Applying the Theory of Planned Behavior: Recruiting Underrepresented Minorities to Engineering and Engineering Technology

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Abstract

There is mounting evidence that the United Sates will soon experience a shortage of qualified high-tech workers that will jeopardize the country's economic future. It is imperative that we recruit more women and minorities into engineering to prevent the anticipated shortage. Clearly, past recruiting strategies have had only moderate success, so a more holistic approach must be taken to encourage women and underrepresented minorities to consider engineering or engineering technology as an attainable career goal. Outreach programs that focus only on the targeted groups may not be doing enough.

The Theory of Planned Behavior describes three main factors that directly affect a person's *intentions to behave* in a particular manner, such as enrolling in an engineering or engineering technology college program. Once a person *intends* to engage in an activity, s/he will typically proceed unless some mitigating circumstances arise. The three main factors affecting intentions are 1) the person's attitude toward the behavior or activity, 2) the perceived subjective norms regarding the behavior, and 3) the difficulty of engaging in the activity.

We have implemented an outreach project that is directed at all of the factors described above to help recruit non-traditional students into engineering and engineering technology careers. We are showing high school students that engineering can be fun, engaging, and *possible* for them through high school clubs and competitions, affecting their perceived behavioral control. We are informing them about careers, job outlooks, and college programs, thus affecting their attitudes. Moreover, we are meeting with parents, teachers, and counselors to educate the community on the opportunities available to these students, affecting the subjective norm for these students. We believe that all of these activities will encourage non-traditional engineering students to strongly consider a career in engineering. In this paper, we will provide details of the project, and measured results of our efforts to date.

Introduction

In 2003, Gibbons[1] reported that the demand for engineers is increasing, but the production of engineers in America is decreasing: the United States is facing an imminent shortage of scientists, technologists, engineers, and mathematicians[2]. One of the reasons for this shortage is that female, African American, Latino, and Native American high-school students continue to show little interest in pursuing careers related to these subjects[2]. These students are depriving themselves of many technical and scientific career choices, as well as access to high salaried

occupations[3]. In 1995, women made up about 46 percent of the U.S. labor force but only about 9 percent of the engineering labor force[4]. Women comprise 52 percent of college students in the US, but only 17 percent of the college freshmen that choose engineering as a major[5]. African Americans make up 5.4 percent of undergraduate engineering enrollment, Hispanic Americans make up 5.5 percent, and other ethnic groups (including Native Americans, Alaskan Natives, Pacific Islanders, and bi-racial people) make up 7.3 percent[4]. Additionally, the National Science Foundation reports that in the decade between 1998 and 2008, the United States faces an anticipated increase of jobs in the science, technology, engineering, and mathematics fields of 51 percent, without a comparable projected growth in the number of skilled workers in these areas[6]. That is 1.9 million new jobs. If more women and minorities can be persuaded to purse a degree in engineering, the shortage can be averted.

We not only need to increase the number of engineers in America, but the diversity of the engineering workforce in America[7]. The business community has come to understand the value of employing a diverse workforce as a business necessity, not just an ethical responsibility. Diverse groups are known to combine their unique perspectives to devise exceptionally creative solutions to the problems they encounter[8]. The different perspectives and frames of reference of a diverse team offers competitive advantages in teamwork, service, product quality and work output because a workforce that mirrors a company's customers is more likely to understand the needs of its customers[9].

Some progress has been made in attracting women and minorities at all levels of education and employment, but they are still less likely to choose careers in engineering than in other fields of study[6]. Has the engineering community presented itself in such a way that we are turning away most women and minority students? Could we create more focused recruiting strategies that highlight those aspects of engineering that would appeal to the personalities, interests and values of these individuals?

The leadership team of the ***Diversity in Engineering Technology*** project, a three-year project funded by the National Science Foundation (NSF award #0302801), believes that we have devised an effective method to encourage female and minority students to pursue engineering and engineering technology careers. We are applying the Theory of Planned Behavior to accomplish the goal of the project: to increase the diversity of the students in engineering and engineering technology programs at the community college and university by encouraging more female and minority students to consider engineering as a career[7]. We have completed the first year of the project and are reporting some promising trends that we have observed.

In the next section, I will provide a general description of the Theory of Planned Behavior. In the section labeled "Project Details", I will provide an explanation of how we are applying this theory. I will then present some demographic data of the clubs and early results of our efforts.

