Investigation of Sense of Belonging to Engineering in Undergraduate Introductory Classes

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Work-in-Progress: Investigation of Sense of Belonging to Engineering in Introductory Classes

Abstract

This work-in-progress paper investigates students' sense of belonging in introductory classes in engineering and engineering physics. The research project involves students at three educational institutions with similar geographic location but with student bodies of differing demographics and character: a regional university; a community college; and a technical college. Studies have pointed to the effect of the lack of belonging among the classrooms, majors, and the institution in general on students' retention rates and performance in future engineering classes. Sense of belonging has been identified as particularly important to the retention of underrepresented minorities (URM) and women. In a multi-year study published in the 2012 ASEE conference [1] researchers at five institutions conducted an extensive research study of belonging among STEM students in four categories; belonging to the classroom, belonging to the major, belonging to the institution as a resource; and belonging to the institution as a community. Results show a statistically significant difference in belongingness among those students in those four categories at the five institutions based on students' classification. However, results suggested that hypothesizing a monotonic increase in the sense of belonging by year in school cannot be supported by the research findings and educators have to ultimately understand what impacts the sense of belonging and how to improve it over time during college years.

At each of the three educational institutions where this current study is performed, the percentage of students who are identified as URMs is about one-fourth of the overall engineering student population. As more initiatives have been emerging in these institutions to help increase diversity and inclusion, the researchers were motivated to conduct this study to improve the belonging of engineering pre-major students in STEM classrooms and their intended majors. This research explores the effect of embedding small interventions designed to improve engineering pre-major students' sense of belonging and self-efficacy into traditionally taught Introduction to Engineering and Introduction to Engineering Physics classes. In addition, this study investigates the effect of the interventions on different student groups (women, first generation, students of color or ethnic background, community college vs. technical college vs. university students, etc.). 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 curriculums without significantly detracting from classroom time available for content directly connected to course outcomes. The three interventions used in this study include a first-day collaborative activity to establish classroom norms; a mid-quarter activity centered around growth mindset and metacognition; and a one-to-one instructor/student meeting.

The effectiveness of the interventions on increasing sense of belonging is assessed using a series of five Likert scale questions drawn from other belongingness surveys found in the literature [2]. The pre-course survey was administered during the first week of the term with nine questions embedded in a broader "Getting to Know You" survey. The post-course survey was administered during the last week of the term with the same nine questions embedded in a broader survey collecting student feedback on the effectiveness of various course learning activities (e.g. homework, projects, lectures, etc).

All work was completed with IRB approval and students identity protection. Qualitative and quantitative data analysis is being performed on the collected data. Researchers anticipate that the three interventions will improve student sense of belonging and will look to use the survey response data to evaluate the relative effectiveness of the interventions as perceived by the students.

Introduction

Sense of belonging measures individuals' perceived social cohesion to various groups or environments, and has both cognitive and affective elements [3]. It has been stated that "the human need to belong is among the most powerful motivators of social behavior" [4]. Research suggested that higher sense of belonging among students leads to higher levels of motivation, engagement, and overall performance during the education system [4]. Therefore, and in an academic setting, the need to feel belonging is crucial to educational and social success. Students work better in areas and capacities where they feel a solid connection to their fields and when their need to experience a sense of belonging is satisfied [4]. This is an important factor in the current higher education system and in STEM education, particularly for recruitment, retention, and success. This topic is largely assessed and evaluated with studies and research that is heavily based on the feedback of students from various STEM field about their sense of belonging in their majors, classrooms, and schools [5]. When analyzing sense of belonging of STEM students in higher education, various contributing factors to this feeling "or the lack of it" is presented in the literature such as culture, family education level, household income, ethnicity, gender, sexual orientation, and the higher education institution general climate [6].

