AC 2011-659: ARE THERE DIFFERENCES IN ENGINEERING SELF-EFFICACY BETWEEN MINORITY AND MAJORITY STUDENTS ACROSS ACADEMIC LEVELS?

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Are There Differences in Engineering Self-Efficacy Between Minority and Majority Students Across Academic Levels?

Abstract

Despite the efforts of countless dedicated individuals, progress in attracting and retaining minorities in engineering has been slow. The students who are attracted are rarely retained. In 2007, the retention to graduation rate for minority students was 37.8% compared to 46.1% for majority students, nationally[8].

Something happens between the minority engineering students' freshman year and the point they decide to either switch their major or drop-out of school altogether. Do 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? These questions are in fact related to their engineering self-efficacy.

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 could potentially improve persistence and sense of belonging for minority students in engineering.

This paper compares self-efficacy constructs of minority and majority engineering students at a predominantly white institution and examines similarities and differences across academic levels. The factors that may be significant in predicting minority student persistence and sense of belonging in engineering are also explored.

Introduction

A degree in Science, Technology, Engineering, or Mathematics (STEM) allows students an open door to a wide variety of successful career opportunities[7]. Students majoring in STEM during their undergraduate tenure can go on to pursue graduate school, medical school, law school or work for top engineering companies and even the government. This career path would seem to be very attractive, yet the number of underrepresented minorities who major in and graduate from these fields remains stagnant. According to the National Science Foundation's Science Resources Statistics the number of bachelor of science degrees awarded in science and engineering to American Indian/Alaska Natives, Black (non-Hispanic), and Hispanic students in 1997 was 0.6%, 7.7% and 6.3%, respectively[10]. Nearly a decade later, those numbers barely changed: 0.7%, 8.3% and 7.7%[10]. In the last decade research has been conducted on various college campuses and within the government to address this issue. Diversity in science and engineering is extremely important, so important that the National Academy of Engineering developed the *NAE diversity program* with a mission to "increase the diversity of the U.S. engineering workforce through developing a strong domestic talent pool." Realizing that the so-called science and engineering "diversity gap" is caused by many socio-economic, historical, and even political factors, an understanding of the root cause as to why underrepresented minorities do not pursue and persist in engineering is worth examining.

There are a number of potential reasons why minorities may not persist or even consider pursuing engineering. Could it be these students feel science and engineering careers are not as rewarding as becoming a doctor, lawyer, teacher or veterinarian? Do these students have role models in engineering fields that they can look up to for mentorship? The stigma that engineering majors must be excellent in math and science may deter students who do not have confidence in their mathematical and scientific abilities. Moreover, underrepresented minorities may not grow up in an atmosphere where hands-on learning is encouraged, which could make them shy away from pursuing engineering. Why is this situation worth examining? To quote William A. Wulf, former president of the National Academy of Engineering, "Our profession is diminished and impoverished by a lack of diversity."

Keeping those thoughts in mind it is important to examine the historical theories and frameworks that will help us not only understand why these students do not pursue engineering, but to also develop interventions to improve the alarming statistics that hamper engineering diversity.

Research Question

Why don't minorities persist or even consider pursuing an engineering degree? William A. Wulf, former president of the National Academy of Engineering, expressed the importance of diversity in engineering when he said, "We need to understand why in a society so dependent on technology, a society that benefits so richly from the results of engineering, a society that rewards engineers so well, engineering isn't perceived as a desirable occupation." Despite his sentiments, little progress has been made to attract women and minorities in engineering. We believe this is true partly because women and underrepresented minority students lack a ***sense of belonging*** in the engineering discipline at predominantly white institutions.

In this paper we discuss similarities and differences of self-efficacy constructs for minority students compared with majority students across academic levels (Freshman, Sophomore, Junior, Senior) at a predominantly white institution.

Social Cognitive Theory

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]. There are several issues addressed within the social cognitive theory framework that help to explain the lack of interest and persistence of minorities in engineering. Various stereotypes exist concerning the capability of minorities to achieve success 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. Many minority students have not acquired these skills during their childhood. Rarely do minority students 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[11]. This is just one of the many challenges these students face when considering the pursuit of an engineering degree. This fact can be summed up as noted by Bandura: "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 which may lead minority students to pursue careers in athletics, entertainment, cosmetology, humanities, and other non-STEM fields. 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.