The Theory Of Planned Behavior

The Theory of Planned Behavior argues that there are three factors that directly affect a person's ***intentions to behave*** in a particular manner (such as enrolling in an engineering program). Those three factors are (see Figure 1):

1. A person's attitude toward a behavior (beliefs, perceived effort, and apparent outcomes)

2. The perceived subjective norm (social pressure to engage or not to engage) related to the behavior
3. The perceived behavioral control (or perceived ability) while participating in the behavior.

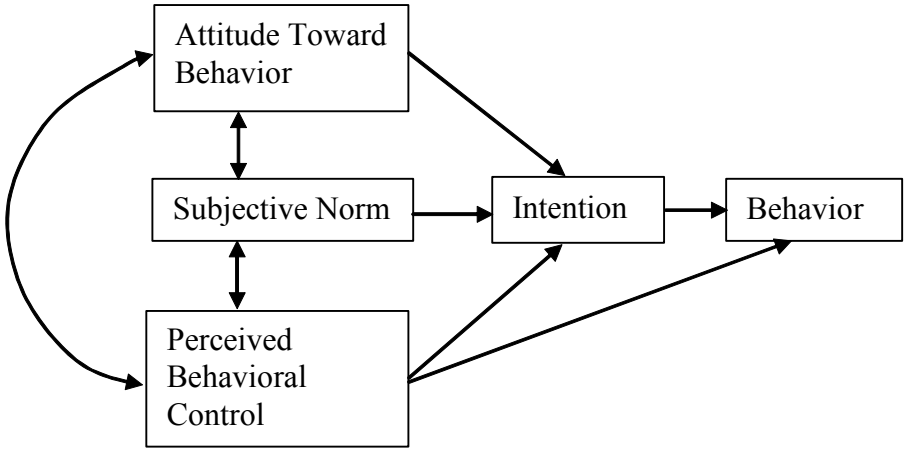

Figure 1: Model of the Theory of Planned Behavior[10]

Intention is what one has in mind to do or bring about, and is considered the immediate predecessor of ***behavior***[10]. A person must ***intend*** to engage in a behavior before they can engage in a behavior. Factors such as their intensity, attitude, subjective norm, and perceived ability may have mediating affects on intention. Simply put, if a person believes they are capable of behaving in a certain manner, believes that the rewards of behaving in that manner are worthwhile and beneficial, and has the support of their peers, family and friends, they will ***intend*** to engage in the behavior.

Behavior, then, is the observable response in a given situation. In the Theory of Planned Behavior, behavior is a function of compatible intentions and beliefs regarding ability. Perceived behavioral control (perceived ability) is expected to moderate the effect of intention on the outcome: behavior. This suggests that a favorable intention produces the behavior ***only*** when the person believes in their ability to engage in the behavior[10]. Because a student's perceived ability affects their attitude, subjective norm, intentions, and behaviors, and is the strongest predictor of behavior, we have concentrated our efforts on developing activities that would convince female and minority students that they were capable of engaging in engineering related activities.

As an example (suggesting the validity of the Theory of Planned Behavior), Cruz and Colom[11] found that the main factors cited as contributing to a students' decision to study engineering were (in this order):

1. They were good in science and math in high school,
2. Engineering was viewed as an empowering career,
3. Parents and relatives supported the decision or provided motivation,
4. The students did well in their college board examination, and
5. The students thought engineering was a prestigious career.

The fact that the students were good in science and math and did well on their college board examination suggests that these students felt they were able to successfully complete an engineering program (perceived behavioral control). The students believed that engineering was an empowering and prestigious career: both considered positive attitudes. The students also said that they had the support of their families (subjective norm). These students exhibited compatible intentions, so it would follow that they would ***intend*** to enroll in an engineering program. The Theory of Planned Behavior suggests that these compatible intentions, coupled with a strong perceived ability would predict actual enrollment in an engineering program.

Project Details

Ajzen, the author of the Theory of Planned Behavior, argued that to affect a change in behavior, one had to design strategies that were directed at one or more of the factors affecting intention[12]. The objectives of the *Diversity in Engineering Technology* project are to develop and implement strategies aimed at affecting all three factors of ***intention*** (attitude, subjective norm, and perceived ability).

Because the strongest predictor of behavior is perceived ability we have concentrated our efforts on developing activities that would convince female and minority students that they were capable of engaging in engineering related activities.