One research hypothesis states that students feel a greater sense of belonging based on race, income and parent education [7]. White, high-income, not-first generation students feel the highest sense of belonging among all groups. The research shows that these students feel more welcomed in their schools because their parents help guide them in the right path along the way since childhood and usually with their tuition not being a big obstacle during their higher education journey. In the contradictory, students with non-college educated parents (first generation students) and with lower income have less guidance and do not feel as though they belong to their educational environment as compared tothe other group [8]. Another study conducted by Jordan and Sorby in 2014 shows that underrepresented minority students (URM) from ethnic backgrounds have a significantly lower sense of belonging compared to their majority student counterparts. A large number of factors can make URM students of varying ethnic backgrounds feel like they do not belong. Most of these factors appear in direct contact with are directly related to students' interactions and relations with people around them such as faculty, classmates, lab instructors, teaching assistants, significant others, family members, friends, and college staff. The researchers emphasized that faculty and peer interaction is one of the biggest driving forces behind increasing the sense of belonging among those students in higher education. This can range from saying hello to having a casual interaction with a professor in the hallway. Accordingly, faculty plays one of the most crucial roles in improving students feeling of belonging to their field of study [9]. Other research focuses on the impact of campus climate on a sense of belonging in colleges for various students' groups and concludes that the institution climate plays a key factor in students' retention and degree completion among all students' groups including URMs [10]. A method was proposed and tested to overcome the lack of belonging among URMs by encouraging the participation of

those students in cross-cultural clubs. Along with those students' groups, white students have also shown an increase in the sense of belonging by participating in intramural clubs. Other studies suggested that students are most likely to succeed in college if they are empowered and view themselves as capable learners through the academic and interpersonal development they undergo from interactions with various institutional resources. These interactions share a positive correlation with a sense of belonging in college and shows that students who receive positive interactions perform better academically as their sense of belonging increases [3].

Another important factor that is widely found in the literature is gender. Female STEM students have been shown to lack the feeling of belonging to their majors/institution as compared to their male counterparts, which often results in leaving STEM for a different field. Females in STEM often feel undervalued among peers and as though less is expected of them [11]. A common reason for this is that women have a lower presence in STEM fields than men. Research shows that women feel more welcomed with a greater sense of belonging if they are in direct one-on-one contact with other female peers and instructors in their institutions. This leads to those female students becoming more comfortable at school and more confident in their abilities and increases their chances to succeed. The research shows that exposing female freshman to women scientists, engineers, and innovators drastically increased their feeling of belonging [12]. The presence of clubs such as Society of Women Engineers (SWE) has allowed females in varying types of engineering disciplines to interact across campuses and across the country with female role models in engineering. SWE also provides workshops in leadership and recognition programs, which contributes to female students' self-efficacy and esteem [13]. The interaction with role models, mentors, and supporting organizations are also linked to increasing female students' grades.

Another factor that is correlated with gender, but also applies to almost all students groups, is the lack of confidence in ability level of basic math and science skills [9]. This is mainly based on preconceptions about a student's ability to apply basic skills to complex problem-solving in the more advanced coursework. Although abilities like math and analytical thinking are crucial to succeed in STEM degrees, they can be improved by adopting a growth mindset strategy in learning [14]. A growth mindset, according to Dr. Dweck, who is intensively studying this learning strategy, is achieved by emphasizing the benefits of the challenges presented within those math and science topics in STEM and suggesting spending more time on such challenges using praise associated with the effort that the students put into their work as opposed to praising them based on intelligence [15]. Studies suggested that several interventions targeting this growth mindset, such as seminar courses, are intended to aid students with general knowledge and to help in student retention and self-efficacy. These interventions also expose students to campus life in their early college years which increase overall student sense of belonging to their institutions and majors [16]. In addition, one study suggested that students who obtain direct feedback and guidance in the classroom around the incremental nature of ability "growth mindset" (e.g. their ability can improve over time with instruction and practice) showed a significant academic improvements, enjoyment & engagement, and overall higher sense of belonging at the end of the term compared to the students who did not receive such instructions [11].