Social Cognitive Career Theory

Expanding Social Cognitive Theory, Lent at. al developed the Social Cognitive Career Theory (SCCT)[6]. 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 of predicting students' academic interests and goals in engineering[7]. SCCT has three overlapping models aimed at understanding how people:

a) Develop basic academic and career interests
b) Make and revise their educational and vocational plans, and
c) Achieve performances of varying quality in their chosen academic and career pursuits.

Within these models, self-efficacy, outcome expectations, goals, and other factors such as gender, race, *barriers*, etc. help shape a students' career path. An example of a *barrier* would be negative contextual influences, or adverse learning conditions[5]. These theories are somewhat foundational when understanding the constructs of self-regulation and self-efficacy.

Self-Efficacy

The lack of progress in recruiting and retaining women and minorities in engineering is partially due to students' self-efficacy. Self-efficacy refers to a person's belief that he or 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 experiences with mastery (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 reactions to a task (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. Strategies for increasing engineering self-efficacy in minority students have the ability to improve recruitment and retention of minority students in engineering. Two studies come to mind when addressing this point, and they are discussed below.

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[4]. 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 is a major step in the right direction to understand why women and underrepresented minorities do not persist or even consider pursuing engineering degrees.

A different study with similar aims sampled 102 ninth and tenth graders from two high schools on their perceived self-efficacy[12]. 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. It was found that selected self-motivational factors make a large contribution to academic attainment. Factors stemming from students' self-regulation were what fueled and influenced their achievement. Self-regulatory factors solely contributed to students' academic attainment. 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[14]. These findings will most likely hold true with minority engineering students as well.

Summary

This discourse provided background information to shape an understanding of the factors that may influence minority student persistence in engineering. Moving forward, the authors summarize the data collection method and results comparing self-efficacy constructs of minority and majority engineering students at a predominantly white institution to examine similarities and differences across academic levels.

Method

Subjects were 394 undergraduate students studying engineering who consented to participate. The distribution of the sample is shown in Table 1 by class and ethnicity. There were 53 racially ethnic minority students (African American/Black, American Indian/Alaskan Native, Asian & Pacific American, Latino(a)/Hispanic American) in the sample, 326 Caucasian students, 12 Foreign National students and 3 students who did not specify either of these categories.

	Minority	Caucasian	Foreign	Other	Total
Freshman	17	100	3	2	122
Sophomore	14	94	3	0	111
Junior	8	83	4	1	96
Senior	14	49	2	0	65
Total	**53**	**326**	**12**	**3**	**394**

Table 1: Distribution of sample size my class and ethnicity

Instrument

The LAESE (Longitudinal Assessment of Engineering Self-efficacy) and APPLES (Academic Pathways of People Learning Engineering Survey) instruments were combined and revised into an 86 item survey that would serve the needs of this research study. The LAESE instrument was created, tested, and validated to measure self-efficacy, inclusion, and outcome expectations[8]. The APPLES instrument measures how students studying engineering experience their education, gain knowledge of what engineering is, and what their plans after graduation are[12].

Figure 1 shows a summary of the subscales measured by the LAESE instrument. The questions related to each subscale were designed to identify the supports and barriers that engineering students' encounter while pursuing an engineering degree, which ultimately determines their engineering self-efficacy.

LAESE Subscales

1. Engineering career success expectations (7 items, alpha = 0.84)
2. Engineering self-efficacy (8 items, alpha = 0.82)
3. Feeling of inclusion (4 items, alpha = 0.73)
4. Coping self-efficacy (6 items, alpha = 0.78)
5. Math outcome expectations (3 items, alpha = 0.84)

Figure 1: LAESE subscales

The expected outcome would be to see an increase in subscale averages as a student progresses through his/her academic tenure, indicating their engineering self-efficacy, feeling of inclusion, etc., increases as they progress through their major.

Of the 16 variables used in the original APPLES instrument to measure the factors influencing students' intentions to persist in engineering, 11 were identified as factors related to engineering self-efficacy. A summary of these items is shown in Figure 2.

