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Intervention to Improve Self-Efficacy and Sense of Belonging of First-Year Underrepresented Engineering Students

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Introduction

A degree in Science, Technology, Engineering, or Mathematics (STEM) allows students an open door to every major successful career opportunity known to man (15). Students majoring in STEM during their undergraduate tenure go on to pursue graduate school, medical school, law school, work for Fortune 500 companies and the government. Additionally, careers in STEM are proving especially profitable for high achieving underrepresented minority students according to an article in Research in Higher Education (17). Among the Gates Millennium Scholars sampled, scholars majoring in STEM fields earned starting salaries between $8,000 and $17,000 more per year compared with those majoring in the Social Sciences, Humanities, and Education. This career path would seem to be very attractive, yet the number of underrepresented minority students who major in and graduate from STEM fields is low. According to the National Science Foundation's Science Resources Statistics the number of Bachelor of Science degrees awarded in science and engineering in 1990 was 65,967 (10,130 of the graduates were women). Of those graduates there were 112 Native Americans, 2,173 African Americans, and 2,473 Hispanic students (20). A decade later, we see an increase: Native Americans accounted for 3,635 of the graduates, African Americans made up 3,635 graduates, and Hispanic Americans made up 6,063 of 79,528 total graduates (14,478 were women). However, there is still more work to be done.

There are a number of reasons why underrepresented minorities do not persist or even consider pursuing STEM degrees. For example, in Eris et al. study (7) these students were found to have low confidence in their math and science skills. Their research also showed that non-persisters were encouraged to study engineering by their parents, and not having found their own desire to pursue engineering, they transferred out of those majors. Additionally, students of low socio-economic status tend not to major in engineering (32).

In the authors' opinion, students feel an engineering career is not as rewarding as becoming a doctor, lawyer, teacher or veterinarian. Do institution size (small, medium, large), type (predominantly white, HBCU, public, private), and setting (urban, suburban, rural) have an effect as well? Could it be that these students do not have role models in engineering fields to look up to for mentorship? Do underrepresented minority students know what an engineer is or does? Does the perception that engineering majors must be excellent in math and science deter students who do not have confidence in their mathematical and scientific abilities? Moreover, what if there are underrepresented minority students who do not grow up in an atmosphere where hands-on learning is encouraged? Would that cause them to pursue options outside of engineering?

One of many factors deterring underrepresented minority students from pursuing an engineering degree is that K-12 math and science programs across the country lack the resources in their schools needed to prepare students to study engineering (23). This fact can be summed up by Bandura's sentiments: "diversity in social practices produces substantial individual differences in the capabilities that are cultivated and those that remain underdeveloped" (1).

Math and science skills are underdeveloped in urban communities. This leads many underrepresented minority students to pursue careers outside of engineering. Addressing this issue should actually take place prior to a student's undergraduate career; when they arrive to the university it is almost too late for them to develop the skills they need to be successful—especially in engineering. If a student *has* made the decision to study engineering, however, understanding the challenges he/she faces and providing resources to ensure persistence from freshman year to graduation should be the focus of engineering educators.

Sociocultural influences such as gender roles and other events often influence a student's decision to pursue or not to pursue engineering (29). Vygotsky asserts that higher order functions develop out of social interaction, and social interaction plays a fundamental role in the development of cognition. Additionally, the path a student takes to pursue higher education is determined by the "nature of societal opportunity structures" (1). Simply put, people select activities associated with their acquired preferences and competencies. These ideals support Social Cognitive Theory (SCT) (1) which suggests that we are neither driven solely by an inner force or by outside influences.

Purpose of the Study and Research Questions

A student's engineering self-efficacy is his/her belief that he/she can successfully navigate the engineering curriculum and eventually become a practicing engineer. A student's engineering self-efficacy is formed by mastery experiences, vicarious experiences his/her physiological state, and social persuasions, especially student-professor interaction. Increasing the awareness of a student's engineering self-efficacy could potentially improve persistence and sense of belonging for underrepresented minority students in engineering.

Do underrepresented minority students feel included in their courses and labs? Do their expectations of what will happen upon graduating with an engineering degree change at some point? Are they experiencing positive interactions with their professors? These questions are in fact related to their engineering self-efficacy. Therefore, this study explored the following research questions:

1. What are the differences in engineering self-efficacy, and sense of belonging for first-year underrepresented minority engineering students compared to majority students?
2. What factors or variables should be considered and/or addressed in designing an intervention to increase engineering self-efficacy and sense of belonging amongst first-year underrepresented minority engineering students?
3. Can a small intervention during the beginning of the first semester improve a student's sense of belonging, engineering self-efficacy, and student-professor interaction?

Review of Literature

Social Cognitive Theory

To understand the effect of self-efficacy and sense of belonging one must understand Bandura's Social Cognitive Theory (1). Social cognitive theory posits that people are not driven by inner forces or controlled by their environments. Rather, they motivate their own behavior and development (1). Sociocultural influences and other events often influence a child's decision to pursue or not to pursue engineering (1). In addition, the path a student takes to pursue higher education is also determined by the "nature of societal opportunity structures" (1). These ideals support Social Cognitive Theory, which suggests that we are neither driven solely by an inner force or by outside influences.

There are several issues addressed within the social cognitive theory framework that help to explain the lack of interest and persistence of underrepresented minority students in engineering. For example, women face gender-role development, or "sex typing". Research shows that parents flood their male child's rooms with educational materials, sporting goods, machines, etc., while the female child's room acquires domestic items, baby dolls, etc. (1). How then will a girl have the opportunity to show interest in engineering?

To be an engineer it is said that one must possess superb mathematical skills. It is also said that one must do well with hands-on learning. Women and underrepresented minority students may not grow up in atmospheres where they have the opportunity to "tinker" with things to learn how they work; there are rarely opportunities to enhance their vicarious capabilities (learning through watching others). Also, many K-12 math and science programs across the country lack the resources needed to prepare students to study engineering (23). These are examples of the many challenge underrepresented minority students face when considering pursuing an engineering degree. This fact can be summed up as noted by Bandura (1): "diversity in social practices produces substantial individual differences in the capabilities that are cultivated and those that remain underdeveloped."

Social Cognitive Career Theory

Expanding Social Cognitive Theory, Lent at al. (14) developed the Social Cognitive Career Theory (SCCT) framework. SCCT envelopes several environmental, behavioral, and person variables that develop a person's academic interest. This theory has been widely accepted in counseling psychology and engineering education research, and has been used as a way to help predict students' academic interests and goals in engineering (15). SCCT has three overlapping models aimed at understanding how people:

1. Develop basic academic and career interest
2. Make and revise their educational and vocational plans, and
3. Achieve performances of varying quality in their chosen academic and career pursuits.

Within these models, self-efficacy (described later), outcome expectations, goals, and other factors such as gender, race, and barriers help shape a student's career path. An example of a barrier would be negative contextual influences, or adverse learning conditions (15). These theories are somewhat foundational when understanding the constructs of self-regulation and self-efficacy.

Addressing engineering diversity issues should actually take place prior to a student's undergraduate career; once they step foot on a college campus it is almost too late for them to develop the skills they need to be successful in engineering. If a student has made the decision to study engineering, however, resources and strategies must be put in place to ensure successful matriculate and graduation in an engineering program. Strategies that have proven successful stem from the theory of self-regulation.

Theory of Self-Regulation

Outside influences help shape a student's decision to pursue engineering, but once a student is capable of being self-directed, self-demands serve as their motivator (2). This describes the theory of self-regulation—"the capacity to exercise self-influence by personal challenge and evaluative reaction to one's own attainments" (2). Self-regulation provides a key cognitive mechanism of motivation and self-directedness, which could potentially lead to improved persistence of underrepresented minority students in engineering.