Methodology

This research explores the effect of embedding small interventions in Introduction to Engineering and Intro to Engineering Physics classes at three different educational institutions. These interventions are designed to improve engineering students' sense of belonging and self-efficacy in their majors. The research team decided to administer three short interventions in four classes at the three institutions. The rationale behind focusing efforts on three simple interventions is due primarily to time constraints. Since all three institutions are on the quarter system, there are only 10 weeks available for each class. Three interventions seemed to be reasonable without interfering with the core class material and the other activities that usually take place during the quarter. The interventions chosen were 1) a collaborative activity to establishing classroom norms, 2) a mid-quarter activity engaging students with the concept of growth mindset, and 3) scheduling a one on one meeting with the instructor for every student in the class. These interventions were chosen to encourage students to connect with other students in their classes, engage in self-reflective processes, and utilize available resources at their institutions.

Institutional Information & Course Descriptions:

The research was conducted at three educational institutions in Whatcom County, WA: Western Washington University (WWU), Whatcom Community College (WCC) and Bellingham Technical College (BTC). All three of these institutions, located within a 5-mile radius, offer engineering programs with both WCC and BTC offering transfer options to WWU for students wanting to earn bachelor degrees in engineering. Having three different institutions participate in the research allows for the involvement of students with differing demographics, backgrounds, educational goals, and character. This allows the research team to investigate the impact of these interventions on different student populations. The researchers chose to administer the interventions into four courses, all of which are designed to prepare students for more complex engineering design and problem-solving skills associated with upper-level engineering courses.

Western Washington University:

Western Washington University (WWU) is a public master's-granting institution with approximately 15,000 students, 160 academic programs, and a vibrant campus community. Western offers the focus on students access to vital academic choices, resources, multicultural diversity, and various curricular and extracurricular activities to grow and thrive. Western students participate in a variety of international experiences including study abroad, internships, volunteer work, and faculty-led study tours. Western faculty plays an active role in their student's lives, not only in the classroom but also through advising student groups, supporting individual student career aspirations, and mentoring programs. The Engineering & Design Department at WWU is a new department formed in 2014 out of the former Engineering Technology department as part of a state-funded effort to transition the engineering technology programs to accredited engineering programs. The department offers five undergraduate-only programs with distinguished faculty in each program; the Electrical Engineering (EE) program, the Manufacturing Engineering (MfgE) program, and the Plastics & Composites Engineering (PCE) program which are all ABET accredited. In addition to non-ABET accredited degrees in Industrial Technology–Vehicle Design and Industrial Design.

The faculty at WWU conducted this research in the Introduction to Engineering & Design course. This course was chosen as a good fit for this project because it is an entry-level engineering course that includes students who declared an interest in one of the five engineering programs and registered in this introductory class to fulfill the requirements for a major application. The class also serve as a requirement for a degree in Manufacturing Supply Chain Management (MSCM) program at Westen, but since this program is part of College of Business and Economics, those students were not part of this study as they are not Engineering majors. This course introduces students to the field of engineering, the design process, and communication of ideas with graphics. Includes team design projects, drawing instruction and assignments, the role of CAD, introduction to the engineering disciplines, engineering history, ethics and case studies of engineering feats and failures, and how things are made. This course has a class capacity of 48 students and offered 5 times throughout the academic year.

Whatcom Community College:

Whatcom Community College (WCC) is a two-year community college that offers a range of transfer-oriented degrees and professional-technical training programs. The college serves approximately 11,000 students annually (4110 full-time equivalent students in 2016-17). Approximately 80% of Whatcom students indicate their intent is to transfer to a bachelor's degree program upon completion of their studies at Whatcom. Whatcom offers four engineering-oriented Associate in Science-Transfer (AS-T) degree pathways with requirements for each degree customized to ensure preparation for junior-ready transfer in a specific engineering major. Enrollment in the engineering transfer program for 2017-18 is estimated at around 130 students.
The faculty at WCC conducted this research in an Introduction to Engineering course and Introduction to Engineering physics course. These courses were chosen as a good fit for this project because they are an entry-level engineering courses that include students majoring in all engineering disciplines as well as some just considering the major. The Intro to Engineering course is a project-based introduction to engineering analysis and modeling exploring the engineering disciplines at a technical level. Topics include academic success strategies, analytical problem solving, applications of mathematics, physics, and chemistry in engineering, dimensional analysis, and unit systems, and introductory computer-aided design. Students develop their knowledge and skills in these areas through hands-on projects, in-class group activities, homework, and class discussion. This course has a class capacity of 24 students.