APPLES Subscales

1. Motivation (Social Good) (3 items, alpha = 0.77)
2. Motivation (Financial) (3 items, alpha = 0.81)
3. Motivation (Parental Influence) (2 items, alpha = 0.83)
4. Motivation (Mentor Influence) (3 items, alpha = 0.77)*
5. Motivation (Intrinsic, Psychological) (3 items, alpha = 0.75)
6. Motivation (Intrinsic, Behavioral) (2 items, alpha = 0.72)
7. Confidence in Math and Science Skills (3 items, alpha = 0.80)
8. Confidence in Professional and Interpersonal Skills (6 items, alpha = 0.82)
9. Confidence in Solving Open-ended Problems (3 items, alpha = 0.65)
10. Academic Disengagement (Liberal Arts Courses) (4 items, alpha = 0.75)
11. Academic Disengagement (Engineering-related Courses) (4 items, alpha = 0.71)

Figure 2: APPLES subscales (*The original subscale had 4 items)

These subscales were used to explain any surprising details that may result when comparing the engineering self-efficacy of minority students with that of majority students.

Procedure

During the fall 2010 semester several avenues were taken to gather a pool of students to sample. 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 include but are 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 students surveyed by major is shown in Table 2.

	Frequency	Percent
Biomedical Engineering	53	13.3
Chemical Engineering	88	22.1
Civil Engineering	58	14.6
Computer Engineering	9	2.3
Electrical Engineering	18	4.5
Environmental Engineering	28	7.0
Materials Science & Engineering	7	1.8
Mechanical Engineering	119	29.9
Bachelor of Science in Engineering (BSE)	2	0.5
Undecided	16	4.0

Table 2: Number of students surveyed by major

Students were given time to read the consent form and were made aware that their participation was voluntary.

By surveying these courses some of the minority students were reached, but in order to attract more minority students a separate event was held on a Saturday where minority students came to one of the dining halls on campus to have lunch and take the survey. There were also a handful of students who met at the university library to take the survey with a proctor because they had not taken it in their courses. It was impossible to survey 100% of the minority students on campus, but the sample collected suits the needs of this study.

Results and Discussion

The data collected was examined to answer the following questions:

1. Are there differences in students' engineering self-efficacy across academic levels?
2. Are there differences in engineering self-efficacy of minority students compared with majority students across academic levels?
3. Do majority students have a greater sense of belonging than minority students?
4. What factors are significant in predicting minority student probable persistence and sense of belonging in engineering?

To analyze the data scores were computed and the appropriate statistical analysis techniques were applied.

Question 1
Are there differences in students' engineering self-efficacy across academic levels?

This question asks if there is a difference in the engineering self-efficacy of a sophomore engineering student as compared to a freshman engineering student, and so forth. This question seeks to find the result for all students, regardless of ethnicity. Table 3 shows the ANOVA table for the subscales contributing to engineering self-efficacy. The results show that there is/are marginally significant difference(s) between means of the four classes (Freshman, Sophomore, Junior, Senior) for math outcome expectations ($F = 14.356$, $p = 0.0$). There may also be a significant difference between the means of the four classes for engineering career success expectations ($F = 1.717$, $p = 0.163$).

ANOVA TABLE

		Sum of Squares	df	Mean Square	F	Sig.
Coping Self-Efficacy	Between Groups	1.896	3	.632	.929	.427
	Within Groups	265.345	390	.680		
	Total	267.241	393			
Math Outcome Expectations	Between Groups	40.280	3	13.427	14.356	.000
	Within Groups	366.614	392	.935		
	Total	406.894	395			
Inclusion	Between Groups	.662	3	.221	.194	.901
	Within Groups	449.538	394	1.141		
	Total	450.201	397			
Engineering Self-Efficacy	Between Groups	1.929	3	.643	.965	.409
	Within Groups	262.566	394	.666		
	Total	264.495	397			
Engineering Career Success Expectations	Between Groups	3.031	3	1.010	1.717	.163
	Within Groups	231.823	394	.588		
	Total	234.854	397			

Table 3: ANOVA Table

Questions 2 and 3

Are there differences in engineering self-efficacy of minority students compared with majority students across academic levels?

Do majority students have a greater sense of belonging as compared with minority students?