Two influential studies lead to understanding student success and persistence in engineering by way of self-regulation. French et al. (9) note several cognitive (high school rank, SAT scores, cumulative grade point average) and non-cognitive (academic motivation and institutional integration) variables that are related to students' persistence in engineering, with motivation being significantly related to persistence. Their research showed reliable improvement in persistence ($p < 0.05$) when motivation was included as a factor. Vogt et al. (28) measured self-variables including academic self-confidence and self-efficacy, as well as other environmental and behavior variables to learn what influences a student's academic achievement. They found that academic achievement was influenced by self-efficacy ($p <= 0.01$) and academic self-confidence ($p <= 0.01$).

The results of these studies lead to a common conclusion. Self-regulation is essential in the persistence of not only underrepresented minority students in engineering, but also all students. Self-regulation has also been found to result in improved student self-efficacy.

Self-Efficacy

Self-efficacy refers to a person's belief that he/she is capable of taking action to achieve a certain goal, such as completion of a college degree. Self-efficacy is formed by a person's mastery experiences (previous success leads a person to believe he/she is capable of completing a similar task), vicarious experiences (when a person sees someone else completing a task and believes he/she could do the same), social persuasions (supportive people in a person's life such as teachers, family, or mentors), and physiological state (anxiety, etc.). Engineering self-efficacy is a person's belief that he/she can successfully navigate the engineering curriculum and eventually become a practicing engineer. Increasing engineering self-efficacy in women and underrepresented minority students could improve retention of these students in engineering. The following is a synopsis of several relevant studies.

In a survey administered to more than one thousand first-year engineering students in Purdue University's Engineering Problem Solving and Computer Tools course self-efficacy beliefs were analyzed (10). The following factors were found to be important in a student's ability to succeed in the course:

1. Understanding or learning the material
2. Drive or motivation toward success

3. Teaming issues
4. Computing abilities
5. The availability of help and ability to access it
6. Issues surrounding doing assignments
7. Student problem-solving abilities
8. Enjoyment, interest, and satisfaction associated with the course and its material
9. Grades earned in the course

Of these factors, understanding or learning the material was cited by over 70% of the female survey respondents. Nearly 40% of the female respondents found the availability of help and ability to access it to be important, whereas not even 20% of the male respondents found that factor to be important. The results of this study were examined in light of Bandura's social cognitive theory and sources of self-efficacy beliefs.

This study helps one understand differences in gender related to persistence in engineering. Next steps should include understanding these factors as they relate to underrepresented minority students, and developing interventions to address these issues. This is where the current research is directed.

Self-efficacy relates to self-regulation as shown in a study where 102 ninth and tenth graders from two high schools were assessed regarding their perceived self-efficacy (26). Two subscales (self-efficacy for self-regulated learning and self-efficacy for academic achievement) were selected. Although the questionnaire was not aimed at engineering per se (the students were questioned about their social studies class), the results are notable. The research showed that self-motivational factors make a large contribution to academic attainment. Factors stemming from students' self-regulation were what fueled and influenced their achievement. Because of their belief in their efficacy for self-regulated learning, they showed improved self-efficacy for academic achievement, influencing their academic goals and overall achievement. These findings were true with underrepresented minority engineering students as well.

Upon uncovering factors influencing achievement, the current study addresses developing a research-based intervention to be implemented during the student's first semester to include these factors.

The Longitudinal Assessment of Engineering Self-Efficacy (LAESE)

The LAESE instrument was created, tested, and validated to measure self-efficacy, inclusion, and outcome expectations (16). They were designed to identify support and barriers engineering students encounter while pursuing their degree, which ultimately determines their engineering self-efficacy. The expected outcome would be to see an increase in subscale averages as a student progresses through his/her academic tenure, indicating engineering self-efficacy, feeling of inclusion, etc., increases as they progress through their major.

Applying the LAESE

In their cross-sectional study of first-year engineering majors, Concannon and Barrow (5) used the Longitudinal Assessment of Engineering Self-efficacy (LAESE) to survey 253 first-year engineering majors enrolled in an engineering course (211 men, 42 women) at a large Midwestern research extensive university. Their intent was to analyze differences in engineering self-efficacy by major, gender, ethnicity, participation in Freshman Interest Groups (FIGs), and participation in undergraduate engineering organizations. The dependent variables in the study were engineering self-efficacy, engineering career outcome expectations, and coping self-efficacy. Using a two-factor experiment with repeated measures for engineering self-efficacy, a multiple analysis of variance was used to determine differences among self-efficacy subscale scores and whether there were interactions. Results showed that freshmen men had statistically higher coping self-efficacy and engineering career outcome expectations than freshmen women. There were no statistically significant differences between freshmen involved with FIGs and those who were not, however, when women were separated from the sample it showed that women involved with FIGs had statistically significant higher engineering career outcome expectations than women who were not. Freshmen involved with undergraduate engineering organizations had statistically significant higher engineering career outcome expectations.

Concannon and Barrow (5) used four of the six subscales in the LAESE to measure engineering self-efficacy, engineering career outcome expectations, and coping self-efficacy. The purpose of this study was to analyze undergraduate engineering majors' intentions to persist in their engineering program. They performed this analysis using the multiple analysis of variance technique to determine whether the sociocognitive predictors for persisting in engineering for women differ from those of men. Their sample consisted of 493 students (424 men and 69 women) at a Midwestern institution.

To determine whether engineering self-efficacy (1 and 2), coping self-efficacy, and engineering career outcome expectations predicted women's and men's persistence in engineering, multiple regression analysis was applied to the survey data. Results showed that engineering self-efficacy 1 and engineering career outcome expectations significantly predicted women's persistence in engineering. For men, engineering self-efficacy 2 and engineering career outcome expectations were significant predictors of men's persistence in engineering. Engineering self-efficacy 1 measures a student's ability to reach academic milestones focusing on courses (Chemistry, Calculus, and Physics) as barriers. Engineering self-efficacy 2 measures a student's ability to reach academic milestones facing all undergraduate engineering majors. This tells us that, for this sample, mastering coursework (earning an A or B) is the most significant predictor for women's persistence in engineering, and completing coursework (not necessarily obtaining an A or B—merely completing the course) is the most significant predictor for men's persistence in engineering. For both men and women, persistence depends upon a student's career expectations.

In their comparison of women and men's engineering self-efficacy beliefs across grade levels, Concannon and Barrow (6) surveyed 746 engineering students (635 men, 111 women) at a large research extensive university. Their goal was to identify statistically significant differences in engineering self-efficacy beliefs among first- through fifth-year engineering students (male compared with female). Using a repeated measures ANOVA the authors identified four variables: engineering self-efficacy 1, engineering self-efficacy 2, engineering career outcome expectations, and coping self-efficacy. These variables were used to measure whether mean differences in engineering self-efficacy (1 and 2) occur by year, gender, and year by gender. Using the LAESE (16), differences in engineering self-efficacy were found by year. Fifth-year engineering students had significantly lower engineering self-efficacy than second-, third-, and fourth-year students. Significant interactions between year in school and all four subscales were found. A reanalysis was performed excluding fifth-year students, and significant differences in engineering self-efficacy 2 were found. First year students had significantly lower scores for engineering self-efficacy 2 compared to second-, third-, and fourth-year students. Lastly, the results showed that freshmen men had significantly higher engineering career outcome expectations compared to upper-class women.

The Academic Pathways of People Learning Engineering Survey (APPLES)

The Academic Pathways of People Learning Engineering Survey (APPLES) is an instrument that was developed by the Center for the Advancement of Engineering Education at the University of Washington. It is one of many research tools developed by the Academic Pathways Study (26). The goal of using the instrument is to understand how students learn about engineering, what motivates students to study engineering, how confident they are in their choice of major, and what their post-graduation plans look like (26).