For the Introduction to Engineering Physics course, nearly all students were intending to transfer to universities to complete their engineering degrees. The course is a calculus-based survey of mechanics principles in which students develop their understanding of Newton's laws and conservation laws. The course is taught with a student-centered, active classroom environment where a student's sense of belonging is important to their participation and comfort in the learning process. Small group lab work and class discussion provide the backbone of student engagement with course content.

Bellingham Technical College:

Bellingham Technical College (BTC) is a two-year technical college that provides hands-on training in a variety of technical fields, including engineering technology. The college is currently one of the smallest colleges in Washington State's community and technical college system, serving approximately 3,000 students per quarter and 5,400 students per year. The engineering technology department at BTC prepares students for careers in the industry at the technical level and/or to transfer to select WA state baccalaureate engineering programs. There are 6 BTC engineering technology specializations students can choose from: civil, mechanical design, clean energy, electronics, composites, and geomatics. The students in the engineering technology program at BTC earn Associate of Applied Science-Transfer (AAS-T) degrees which prepare them for careers in industry as well as transfer to baccalaureate engineering programs.

The faculty at BTC conducted this research in the Introduction to Engineering & Design course. This course was chosen as a good fit for this project because it is an entry-level engineering course that includes students majoring in all 6 of the engineering specializations. The course explores the role of teamwork, creativity, and communication in innovative engineering design. Topics include engineering design process, collaborative problem-solving techniques, and computer applications. Students develop their knowledge and skills in these areas through hands-on design projects, in-class activities, and class discussion. This course has a class capacity of 24 students.

<u>The Three Interventions:</u>

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 a list of classroom norms that they think is important to achieve a respectful and encouraging learning environment throughout the quarter. 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 [15]. 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. In a study, Dweck and her colleagues followed a group of female students through a calculus course and monitored their feelings of belonging in the field of math. Throughout the semester those students with a growth mindset displayed a high sense of belonging while those who had a fixed mindset about math reported a shrinking sense of belonging in the class. 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. 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 an 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.

One-on-one meeting with the instructor

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 believe that, through this practice, students would develop an informal relationship with the instructor and would be less hesitant to ask for help later in the term or whenever the need arose. The instructors constructed a list of guidelines to be followed in all the meetings with the students as follows:

- Meet each student individually in your office during regularly scheduled office hours. This way they know where your office is located and know your availability.
- Meet early on in the quarter (within the first 2 weeks).
- The conversation should be informal in nature and faculty should allow time for additional, unexpected conversation topics. Schedule about 20 minutes per student.
- Have a copy of the syllabus available so you can refer to course outcomes, etc.
- Common questions should focus primarily on the course (outcomes, topics, projects, etc.), in addition to the following:

    - Ask students to share a bit about their background (could be education and/or personal in nature depending on what the student wants to share)
    - What are you excited about related to this course?
    - Is there anything you are anxious about?
    - Do you have any questions about the course outcomes or goals; team projects; homework assignments, etc.?
    - What do you see as your strengths and weaknesses with respect to the course assignments and team projects? (what can you provide your team? What do you hope to learn from your team members or how do you hope to improve?)
    - How do you see yourself best engaging with other students in the class? How can you contribute to a positive team and/or personal experience related to this course?
- Encourage them to communicate with you early and often, especially if they experience challenges.
- Share a list of college resources that are available to students.
- Remember to always be nice, warm, open and friendly.

Assessment:

The two research questions to be assessed throughout this research are:

- How effective will small in-class interventions be on increasing the sense of belonging among engineering students?
- Is there a difference between the effect of interventions on different student groups (women, URMs, etc.)?