To interest these high school students, we started engineering clubs at almost twenty high schools in the region. High school teachers are paid a stipend to coordinate the clubs and ensure that a minimum of 50 percent of the club consists of non-traditional engineering students. The demographic make up of the clubs is shown below in Table 1:

Table 1: Club Demographic Data

Demographic Data of the High School Clubs										
Male					Female					
Black	**Asian**	**Hispanic**	**White**	**Other**	**Black**	**Asian**	**Hispanic**	**White**	**Other**	**Total**
44	26	10	120	12	27	7	8	55	4	44
14%	8%	3%	38%	4%	9%	2%	3%	18%	1%	14%
Total Male			212	68%	Total Female			101	32%	

We considered all students, other than Caucasian males, as being non-traditional engineering students. Caucasian males make up 38 percent of club membership, leaving 62 percent non-traditional students.

Table 2 shows the demographic data from UNC Charlotte's Engineering Technology Department, the national demographic data for engineering and engineering technology college programs (provided by ASEE), the regional demographic data (from the 2000 U.S. Census bureau), and the High School clubs. In comparing this data, we see a positive trend: we have retained for the first year many non-traditional students in the engineering clubs and piquing their interest in engineering. It remains to be seen if they will choose to pursue a career in engineering or engineering technology.

Table 2: Demographic Data at UNC Charlotte, the U.S., the Region, and the Clubs

	White	African-Amer.	Hispanic[3]	Asian	Male	Female
UNC Charlotte	77%	14%	1%	5%	91%	9%
National Stats in Eng./Tech[1]	69%	8%	6%	7%	89%	11%
Regional Population [2]	75%	19%	5%	2%	48%	52%
High School Clubs	56%	23%	6%	10%	68%	32%

[1] from ASEE [2] 2000 US Census Bureau [3] Hispanic – any race

Affecting Perceived Behavioral Control: Club Activities/Competitions/Events:
The club members engage in several common activities throughout the year, but may participate in individual events at their schools. The common events this year were:

- Trebuchets
- Career Exploration Presentation
- Engineering Science Fair: Alternate Methods to Generate Electricity
- TEAMS Test/Robotic Competition

The trebuchets were an exercise in mechanical engineering. We provided a simulation program (purchased through RLT.com) for the students to simulate the effects of design considerations prior to construction. We then invited the clubs to the university campus to compete against other clubs in distance and accuracy. Because of the interest in physics and engineering principles generated by the competition, teachers at one of the schools were able to offer an elective course in physics (Physics II: Physics for Engineering) and enroll 7 non-traditional engineering students in the class (we see this as a positive outcome of the competition).

The Career Exploration Presentation met several objectives. We wanted the high school students to explore engineering careers, discover typical salaries for several disciplines, determine what level degree they would need, costs, what courses they should concentrate on in high school, etc. The students were then required to write a paper answering specific questions, and then present their findings to at least two classes at the high school. We chose the seven best papers, and invited the authors (with their families and teachers) to the university to present their paper to several faculty members, parents, teachers, and others in the audience. Every students participating in the event received a cash prize. It should be noted that all authors invited to the university were female or minority students, not by design, but because the judges determined that these were the best papers (our judges were not provided any identifying information regarding the authors).

The outcomes of this event were that high school students learned about engineering careers from their peers. Parents observed that many girls and minority students were interested in engineering, and through the students' and our introductory remarks at the event, understood that it is normal for females and minorities to pursue engineering careers (we affected their subjective norm). Students also learned why they needed to concentrate on math and science while in high school

For the Engineering Science Fair, we asked the students to research alternate methods for generating electricity and then, through experimentation, determine parameters such as efficiency, cost, power out, etc. The entrants researched fuel cell technology, solar energy, wind

energy, and river current. The students were invited to the university to demonstrate their projects and were judged by several engineering technology faculty with expertise in alternate energy. It should be noted that 80 percent of the entrants were female.

The TEAMS Test/Robotic competition is a double event. Students began the day by taking the TEAMS Test (offered by JETS – the Junior Engineering Technical Society: see www.jets.org). The TEAMS Test is a college freshman-level math and science test given to high school students. A team of four to eight students attempts to answer 100 multiple-choice questions (based on calculations) in 90 minutes. They then answer five open-ended questions based on topics found in the first part of the test. This was the first time this test had been offered in this region. Three of the teams placed nationally, an achievement of which they were extremely proud.

We then had robots compete in a "soccer game". The students were allowed to use the parts from one Lego Mindstorms robot to design, build, and program their robots (cost is approximately $200 and was provided by the grant). This competition generated a lot of interest in engineering and excitement about the clubs. In our first competition, we had over 100 students participating. This year, we expect between 250 and 300 students to participate in this event.