Applying the APPLES

In their first administration of the APPLES instrument, Sheppard et al. (26) sampled over 900 students at four institutions. In their second administration of the APPLES instrument, Sheppard et al. (26) sampled 4,266 students across 21 universities. Students were offered $4 to participate. In terms of demographics, women represented 35.8% of the first-year engineering student population, and underrepresented minority students (defined as Black/African American; Hispanic/Latino/a; American Indian/Alaska Native; and Native Hawaiian/Pacific Islander) comprised 19%. In their comparison of men versus women, women reported more frequent involvement in engineering extra-curricular activities than men. They also reported more frequent curricular overload and greater pressure to balance their social lives and academics. Lastly, women reported professional and interpersonal skills as being more important.

In terms of underrepresented minority students the authors made comparisons by gender. Underrepresented men were more psychologically motivated to study engineering than their majority. There were no other significant differences found.

In effort to improve retention, Eris et al. (7) used the APPLES instrument to understand why students leave engineering. The instrument was administered to a cohort of 160 students (61% male, 39% female). Thirty-five percent of the students were underrepresented in engineering. Their small sample size did not allow extensive generalization, however, significant implications were observed. For example, their findings indicated that non-persisters' intentions to pursue engineering as a major decrease over time, and the decline begins a minimum of two semesters before they change their major.

The APPLES instrument has also been used to predict students' graduate school plans (25), and explore gender diversity in engineering (12).

The Student-Professor Interaction Scale

Cokley et al. (4) developed the Student-Professor Interaction Scale to examine student-faculty interactions in terms of academic motivation, academic self-concept, and academic achievement. Steps taken to develop their scale included defining the constructs, identifying content, generating items, conducting a pilot study, refining the scale, item analysis, and validating the instrument. The results of the study indicated that there are 9 factors representing student-professor interaction:

1. Respectful interaction
2. Career guidance
3. Approachability
4. Validity
5. Caring attitude
6. Off campus interactions
7. Connectedness
8. Accessibility
9. Negative experiences

These studies provide support for the use of these instruments in the current study.

There have been several studies aimed at improving retention of first-year underrepresented minority engineering students. For example, Knight et al. (12), found that hands-on, team based design projects during a student's first-year in the engineering program have the potential to improve retention. The authors measured engineering program retention at the third, fifth and seventh semesters for all students participating in the study. Results showed that those students participating in hands-on, team based design projects were retained at a significantly higher level into the third, fifth and seventh semesters ($p < .05$).

Waller (30) used a mixed methods approach to investigate Summer Bridge Programs (SBP) for underrepresented minority engineering students in terms of the program's strengths and weaknesses. The study called for program administrators to assess SBP outcomes to ensure support structures are in place for the enhancement of retention and graduation rates of at-risk students.

Methodology

An intervention used to mitigate doubts about students' sense of belonging [in engineering] could raise their academic achievement and improve retention, as observed in Walton and Cohen's (31) study of race, social fit, and achievement. Their study housed two experiments, one of which "tested an intervention aimed at mitigating belonging uncertainty" (31). The aim of the intervention was to normalize doubts about academic uncertainty to improve the academic motivation and achievement of first-year underrepresented minority students in computer science. During the intervention these students (18 Black, 19 White) were told that their doubts about belonging in school were not unique to their racial group, and that these doubts would decrease over time. The information was presented to the students in the form of survey results from upper-class students showing that all students, regardless of race, worried during their first year of school about whether they were accepted. As a result of the intervention, "Black students' sense of fit against academic adversity improved their achievement", their engagement in achievement behaviors (i.e. attending professors office hours) increased, and their grade point averages improved (31). The aforementioned approach was used as a model for the current study's intervention.

Purpose of the Study

The purpose of this study was to assess engineering self-efficacy of underrepresented minority first-year engineering students, determine what variables to consider when developing an intervention to improve their engineering self-efficacy, and determine whether a small intervention will improve their engineering self-efficacy and sense of belonging in engineering. The Longitudinal Assessment of Engineering Self-Efficacy (LAESE) instrument, Academic Pathways of People Learning Engineering Survey (APPLES), and Student-Professor Interaction Scale will be used for this study. The following questions were addressed in this research.

1. What are the differences in engineering self-efficacy and sense of belonging for underrepresented minority engineering students (across academic levels) compared to majority (White) students?
2. What factors or variables should be considered and/or addressed in designing an intervention to increase engineering self-efficacy amongst first-year underrepresented minority engineering students?
3. Can a small intervention during the beginning of the first semester improve a student's sense of belonging, engineering self-efficacy, and student-professor interaction?

This chapter provides a description of the research design and methodology used to address these research questions, including sample/sampling method, instruments used, and data collection procedures.

Research Design

This study featured a quantitative research design. A summary of the approach and how the approach aligns with each research question is provided in Table 1. The institutions participating in the study were Michigan Technological University (Michigan Tech), New Jersey Institute of Technology (NJIT), Virginia Polytechnic Institute and State University (Virginia Tech), and The Ohio State University (OSU). These sites were selected based on their engineering program ranking and underrepresented minority student population in engineering. Additionally, the authors had working relationships with faculty and staff at each institution. Having had personnel at each site was beneficial because these faculty and staff members had relationships with the students, which helped when recruiting participants for the study.

Research Question	**Participants/Location**	**Instruments/Method**	**Data Analysis**
RQ1	1043 students (freshmen through seniors)	LAESE, APPLES Demographic Data	2 (ethnicity) X 4 (class

	Michigan Tech, Virginia Tech and NJIT		standing) ANOVA
RQ2	394 students (freshmen through seniors) Michigan Tech, NJIT, Virginia Tech	LAESE, APPLES	Means Independent groups t-tests
RQ3	406 students (freshmen) NJIT, Virginia Tech, The Ohio State	LAESE, Student Professor Interaction Scale	Means Independent groups t-tests (from pre and post tests

Table 1: Summary of research questions aligned with methods and data analysis

Summary of Data Collection Methods

Phase One

To analyze differences in engineering self-efficacy and sense of belonging for underrepresented minority engineering students across academic levels compared to majority (White) students the LAESE and APPLES instruments were used. The researcher received permission to utilize both assessment tools from the instrument developers.

The LAESE and APPLES instruments were combined and revised into an 86-item survey. The LAESE instrument was created, tested, and validated to measure self-efficacy, inclusion, and outcome expectations (16). The APPLES instrument measures how students studying engineering experience their education, gain knowledge of what engineering is, and what their plans after graduation are (26). The questions were designed to identify the supports and barriers that engineering students encounter while pursuing an engineering degree, which ultimately determines their engineering self-efficacy. The expected outcome would be to see an increase in subscale averages as a student progresses through his/her academic tenure, indicating engineering self-efficacy, feeling of inclusion, etc., increases as they progress through their major.

Several avenues were taken to gather a pool of students to sample at Michigan Tech. The survey was administered to classrooms across the first year engineering program and upper level engineering courses across several majors within the college of engineering. These classes included but were not limited to Calculus II, Engineering Economics, Mechanical Engineering Laboratory, Circuits & Instrumentation, Introduction to Spatial Visualization, Chemical Engineering Fundamentals, Environmental Engineering Fundamentals and Introduction to Materials Science & Engineering. Students were given time to read the consent form and were made aware that their participation was voluntary.

Some of the underrepresented minority students were not reached by surveying these courses. In order to attract more students a separate event was held on a Saturday. Minority students were asked to come to one of the dining halls on campus to have lunch and take the survey. Another opportunity for students to participate was held at the university library. It was impossible to survey 100% of the underrepresented minority students on campus, but the sample collected suited the needs of this research phase.