The pre-and-post sense of belonging surveys were developed and given to the students at the beginning and end of the quarter for formative assessment. The surveys were developed collectively by all 3 faculty members involved in this research project and the questions were based on belongingness surveys found in the literature [2]. To ensure a high response rate, the surveys were administered as graded assignments within each of the courses. 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. For the pre-survey, demographic information such as gender, age, year in college and ethnic background were collected. To be able to statistically measure the effectiveness of the three interventions mentioned above, a set of eleven Likert scale survey questions were asked in exactly the same way in both the pre and post-survey. The Likert scale and questions that were asked in the pre and post survey are as follows:

Likert Scale:

1 = Strongly Disagree, 2 = Somewhat Disagree, 3 = Neutral, 4 = Somewhat Agree, 5 = Strongly Agree

Questions (pre and post survey):

1. I am familiar with the institutional resources available to support me at this point in my studies
2. I feel the institution resources are useful in supporting my learning

3. I feel connected and supported by my peers and the institution community
4. I feel comfortable reaching out to my professors with questions and concerns
5. I feel comfortable working with my peers on class-projects inside the classroom
6. I feel comfortable working with my peers on class-projects outside the classroom
7. I feel supported in this class
8. I feel that I am part of this class
9. I really enjoy going to school here
10. I feel that there is a real sense of community at this school
11. I feel that I will continue to pursue an engineering major

The post-survey included a selection of questions from the pre-survey along with additional questions related to the interventions. The goal was to compare the impact of the targeted three interventions with the rest of the course activities and assignments.

Since each of the four classes at the three institutions have different course content (projects, activities, requirements) each set of questions in the second set in the post-survey was tailored toward the specific class. Note that the first three questions were identical for all four classes since each class incorporated the three interventions. The following is an example of the scale and set of questions asked as part of the post-survey.

Scale:

- 0 = Unsure and/or do not remember
- 1 = Large negative impact
- 2 = Small negative impact
- 3 = Neutral impact
- 4 = Small positive impact
- 5 = Large positive impact

Question (post-survey only):
How did the following course activities impact your sense of belonging in the course, at the college, and/or in your major.

- Establishing classroom norms during the first week of class.
- Growth mindset video and activity
- Required office hour visit with the instructor.
- Tall Tower Activity
- Paper drop activity
- Egg drop project
- Guest speakers
- In-class teamwork (e.g. group activities)
- Out of class teamwork
- Engineering Disasters Videos and Discussion
- Orthographic Homework assignments
- CAD Labs using CATIA
- TA assistance in the lab and events

It is important to note that faculty at each institution could include additional questions to the surveys to gather information from students related solely to their particular course and/or institution. The additional questions were not used for this research project.

Challenges and Next Steps

As this is a WIP research, the researchers are planning to keep collecting more data throughout the rest of this academic year and during the next academic year to ensure a representative sample and to draw inclusive conclusions about the data and the approach. The focus of this work to date was on conducting a literature review, development of the interventions, administration of the pre and post survey, and a preliminary analysis of the results. Since this was the first round of the data collection, the researchers were faced with challenges throughout the process which will be addressed and improved upon in order to achieve the study goals. Some of these challenges include:

- In the first round of data collection, there were issues with inconsistent student interpretation of survey questions. The research team is working to review and modify these questions to ensure consistency in interpretation.
- Different teaching styles among instructors may affect how the students respond to the questions. One potential solution is to add additional survey questions related to student perception of the effectiveness of instructional techniques.
- The time chosen for a one-on-one meeting with the instructors was not consistent due primarily to the differences in class size (i.e. for the larger classes, it took more than 2 weeks to schedule meetings with all students). This may have an impact on the effectiveness of the intervention.
- There were some key differences between the way in which each instructor administered the Mindset intervention which may have impacted the effectiveness of the assignment. A solution to that is to standardize method of which this activity was administrated.

The next stage of this research project will involve a second round of data collection. The research plan to refine the process to eliminate inconsistencies and address the challenges discussed above. In addition, the research team plans to incorporate a few additional efforts to improve the quantitative and qualitative aspects of the research. This includes the following:

- Finalize the interventions and share educational resources to ensure consistency among delivery and instructional techniques.
- Add a control group in the next round of data collection which will allow the team to more easily identify data trends. This effort would involve administering the pre and post survey in additional sections of each course at each institution.
- Further standardize survey questions and review for inconsistencies and potential for misinterpretation.
- Consider adding additional research questions related to the effect of the interventions on different student populations.

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