students often feel overwhelmed. The researchers hypothesize that those factors may influence answers to survey questions.

Essay questions analysis

For both sections of Fall 2019 courses (study group and control group), all students were required to complete an "end of quarter reflection" writing assignment. This assignment is an open-ended essay question that asks the students to reflect on two questions:

1. Considering all you have learned and experienced this quarter, what will you take with you into the future?
2. What (if any) particular aspects of this class do you think will be the most beneficial to your future as a student?

The researchers read through the student responses to the essay question and coded the responses based on student reference to the norm activity, the mindset intervention, connection to the instructor, and indication of development of sense of belonging. Table 4 below summarizes the results of qualitative coding of the essay question. Coding indicates a positive response related to one of the following: norms, mindset, instructor connection, and sense of belonging.

Table 4: Qualitative coding analysis of "end of quarter reflection" essay question

	Fall 2019	***Study group***	***Control group***
# Students	*n*	24	28
Sense of belonging in the class	*% total students reporting positive SOB*	54.2%	25%
	% female reporting positive SOB	20.8%	7.10%
	% URM reporting positive SOB	8.3%	7.10%
Intervention	*Norms*	50.0%	NA
	Mindset	83.3%	NA
	Instructor connection	37.5%	NA

The results of the coding shows that 54.2% of the F19 study group reported a positive impact on their sense of belonging with half of the students specifically mentioning the norms and 83.3% mentioning the mindset activity. This is in contrast to only 25% of students in the control group reflecting positively on their sense of belonging. Further analysis shows that of the students who were coded as reporting positive sense of belonging, 100% of students mentioned mindset, over half mentioned the norms, and 30.7% mentioned all three interventions (norms, mindset, and instructor connection) in their essay as shown in Table 5 below.

Table 5: Coding results of students showing positive impact on sense of belonging

F19 study group *coded as reporting positive impact on sense of belonging*	
n	13
norms	53.9%
mindset	100.0%
instructor connection	38.5%

more than one *intervention*	53.80%
all three *interventions*	30.7%

The results of the coding show that there is a difference between the study group and the control group with regards to their reflections of sense of belonging. Considering that the essay question was open-ended, it is of significance when students mention one of the interventions in their response. Since the interventions themselves are short (both the norms and mindset activities take less than an hour), the researchers were surprised to see that so many students reflected positively on those activities. What the essay is not measuring, however, is the change in student sense of belonging over the course of the quarter. The researchers plan to conduct future research to investigate this further.

Conclusion, Limitations & Challenges

The norms and mindset interventions designed as part of this research study are of high quality and are easy to embed into an existing course. The results of the survey analysis indicated that there was no statistically significant improvement to student SOB over the course of the quarter due to the inclusion of the interventions in the course. For both of the research questions posed, no statistically significant conclusions can be drawn as a result of this research study. However, the initial results of qualitative coding analysis of the essay question shows that for the class that included the interventions, students indicated a positive sense of belonging and referred to the interventions in a positive way in their essay. In addition, the difference between the percentages of students reporting positive sense of belonging for the study group was nearly double that of the control group. These results lead the research team to believe that there are some potentially significant limitations to the research design, specifically related to the survey.

- Asking students to reflect on how a particular activity impacts their sense of belonging by asking "*How much did the following course activities impact your sense of belonging in the course, at the college, and/or in your major?"* may not be indicative of the actual impact of the activity. Do students understand what we mean by "sense of belonging?" and can they effectively evaluate how it has changed over the course of the quarter? There might be a more effective way to ask this question and/or evaluate the impact of particular activities/interventions.
- Can we reasonably expect a student's perception of their sense of belonging to change dramatically in 10 weeks timespan? While it is possible that these interventions positively impact student sense of belonging, at what point does that make a difference to how they answer questions related to feeling comfortable, being supported, and enjoying school?
- The qualitative essay question does not examine the *change* in belonging over the course of the quarter so it cannot be used to show the impact of the interventions on student belonging in the course. However, it is quite useful as a comparative tool to measure SOB of students in the study group vs the control group. The research team would like to explore using the qualitative analysis as a possible way to measure the impact of particular interventions on sense of belonging.
- Although it is not statistically significant, it is noteworthy that the sense of belonging of composite survey factors between the pre and post survey for all students decreases while for females and URM's the values increase.
- The timing of survey administration the two surveys may have had an effect on how students actually interpreted the questions and responded to them. Are students more stressed at the end of the quarter? Does this impact their perceived SOB? Are they taking the survey seriously?
- The 5-point Likert scale in the pre and post-survey was not enough to provide a good balance of discrimination between the responses. Some literature suggests that a 6 or 7-point scale tends to provide a better balance in terms of having enough points of discrimination [20].
- The surveys did not capture other factors that might have an effect on SOB, such as negative team experience, a health or wellness issue, and external stressors. These types of factors may have been

addressed by students in the essay question however, for this study, the research team did not examine this specifically.

- The one-on-one meeting with the instructors was a time challenge due primarily to the large class size. Note that although 25-28 students participated in the study, the class size is 50 students. At 20 minutes per student meeting, a total of 16 hours outside of class time is required for the required office hour visit. Two of the three faculty members who taught the course with the required office hour visit felt that although meeting with each student individually is valuable, it is too time consuming. This is especially true for part-time faculty members.
- In addition to the above, the interaction with an instructor during the required office hour could have potential negative impacts on students if the faculty member is not comfortable with informal conversation, does not have adequate awareness of campus or community resources and/or and is unable or unwilling to support students or address concerns.
- Student participation in the development of course norms will vary depending on how this discussion is facilitated by the instructor. Some instructors may benefit from training or instruction related to this intervention.

To overcome some of the above limitations and challenges, especially related to the survey, the researchers determined it would be beneficial to conduct a discussion or focus group with the students to gain more insight as to how students actually perceive sense of belonging and what factors might affect that in any classroom setting. It was clear to the researchers from analyzing the data that measuring feelings of connectedness and belonging is very a challenging task, and that perhaps ten survey questions are not enough to do that. The research team would like explore this further by conducting a more rigorous research study that involves improved survey instruments, qualitative essay questions, and focus groups. Moreover, the researchers conclude that although a short activity or intervention in a course might positively impact sense of belonging, it is essential to think more broadly and deeply as to how to positively impact sense of belonging for our students.

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