For data collection at Virginia Tech and NJIT, the author's advisor visited both institutions. An e-mail was sent to all first-year underrepresented minority students asking that they attend a session where they would take a written survey via Scantron coding sheets.

The purpose of the research and procedures for opting out if they desired was explained at all three institutions. Additionally, each student who participated signed a consent form. To develop treatment and control video footage for the pilot intervention at Michigan Tech the upper-class students selected to be filmed were given the following statement:

> "We are trying to create a compelling video that will increase incoming student's sense of belonging, and increase their confidence in their ability to be successful in their major and their career. The questions we will ask you are related to these things – sense of belonging and self-confidence. Please speak of your experiences honestly, but be as positive as possible. We will start with asking you about when you may have questioned whether you belonged, or questioned your ability to be successful. Then we will focus on academic or social behaviors that helped you to cope, realize you belonged, or increased your confidence. In the end, we hope the video shows new students that it is perfectly normal to question whether they "belong", and for experiences to lower their confidence – but give them ideas for how to use those experiences to increase confidence and sense of belonging."

The treatment video addressed issues of belonging in the engineering program. The control video focused on extracurricular activities for students. Michigan Tech's media department with the help of the author edited footage from the videos, and two videos (one treatment, one control) were developed.

Phase Two

Several adjustments were made to the research protocol in phase two:

- The order of the interview comments was rearranged such that the problem is brought to the front, and the social and academic strategies/advice, as well as coping mechanisms for environment follow.
- Aspects of engineering self-efficacy were added to the treatment video.
- Names of professors and dates were not included in the videos; however, students' first names along with their level (and engineering major) appeared in the video.
- Only engineering majors were included in the videos.
- Interviewees were provided with a survey to complete prior to the interview that provides questions they will be asked such that they can better prepare for the interview and make sure they address particular points.
- The control group video was replaced with a TED Talk about creativity in the educational system.

- Although the study initially considered both the APPLES and LAESE, it was determined that the LAESE provided the needed measures; hence the APPLES was removed from the study.
- The math outcome expectations and engineering career success expectation subscale items were removed from the instrument and the Student-Professor Interaction Scale was added.

Interviews of upper-class engineering students were conducted at OSU, Virginia Tech and NJIT. The authors edited all of the videos using a MacBook Pro and Apple's iMovie software. One treatment video was developed for each institution.

The researchers conducted revised interventions at OSU and NJIT. Virginia Tech was not included in this phase due to low participant recruitment. At OSU an e-mail was sent to all first-year underrepresented minority engineering students inviting them to participate in the research study. Students were given the opportunity to sign up for a time where they would come to a conference room, take the pre-assessment via Scantron coding sheets, and watch either the treatment video or the TED Talk. They received a $15 gift card to Target as an incentive for their participation. Several weeks later the students were asked to come back to complete the post-assessment. At NJIT, the same procedure was conducted, however the students were not offered monetary incentives.

Phase Three

During the fall 2013 semester, the final attempt to implement the research protocol was conducted at Virginia Tech and OSU. At OSU, 8 sections of the first-year engineering program course ENGR1181 participated in the study. The revised LAESE and Student Professor Interaction Scale instrument was uploaded to an online software called Qualtrics, and a link to the assessment will be placed on the ENGR1181 course website. The survey opened for students to take on their own time between August 26th and September 4th. Three sections of the ENGR1181 were selected at random watch the treatment video. The other 5 sections did not watch a video (so as to eliminate potential confounding variables). The post-assessment (via the same survey link used to take the pre-assessment) opened October 7th through October 11th for all of the students to take, and a comparison of scores for those who watched the video and those who did not watch the video was completed by the author.

At Virginia Tech, students who participated in STEP (Student Transition Engineering Program) participated in the intervention. These students took the LAESE and Student Professor Interaction Scale instrument via Scantron coding sheets during their orientation. Half of the participants were randomly selected to watch the intervention video developed specifically for Virginia Tech. After 5 weeks, all of the students took the post-assessment via the Qualtrics web survey link.

Quantitative Findings: Phase 1

The survey was administered to classrooms across the first year engineering program and upper level engineering courses across several majors within the college of engineering during the Fall 2010 semester at Michigan Technological University. These classes included but were not limited to Calculus II, Engineering Economics, Mechanical Engineering Laboratory, Circuits

& Instrumentation, Introduction to Spatial Visualization, Chemical Engineering Fundamentals, Environmental Engineering Fundamentals and Introduction to Materials Science & Engineering. The number of survey respondents was 1101. In terms of gender, 74.1% of the participants were male, and 25.9% of the participants were female. White respondents made up nearly half of the participants, while underrepresented minority students (African American, Native American, Hispanic/Latino(a)) combined made up about a third of the respondents. For the purposes of this research, Asian Americans are not considered underrepresented in engineering.

A variety of intended majors of study were represented in the sample. Chemical engineering students represented 20% of the population, while Mechanical and Civil engineering made up 13.7% and 11.3%, respectively. Students who had not decided their major made up 20% of the population. In terms of institution, the Michigan Technological University respondents represent 38.8% of the population, the Virginia Tech respondents made up 14.4%, and NJIT respondents made up 46.8%.

Before further data analysis took place underrepresented minority students (African American, Native American, Hispanic/Latino(a)) were combined into one variable (underrepresented minority-***URM)***, and foreign students were removed from the sample. Thus, the sample size moving forward is as shown in Table 2.

Ethnicity	**n**	**%**
URM	364	34.9
White	538	51.6

Table 2: Final sample size

Table 3 provides a t-test comparing underrepresented minority students and white students for each of the LAESE subscales to answer the following research question: What are the differences in engineering self-efficacy and sense of belonging for underrepresented minority engineering students (across academic levels) compared to majority (White) students? Significance levels (p-values) less than 0.05 are considered significant.

LAESE Subscale	**URM**	**White**	**t(df)**	**Sig.**
Coping Self-Efficacy	5.70	5.70	0.03 (884)	0.98
Math Self-Efficacy	5.69	5.51	2.45 (886)	0.02
Inclusion/Sense of Belonging	4.80	5.23	-5.82 (892)	0.00
Engineering Self-Efficacy 1	5.46	5.42	0.66 (891)	0.51
Engineering Self-Efficacy 2	5.72	5.79	-1.08 (890)	0.28
Engineering Career Success Expectations	5.88	5.84	0.83 (894)	0.41

Table 3: T-Test for Underrepresented Minority (URM) students vs. White students (all institutions)

The data shows a significant difference between underrepresented minority students and whites for the math self-efficacy and inclusion/sense of belonging subscales (p = 0.015 and 0.000, respectively). To gain better understanding of these differences we now compare these students by their academic level (freshman through senior). Table 4 provides the analysis of variance (ANOVA) table. Significant differences were found for coping self-efficacy, math self-efficacy, and inclusion/sense of belonging.

In terms of inclusion/sense of belonging all underrepresented minority students, regardless of year in school, had lower inclusion/sense of belonging than white students.

LAESE Subscale	SS	df	MS	F	Sig.
Coping Self-Efficacy					
Between Groups	17.65	2	8.823	12.5	0.00
Within Groups	721.82	1022	0.71		
Total	739.48	2024			
Math Self-Efficacy					
Between Groups	8.76	2	4.38	4.06	0.018
Within Groups	1105.5	1024	1.08		
Total	1114.26	1026			
Inclusion/Sense of Belonging					
Between Groups					
Within Groups	50.29	2	25.15	20.87	0.00
Total	1241.37	1030	1.21		
	1291.67	1032			

Table 4: ANOVA Table for Underrepresented Minority (URM) students vs. White students (all institutions) by year in school

Each institution was examined separately to gain a better understanding of variation across the three institutions. Table 5 provides a t-test of each LAESE subscale comparing underrepresented minority students with white students at Michigan Tech.