Table 4 shows a comparison of the subscales across classes of minority students compared with majority students using Pearson's Chi-Square test. The results show a significant difference in minority students' math outcome expectations compared to majority students. Minority students' were found to feel less included compared with majority students, and their level of engineering self-efficacy is lower than that of majority students.

Coping Self-Efficacy	**Chi-Square Value**	**df**	**Sig.**
Minority	52.016	45	0.220
Caucasian	81.245	81	0.471
Math Outcome Expectations			
Minority	50.903	33	0.024
Caucasian	88.301	51	0.001
Inclusion			
Minority	60.975	51	0.160
Caucasian	62.017	75	0.858
Engineering Self-Efficacy			
Minority	50.780	54	0.599
Caucasian	94.102	117	0.941
Engineering Career Success Expectations			
Minority	29.726	39	0.858
Caucasian	49.142	57	0.761

Table 4: Subscale comparisons across class (minority vs. majority)

Question 4

What factors are significant in predicting minority student persistence and sense of belonging in engineering?

When determining the factors significant in predicting minority student persistence and sense of belonging in engineering the APPLES subscales were used. Tables 5 shows the subscales having significant differences in the means when comparing minority students with majority students. The table also includes those subscales with high means indicating these subscales could potentially be factors influencing minority student persistence in engineering.

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 it may bring (μ=2.6078) compared with African American/Black students (μ=3.2593). Relatively high means for intrinsic psychological motivation show that 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	3.5000
	American Indian/Alaskan Native	3.3889
	Asian & Pacific American	3.6667
	Latino(a)/Hispanic American	3.2255
Motivation (Financial)	African American/Black	3.2593
	American Indian/Alaskan Native	2.9444
	Asian & Pacific American	3.0000
	Latino(a)/Hispanic American	2.6078
Motivation (Intrinsic, Psychological)	African American/Black	3.7222
	American Indian/Alaskan Native	3.4167
	Asian & Pacific American	3.6000
	Latino(a)/Hispanic American	3.3750
Motivation (Intrinsic, Behavioral)	African American/Black	3.7500
	American Indian/Alaskan Native	3.5000
	Asian & Pacific American	3.3500
	Latino(a)/Hispanic American	3.3750
Confidence in Professional and Interpersonal Skills	African American/Black	3.9259
	American Indian/Alaskan Native	3.6111
	Asian & Pacific American	3.7333
	Latino(a)/Hispanic American	3.8646
Confidence in Solving Open-ended Problems	African American/Black	5.2000
	American Indian/Alaskan Native	5.0000
	Asian & Pacific American	4.9000
	Latino(a)/Hispanic American	4.7157
Academic Disengagement (Liberal Arts Courses)	African American/Black	3.2500
	American Indian/Alaskan Native	4.5417
	Asian & Pacific American	2.5833
	Latino(a)/Hispanic American	2.3906
Confidence in Math and Science Skills	African American/Black	3.5741
	American Indian/Alaskan Native	3.3889
	Asian & Pacific American	3.7000
	Latino(a)/Hispanic American	3.6875

Table 5: APPLES Constructs by Ethnicity

The theory of self-efficacy builds upon that of social cognitive theory of self-regulation. According to Bandura[2], self-regulation envelopes self efficacy which is key in exercising our right to make choices in life by impacting our thoughts, motivation and actions. A student must **believe** he/she can obtain an engineering degree in order to successfully **see** it through from orientation to graduation. After all, for most people, "seeing is believing." Inclusion was shown to be a significant factor in predicting minority student persistence in engineering. If a student does not feel included in his/her major or college, how likely will it be for that student to see him/herself graduating? If a student is unable to cope with being the only person of a specific ethnicity or gender, how likely will it be for that student to persist in the college of engineering?

Conclusion

For the institution under consideration there were no significant differences in engineering self-efficacy of minority students compared to majority students across academic levels. Reasons as to why this may be true are that the majority of the minority students participating in this study come from high performing high schools and are involved with professional engineering societies such as the National Society of Black Engineers (NSBE), Society of Hispanic Professional Engineers (SHPE), American Indian Science and Engineering Society (AISES), and the Society of Women Engineers (SWE). These organizations serve as a coping mechanism for minority engineering students. The authors plan to compare the results of this study with that of several other predominantly white institutions to understand if these results are accurate.

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