LAESE Subscale	URM (n = 56)	Whites (n=344)	t(df)	Sig.
Coping Self-Efficacy	5.90	5.69	1.19 (396)	0.23
Math Self-Efficacy	5.59	5.56	0.12 (398)	0.91
Inclusion/Sense of Belonging	4.93	5.23	-2.03 (400)	0.04
Engineering Self-Efficacy 1	5.60	5.29	1.88 (400)	0.06
Engineering Self-Efficacy 2	5.63	5.70	-0.65 (399)	0.52
Engineering Career Success	5.81	5.78	0.19 (400)	0.85

Expectations				

Table 5: T-Test for Underrepresented Minority (URM) students vs. Whites (Michigan Tech)

Underrepresented minority students' sense of belonging was significantly lower than white students (p = 0.04). Additionally, one could say that white students engineering self-efficacy 1 (p = 0.06) had a score approaching significantly lower than underrepresented minority students. As a reminder, engineering self-efficacy 1 measures a student's ability to reach academic milestones focusing on courses (Chemistry, Calculus, Physics) as barriers.

As shown in Table 6, underrepresented minority students feeling of inclusion/sense of belonging drops continually from Freshman to Junior year. It is worth mentioning that the highest score for the Likert items is 7, so the means for all students suggest their feeling of inclusion/sense of belonging could be improved.

	Freshman URM	**Freshman White**	**Sophomore URM**	**Sophomore White**	**Junior URM**	**Junior White**	**Senior URM**	**Senior White**
Inclusion	5.39	5.19	4.83	5.27	4.50	5.21	5.09	5.29

Table 6: Means of Underrepresented minority (URM) students Inclusion vs. Whites (Michigan Tech)

Table 7 provides a one-way analysis of variance (ANOVA) by year in school for Michigan Tech. Significant differences were found for the math self-efficacy subscale (p < 0.01).

LAESE Subscale	**F**	**Sig.**
Coping Self-Efficacy	0.98	0.42
Math Self-Efficacy	3.71	0.01
Inclusion/Sense of Belonging	0.48	0.75
Engineering Self-Efficacy 1	1.72	0.15
Engineering Self-Efficacy 2	1.78	0.13
Engineering Career Success Expectations	1.38	0.24

Table 7 One-Way ANOVA by Year in School (Michigan Tech)

From Table 8 one notices that as students progress by year in school from Freshman to Junior their math self-efficacy decreases. Additionally, math self-efficacy for underrepresented minority students is lower than for white students.

	Freshman URM	**Freshman White**	**Sophomore URM**	**Sophomore White**	**Junior URM**	**Junior White**	**Senior URM**	**Senior White**

Math SE	6.11	5.93	6.00	5.53	5.13	5.21	4.95	4.90

Table 8: Means of Math Self-Efficacy by Year in School and Ethnicity (Michigan Tech)

Turning our attention to Virginia Tech, Table 9 provides t-tests for each LAESE subscale comparing underrepresented minority students with white students. Significant differences were found for feeling of inclusion/sense of belonging ($p < 0.01$) and engineering career success expectations ($p = 0.03$).

LAESE Subscale	**URM (n = 48)**	**White (n ~ 96)**	**t(df)**	**Sig.**
Coping Self-Efficacy	5.71	6.09	-1.68 (142)	0.09
Math Self-Efficacy	5.45	5.67	-1.31 (142)	0.19
Inclusion/Sense of Belonging	4.78	5.56	-4.27 (142)	< 0.01
Engineering Self-Efficacy 1	5.62	5.79	-0.50 (142)	0.62
Engineering Self-Efficacy 2	5.76	6.01	-1.73 (142)	0.09
Engineering Career Success Expectations	5.89	6.17	-2.21 (142)	0.03

Table 9: T-Test for Underrepresented Minority (URM) students vs. Whites (Virginia Tech)

Comparing underrepresented minority and white students by year in school for feeling of inclusion/sense of belonging and engineering career success expectations, one notices that underrepresented minority students had lower inclusion than whites in each academic level (freshman through senior) (Table 10). Sophomore underrepresented minority students had lower engineering career success expectations than whites.

	Freshman URM	**Freshman White**	**Sophomore URM**	**Sophomore White**	**Junior URM**	**Junior White**	**Senior URM**	**Senior White**
Inclusion	4.94	5.49	4.81	5.62	4.08	5.26	4.27	5.81
Eng Succ	6.07	6.12	5.53	6.39	5.92	5.95	5.59	6.31

Table 10: Means of Inclusion and Engineering Career Success Expectations by Year in School and Ethnicity (Virginia Tech)

Table 11 provides a one-way ANOVA by year in school for Virginia Tech. One would say the score for math self-efficacy is approaching significance ($p = 0.07$), however there were no significant differences found for the scores when year in school was factored. Table 12 shows that both groups of students math self-efficacy decreased from freshman to sophomore year and from junior to senior year.

LAESE Subscale	F	Sig.
Coping Self-Efficacy	1.07	0.37
Math Self-Efficacy	2.22	0.07
Inclusion/Sense of Belonging	1.39	0.24
Engineering Self-Efficacy 1	0.95	0.44
Engineering Self-Efficacy 2	0.42	0.79
Engineering Career Success Expectations	1.29	0.28

Table 11: One-Way ANOVA by Year in School (Virginia Tech)

	Freshman URM	**Freshman White**	**Sophomore URM**	**Sophomore White**	**Junior URM**	**Junior White**	**Senior URM**	**Senior White**
Math SE	5.42	5.92	5.18	5.76	5.52	5.61	4.75	5.33

Table 12: Means of Math Self-Efficacy by Year in School (Virginia Tech)

When comparing students across academic levels at NJIT one finds significant differences in the coping self-efficacy and engineering self-efficacy 2 subscales (Table 13). Table 14 provides a breakdown of the coping self-efficacy subscale by ethnicity and year in school. One notices that underrepresented minority freshman sophomore, and senior students had lower coping self-efficacy than white students. Coping self-efficacy decreased for both underrepresented minority students and white students from the freshman to sophomore year.

LAESE Subscale	F	Sig.
Coping Self-Efficacy	9.03	< 0.01
Math Self-Efficacy	0.84	0.43
Inclusion/Sense of Belonging	0.79	0.46
Engineering Self-Efficacy 1	1.98	0.14
Engineering Self-Efficacy 2	4.01	0.02
Engineering Career Success Expectations	1.69	0.19

Table 13: One-Way ANOVA by Year in School (NJIT)

	Freshman URM	Freshman White	Sophomore URM	Sophomore White	Junior URM	Junior White	Senior URM	Senior White
Coping SE	5.54	5.99	5.48	5.69	5.75	5.65	5.77	5.97

Table 14: Means of Coping Self-Efficacy by Year in School (NJIT)

Summary of Quantitative Findings (Phase 1)

A summary of the quantitative findings from phase 1 is necessary to gain some perspective. For the combined sample (all institutions), underrepresented minority students had lower feeling of inclusion/sense of belonging scores than white students. When looking at each school separately, both Michigan Tech and Virginia Tech had underrepresented minority students with significantly lower feeling of inclusion/sense of belonging scores than white students. Underrepresented minority students had significantly higher math self-efficacy than whites. For all of the institutions combined, underrepresented minority students in their sophomore through junior year had higher math self-efficacy than white students. However, when singling out Michigan Tech one notices that as students progressed by year in school from Freshman to Junior their math self-efficacy decreased. Additionally, math self-efficacy for the underrepresented minority students was lower than for white students at Michigan Tech.

Lastly, underrepresented minority freshman, sophomore, and senior students at NJIT had lower coping self-efficacy than white students.

These findings provide reasoning to develop an intervention to be implemented during the first-year that will help improve feeling of inclusion/sense of belonging for underrepresented minority engineering students. We now move on to phase two of the study, which focuses on determining factors or variables to consider when designing an intervention to improve sense of belonging.

Quantitative Findings: Phase 2

The second phase of the research was designed to answer the following research question: What factors or variables should be considered and/or addressed in designing an intervention to increase engineering self-efficacy and sense of belonging amongst first-year underrepresented minority engineering students? To answer this question the author utilized the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) and Academic Pathways of People Studying Engineering Survey (APPLES). Table 15 provides those subscales with high means indicating these subscales could potentially be factors influencing underrepresented minority student sense of belonging in engineering. Focusing only on underrepresented minority engineering students, each ethnicity was separated out for better understanding. Additionally, the APPLES scores were on a scale of 1 to 4.

The results show relatively high means for *motivation for social good*, meaning students study engineering because they feel that engineers contribute to fixing the problems in the world. In terms of being motivated by *financial reasons*, there is variability in the means for the different ethnic groups with Latino(a)/Hispanic American students being less motivated to pursue engineering because of the financial outcome (μ=2.6078) compared with African American/Black students (μ=3.2593). Relatively high means for *intrinsic psychological motivation* show that underrepresented minority students study engineering because they think it is fun and interesting. The same holds true for *intrinsic behavioral motivation*; students study engineering because they like to figure out how things work. Students across the board have high confidence in their *professional and interpersonal skills*, and their *problem solving skills*. Variability in the means for students' *academic disengagement* in their liberal arts courses shows that Latino(a)/Hispanic American students are more engaged in their liberal arts courses than American Indian/Alaskan Native students. Lastly, students have relatively high confidence in their math and science abilities.

APPLES Constructs	**Ethnicity**	**Mean**
Motivation (Social Good)	African American/Black	3.50
	American Indian/Alaskan Native	3.39
	Latino(a)/Hispanic American	3.23
Motivation (Financial)	African American/Black	3.26
	American Indian/Alaskan Native	2.94
	Latino(a)/Hispanic American	2.61
Motivation (Intrinsic, Psychological)	African American/Black	3.72
	American Indian/Alaskan Native	3.42
	Latino(a)/Hispanic American	3.38
Motivation (Intrinsic, Behavioral)	African American/Black	3.75
	American Indian/Alaskan Native	3.50
	Latino(a)/Hispanic American	3.38
Confidence in Professional and Interpersonal Skills	African American/Black	3.93
	American Indian/Alaskan Native	3.61
	Latino(a)/Hispanic American	3.86

Confidence in Solving Open-ended Problems	African American/Black	5.20
	American Indian/Alaskan Native	5.00
	Latino(a)/Hispanic American	4.72
Academic Disengagement (Liberal Arts Courses)	African American/Black	3.25
	American Indian/Alaskan Native	4.54
	Latino(a)/Hispanic American	2.39
Confidence in Math and Science Skills	African American/Black	3.57
	American Indian/Alaskan Native	3.39
	Latino(a)/Hispanic American	3.69

Table 15: APPLES Constructs by Ethnicity

This information tells us that, in addition to addressing students' sense of belonging and coping self-efficacy, an intervention to improve engineering self-efficacy and sense of belonging for underrepresented minority students should include opportunities to appeal to their motivation for social good. It should also include reminders that engineering is fun and interesting.

With this information in mind we move on to developing the pilot intervention. For this experiment, the null hypothesis would be that the intervention video has no effect on students' sense of belonging in engineering. The author is attempting to reject the null hypothesis. The author performed power analysis to calculate the minimum sample size required to detect an effect because of the treatment video. For a desired statistical power of 0.8 and a medium effect size ($d = 0.5$), the sample should be 64 participants. For a small effect size ($d = 0.2$), a sample size of 393 is required. The authors therefore aimed for a sample of participants between 64 and 393.

Pilot Intervention Synopsis

To assess and potentially improve first-year underrepresented minority engineering students' feeling of inclusion/sense of belonging the author modeled the "social belonging" intervention first introduced at Yale for African-American computer science students. For the current study, upper division students of diverse backgrounds were videotaped describing how they overcame feelings of non-inclusion over time. The video footage was edited to produce a compelling short video showing that all first-year students regardless of race, ethnicity, or gender, experience the same feelings of not belonging, but that they overcome these feelings over time.

A second control video was produced as well with the same group of students sharing ideas about how to get involved on campus.

A treatment group of underrepresented minority students viewed the video footage and discussed it as a group. They also completed the LAESE instrument and filmed a testimonial for future students. A control group of underrepresented students also viewed the control video footage and discussed it as a group and completed the LAESE instrument as well. The LAESE instrument was administered to a group of white first-year engineering students to gather baseline data of majority students for comparison.

Video Footage Participants

Nine (9) upper class students (5 women, 4 men—3 African-American, 2 Native American, 2 Caucasian, and 2 Hispanic/Latino(a)) were selected to film the video footage. The students were paid $50 for their participation.

"Sense of Belonging" (Treatment) Video

To capture video participants' opinions about their sense of belonging, the students were asked questions related to how they first felt when arriving to campus, friends they have made from different backgrounds, and questions about faculty members. The goal was to address the feeling of inclusion/sense of belonging and coping self-efficacy subscales of the LAESE instrument. Responses to the questions were captured and edited to produce a video that showed that all students might feel as if they do not belong when first arriving to campus. The final video included these sorts of snippets accompanied by "techno" music and was about 16 minutes in length.

Campus Involvement (Control) Video

A video was created using responses from the same students who helped develop the treatment video. This video was a general video about how students are involved on campus via student organizations, volunteering, and campus jobs. The control video was also 16 minutes in length.

Treatment and Control Group Subjects

A treatment and control group was created using first-year engineering students (6 male, 5 female) at Michigan Tech. Ten of the students were first-year, first semester college students; one student transferred from a community college. The students' racial/ethnic composition was as follows:

- 3 African American
- 1 Asian
- 2 Hispanic/Latino, and
- 5 multiracial students.

For comparison, a second control group of 13 first-year engineering students (11 male, 2 female) were used. 12 of the students were white and one student was multiracial. The LAESE instrument was administered to these students solely for the purpose of gathering baseline data to compare their survey responses with those of the underrepresented minority students.

Recruiting Participants

To recruit underrepresented minority students for participation an e-mail blast was sent to all first-year underrepresented minority students at the institution. Students self-selected into the treatment and control conditions through their choice of attending 1 of 2 available time slots for participation.

Treatment Group

Six underrepresented minority students attended the treatment session. Students were introduced to the research and it was explained to them that their participation was voluntary. All of the students consented to take the LAESE assessment, watch the treatment video, be recorded via video camera their name and their intended major, and have their fall 2011 final grades shared with the author. The entire session lasted 30 minutes and all students received a $10 iTunes gift card at the end of the session.

Control Group

Five underrepresented minority students attended the “control” session. These students were told that their participation was voluntary as well. They were not told that they would be watching a different video than the first group. These students consented to take the LAESE assessment and watch the control video. They did not video record their intended major. They did consent to have the authors pull their final grades for the fall 2011 semester.

Pre-Intervention Results

Table 16 provides the means of the subscales for all of the students (treatment group, control group (underrepresented minority students), and second control group). The highest score attainable for each subscale is 7. The data shows that on average students have the highest means for engineering career success expectations and math outcome expectations.

LAESE Subscale	**Mean (n=24)**
Engineering Career Success Expectations	6.17
Engineering Self-efficacy I	5.95
Engineering Self-efficacy 2	5.81
Inclusion/Sense of Belonging	5.22
Coping Self-Efficacy	5.41
Math Outcome Expectations	6.18

Table 16: LAESE Subscale averages of all students (pre-test)

Table 17 provides a breakdown of the subscale means comparing all of the underrepresented students (both the treatment and control groups) with their white counterparts. There were no significant differences found.

LAESE Subscales	**URM**	**White**
Engineering Career Success Expectations	6.18	6.15
Engineering Self-Efficacy 1	5.98	5.92
Engineering Self-Efficacy 2	5.81	5.80
Inclusion/Sense of Belonging	5.14	5.28
Coping Self-Efficacy	5.36	5.44
Math Outcome Expectation	6.15	6.20

Table 17: LAESE Subscale averages of all underrepresented students vs. white students (pre-test)

Of the original participants, 3 from the treatment group, 3 from the control group, and 8 from the second control group (white students) volunteered to take the post assessment. Table 18 shows the overall average gains for the students in the three groups on the LAESE subscales. As aforementioned, the LAESE assessment was administered at the beginning and end of the fall semester.

LAESE Subscale	**Experimental Group (n=3)**	**Control Group 1 (URM) (n=3)**	**Control Group 2 (White) (n=8)**
Engineering career success expectations	-0.14	-0.34	0.05
Engineering self-efficacy I	-0.28	-0.33	-0.12
Engineering self-efficacy 2	-0.67	-0.73	-0.53
Inclusion/Sense of Belonging	0.92	0.08	-0.03
Coping self-efficacy	0.22	0.22	-0.02
Math outcome expectations	-0.11	-0.44	-0.46

Table 18: LAESE Mean Gains of all students

The number of students in each group was very low, making statistical inferences unreliable. Despite the small sample sizes, the following observations were made in examining the data presented in Table 18:

- For the engineering career success expectations, underrepresented students in the intervention group showed a slight decrease, and underrepresented students in the non-intervention group showed a slightly higher decrease.
- For both self-efficacy subscales, all three groups showed a decrease over the course of the semester. The decrease was slightly less for majority students than it was for underrepresented students. Further the underrepresented students in the non-intervention group showed the largest decrease in self-efficacy.
- For the feeling of inclusion, there was essentially no change for either of the control groups; however, there was a seemingly large increase for the underrepresented students in the intervention condition.
- Coping self-efficacy increased slightly for all underrepresented students; for majority students there was no change.
- Interestingly, the math outcome expectations for both control groups decreased by about the same amount. The decrease in math outcomes expectations for students in the intervention group was less than either of the two control groups.

Final Grades and Grade Point Averages (GPAs)

The students consented to have their grades assessed, so student grades were also compared in this analysis. Table 19 provides the average GPA for the treatment group (underrepresented students), control group (underrepresented students), and second control group (white students). It should be noted that not all students were enrolled in the same math, science and engineering courses; however, for this analysis, all grades earned in those subjects were combined. The overall Math/Science/Engineering (MSE) GPA was computed for each group as well as the overall GPA earned by that student for the semester as presented in Table 19.

Course	**Treatment**	**Control 1**	**Control 2**
Chemistry	1.67	2.00	2.13
First-Year Engineering	2.00	2.40	1.92
Math	3.00	1.70	2.69
MSE GPA	2.35	2.03	2.24
Overall GPA	2.27	2.27	2.48

Table 19: Average GPAs of all participants

From this data it appeared that the students in the treatment group did slightly worse in chemistry courses, about average in engineering courses, and much better in their math courses than did the students in the two control groups. The better performance in math for this group likely contributed to the fact that this group experienced a lower decrease in math outcome expectations on the LAESE instrument. Interestingly, the treatment group appeared to have earned better grades on average in math/science/engineering courses compared to students in control group1 even though their average overall GPAs were identical.

Summary of Quantitative Findings (Phase 2)

The results from this phase are encouraging; however, due to small sample sizes, the results were not definitive and further exploration was required. Nonetheless, it did appear that the intervention designed to improve sense of belonging for underrepresented engineering students had a positive impact. The group that participated in the intervention had an increased sense of belonging over the semester compared to underrepresented students in the control group. The impact, if any, of the pilot intervention on grades appeared to be mixed. The next phase of the research included extending the intervention to a larger group of students to see if these preliminary results were repeatable and if statistical inferences could be drawn from the results.

Quantitative Findings: Phase 3

To improve this research protocol the authors assembled a panel of advisory board members during the summer of 2012. The advisory board consisted of practicing engineering educators with experience in instrument construction and statistical analysis. These advisors made several suggestions to improve the intervention. They are as follows:

- Moving forward, another representative engineering school with a population of minority engineering students to sample from needed to be added to the study. With only the large rural institution as a representative school, the research would not have the same impact to the engineering education community.
- It was suggested that the order of the interview comments be rearranged such that the problem is brought to the front, and the social and academic strategies/advice, as well as coping mechanisms for environment follow.
- It was suggested that even though issues of belonging were the only significant element, it would be beneficial to have aspects of engineering self-efficacy in the video. Additionally, all names of mentioned professors or dates should be removed, however, include students' first names along with their level and engineering major in the video.
- There was concern that in the pilot video there were two people who did not have engineering degrees. Videos moving forward should only including engineering majors.
- It was suggested to provide interviewees with a survey to complete prior to the interview that provides questions they will be asked. Doing so will better prepare them for the interview and make sure they address particular points.
- It was suggested to remove the control group video because it may have given a similar message as the treatment video.
- It was suggested to keep the large urban institution in the study as it serves as a model engineering school for diversity (i.e. no majority or minority groups).
- It was suggested to add items from the Student-Professor Interaction Scale to the LAESE. Further it was suggested that the reflection questions regarding students' aspirations should be removed, as they are not in concert with the research questions.

The intervention was attempted at OSU and NJIT during the 2012-2013 academic school year. It was attempted at Virginia Tech, however key personnel at this institution were not able to gather enough students to participate.

The authors developed intervention videos for both OSU and NJIT. Upper-class students from diverse backgrounds were solicited to have themselves video recorded, and they received $10 Target gift cards.

During the 2012-2013 academic school year the author implemented the intervention at both OSU and NJIT. At OSU the author sent an e-mail to underrepresented first-year engineering students asking that they sign-up to attend a session where they would watch a video, take a survey, and have a short discussion. At NJIT the author hosted the session during the school's "common hour". Students chose between two times to participate and did not know whether they were in the treatment or control group. The treatment group took the LAESE instrument in person via Scantron coding sheets (including questions from the Student-Professor Interaction Scale) and watched the video that was developed for that institution. The control group took the instrument and watched a TED Talk about creativity in schools. All of the groups were asked to complete the post-assessment via an online Qualtrics survey at the end of the semester. There were no significant differences found in any of the subscales between the intervention and control groups at each institution. Table 20 provides mean gains for each institution's treatment and control group. A summary of the data is found below the table.

OSU Treatment (n=13)	**Pre Test**	**Post Test**	**Gain**
Engineering Self-Efficacy 1	5.36	5.41	0.05
Engineering Self-Efficacy 2	5.26	6.04	0.78
Inclusion/Sense of Belonging	5.30	5.30	0.00
Coping Self-Efficacy	5.76	5.87	0.11
Student Professor Interaction	5.56	4.88	-0.68
OSU Control (n=13)	**Pre Test**	**Post Test**	**Gain**
Engineering Self-Efficacy 1	5.12	4.72	-0.41
Engineering Self-Efficacy 2	6.26	5.71	-0.56
Inclusion/Sense of Belonging	5.34	4.96	-0.39
Coping Self-Efficacy	5.77	5.19	-0.57
Student Professor Interaction	5.50	4.38	-1.12
NJIT Treatment (n=17)	**Pre Test**	**Post Test**	**Gain**

Engineering Self-Efficacy 1	5.062	5.25	0.19
Engineering Self-Efficacy 2	5.86	5.55	-0.31
Inclusion/Sense of Belonging	5.53	5.34	-0.19
Coping Self-Efficacy	5.56	5.64	0.08
Student Professor Interaction	5.44	5.28	-0.17
NJIT Control (n=20)	**Pre Test**	**Post Test**	**Gain**
Engineering Self-Efficacy 1	5.37	5.14	-0.23
Engineering Self-Efficacy 2	5.97	5.74	-0.22
Inclusion/Sense of Belonging	5.59	5.29	-0.29
Coping Self-Efficacy	5.58	5.5824	0.00
Student Professor Interaction	5.775	5.2528	-0.52

Table 20: Mean Gains of OSU and NJIT

To summarize these findings:

- The students who participated in the treatment at OSU showed positive gains for the engineering self-efficacy 2 and coping self-efficacy subscales.
- The students who participated in the control group at OSU showed negative gains for each subscale measure.
- The students who participated in the treatment group at Virginia Tech showed a positive gain for the engineering self-efficacy 1 subscale.
- The students who participated in the control group at Virginia Tech showed negative gains for all but the coping self-efficacy subscale.

There were several issues that occurred during the implementation of this intervention. These issues could have affected the outcome of the results.

The final attempt to implement the intervention took place during the Summer 2013 and Fall 2013 semesters at OSU and Virginia Tech. At Virginia Tech students who participated in the summer bridge program were subjects in the study. Table 21 provides demographic data about the students participating in the study.

Gender	**n**	**%**
Male	36	58.1
Female	26	41.9

Ethnicity/Citizenship	**n**	**%**
African American/Black	11	17.7
American Indian/Alaskan Native	3	4.8
Asian & Pacific American	11	17.7
Latino(a)/Hispanic American	3	4.8
Caucasian American	29	46.8
Foreign National on student visa	1	1.6
Foreign National/U.S. Resident (green card)	4	6.5
Major	**n**	**%**
Bachelor of Science in Engineering	5	8.1
Biomedical Engineering	3	4.8
Chemical Engineering	5	8.1
Civil Engineering	1	1.6
Computer Engineering	20	32.3
Electrical Engineering	1	1.6
Environmental Engineering	2	3.2
Materials Science & Engineering	3	4.8
Mechanical Engineering	12	19.4
Undecided	9	14.5

Table 21: Demographic Data of Virginia Tech Participants

At Virginia Tech a total of 90 students took the survey initially. Sixty-two students took the post-test. Of the students who took the post-test, 27 watched the video and 35 did not watch the video. There were no significant differences in the two groups.

All 62 participants took the paper version of the instrument during one of their required bridge program sessions. Two weeks later, key personnel at the institution invited the random sample of students to watch the treatment video. At the end of the bridge program all students were asked to take the post-assessment online.

Table 22 provides mean gains for each subscale. The results show that those in the treatment group had increases in their mean gain scores for engineering self-efficacy 2. The control group showed slightly higher negative mean gains for student-professor interaction.

Subscale	**Experimental Group (n=27)**	**Control Group (n=35)**
Engineering Self-Efficacy 1	0.07	-0.11
Engineering Self-Efficacy 2	0.36	0.00
Inclusion/Sense of Belonging	0.06	0.13
Coping Self-Efficacy	0.01	-0.01
Student Professor Interaction	-0.04	-0.14

Table 22: Mean Gains for Virginia Tech

At the OSU during the third week of the semester the author visited 8 sections of the first-year engineering program course to introduce herself and the purpose of the research. The students were asked to take the online version of the instrument and complete the consent form electronically. During the fourth week of the semester 3 sections were chosen at random to watch the treatment video of upper-class students sharing their experiences in engineering. During the seventh week of the semester all 8 sections were asked to complete the survey instrument again (electronically). Students who opted to participate in the research study received extra credit points in the form of one journal grade. Students who did not opt to participate in the research study also were given a chance to receive extra credit. They had the option of watching a 15 minute TED Talk about creativity in school and to submit a critique of the video. The TED Talk can be found via the following link:

https://www.ted.com/talks/lang/en/ken_robinson_says_schools_kill_creativity.html

No students chose to receive extra credit in this manner.

The initial pool of participants was 1,048. Three sections of the first year engineering program (n=216) were shown the treatment video. Not all of the students who watched the treatment video took the post-assessment. The number of students who took the pre-assessment and post-assessment, and watched the video was 172. A random control sample of 172 students who took the pre and post-assessment will be used for comparison.

Summary of Quantitative Findings (Phase 3)

Table 23 provides the mean gains for each group (experimental and control). The data shows significant increases in the mean scores for students in the experimental group for engineering self-efficacy 1 and 2, and a slight increase in student professor interaction (based on a desired effect size of 0.2). Hence, a small intervention could potentially improve students' engineering self-efficacy during their first-year in the engineering program. The next chapter provides discussion and conclusions for this study.

LAESE Subscale	Experimental Group (n=172)	Control Group 1 (n=172)	Sig.
Engineering Self-Efficacy 1	0.34	-0.19	0.015
Engineering Self-Efficacy 2	0.45	0.03	
Inclusion/Sense of Belonging	0.04	-0.04	
Coping Self-Efficacy	0.01	-0.04	
Student Professor Interaction	0.19	-0.24	

Table 23: Mean Gains for OSU

Discussion

Combining data from three institutions of varying characteristics showed that underrepresented students had lower feeling of inclusion/sense of belonging than white students. Per Walton and Cohen (31), belonging uncertainty can lead to racial disparities in achievement. Additionally, inclusion has been shown to be a significant factor in predicting minority student persistence in engineering (3). If the engineering education community is calling for a diverse engineering workforce, addressing sense of belonging for underrepresented students in engineering should be a high priority.

Knowing that underrepresented students had lower feeling of inclusion/sense of belonging than whites, it was the author's goal to determine what factors or variables would be important when developing an intervention to improve these students' sense of belonging and engineering self-efficacy. The data in this study showed that an intervention to improve engineering self-efficacy and sense of belonging for underrepresented students should include opportunities to appeal to their motivation for social good. This means that students need to see how an engineering degree will help them give back to their community and society as a whole. The intervention should also address the fact that engineering is fun and interesting.

From this information the author developed a small intervention in the form of compelling short videos that first-year engineering students watched that were meant to increase their engineering self-efficacy and sense of belonging. To address social good as well as showing engineering to be fun and interesting, the author made it a point to have video interviewees highlight opportunities such as studying abroad, internships, undergraduate research, etc. when speaking of their undergraduate experience. Comparing means from the pre- and post-tests the students took showed that a small intervention during the beginning of the semester could potentially help improve students' engineering self-efficacy. Although it will take more than a short video to see students, especially underrepresented minority students, from their freshman to their senior year, the intervention seemed to have a positive effect.

Although the students who watched the intervention video showed positive mean gains in their engineering self-efficacy, underrepresented minority students at OSU still showed significantly lower scores for engineering self-efficacy 2, sense of belonging, and student-professor interaction when compared to majority (White) students (Table 24). This means there is still work to be done to ensure underrepresented minority students feel included in the engineering program.

LAESE Subscales	**URM**	**White**	**Sig.**
Engineering Self-Efficacy 1	5.59	5.75	0.11
Engineering Self-Efficacy 2	5.62	5.84	0.04
Inclusion/Sense of Belonging	5.01	5.49	0.00
Coping Self-Efficacy	5.65	5.78	0.14
Student-Professor Interaction	5.19	5.53	0.03

Table 24: LAESE subscale averages of underrepresented students vs. Whites (OSU post-test)

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