Individual clubs have developed activities such as tower building with plastic straws, water powered rockets, bridge building, etc. to keep the kids interested when they are not preparing for competitions at the university.

We have also held two, one-week camps with similar activities, intending to pique the interest of high school minority and female students. The students stay in the dorms, eat on campus, interact with college students (who are employed as counselors for the camps), and are engaged in engineering activities and theory for one week. Many of these students, after participating in the camps, have indicated a desire to pursue engineering careers.

All of the preceding activities were designed to demonstrate to these students that they are capable of engaging in engineering related activities. Many students have decided to consider engineering careers; a positive indication of our efforts. At this point, I have only described strategies designed to affect the students' perceived behavioral control (ability). We believe that these strategies will prove to be worthwhile, but we wanted to affect all of the determinants of ***intentions*** as described by the Theory of Planned Behavior.

Affecting Attitudes:
To affect attitudes toward engineering we speak to high school math and science classes. We show the expected need for engineers and technicians in our region over the next few years (data presented is from the U.S. Department of Labor Statistics). We illustrate the expected salaries for this region and talk about success stories of our graduates. We briefly discuss several engineering disciplines and encourage and offer suggestions as to how these students can research additional information for themselves. We then explain the several options the students have to achieve an engineering or engineering technology degree through the university or through a 2+2 option through the community colleges.

We have spent whole days at high schools to meet with several classes. To date we have spoken at 12 of the 20 schools participating in the project as well as many middle schools. We plan to speak at all the schools. Combining the strategies to improve attitude and improve perceived ability have shown positive trends (see below).

Affecting Subjective Norms:
To affect the subjective norm we are executing an engineering awareness program. We are providing workshops for teachers and career counselors so that they are aware of the career options, education options, and entry-level salaries for engineering graduates. We are talking with parents at middle school PTO meetings and participating in career days at the high schools and middle schools. The clubs offer many minority and female high school students an opportunity to get involved in "hands-on" engineering related activities[7]. In response, female and minority students have become more interested in math and science and feel encouraged to pursue a degree in engineering[7].

Results

We believe that our combined strategies have had a positive effect, and anticipate verification as the program progresses and these high school students prepare to enter college. The engineering clubs at the high schools provide students a chance to participate in engineering related activities. Observed results are that students are finding that math and science can be fun and they see a practical application for these subjects[7]. Blaisdell suggests that quality math and science experiences will affect students' perceived ability[13]. I agree, but also suggest that these students' interest levels must be raised first, through activities such as the ones provided in the clubs. The students will then find a reason to focus more on the math and science behind the activity, apply the math and science, and thereby, have increased their perceptions of their abilities and interest in math and science.

In a survey conducted immediately after the first competition, students responded as shown in Tables 3 and 4. This survey was conducted after the students had been involved in the clubs for six months.

Table 3:Results of Student Survey

Statement:	Agreed	Not Sure	Disagreed
I am enjoying the Club	94.4%	5.6%	0.0%
I have enjoyed working with the robot	95.6%	3.3%	1.1%
I have enjoyed preparing for the TEAM+S[1] Competition	44.4%	36.7%	18.9%
I will be in the club next year[2]	82.5%	15.9%	1.6%

[1] The TEAM+S test is a college level math and science test in which a team of eight students works together to solve 100 problems
[2] Responses from Freshman, Sophomore, and Juniors only

Ninety-four percent of the club members have enjoyed being a part of the club. This indicates that there are high school students that are looking for this type of activity in which to be involved (there are close to 400 students in 18 high schools involved in the clubs). Ninety-five percent of the club members have enjoyed working with the robots. We are hosting several other activities and competitions but, at the time of this survey, the students had only worked in preparing for a robot competition.

Forty-four percent enjoyed preparing for the TEAM+S competition (97 students participated in the TEAM+S Test). It may be more significant to note that only nineteen percent (18.9%) indicated that they did not enjoy preparing for the competition. At first glance, these seem like poor outcomes. High school teachers have insisted that these are very good outcomes. The teachers have pointed out that it is very unusual for ***any*** students to ***enjoy*** preparing for any test, especially a math and science test. The fact that 44 percent enjoyed preparing for the test as a club activity (some did this as extra credit homework) amazed most high school teachers.

Table 4: Percentage Of Each Group Reporting That They Agreed With The Statement

Statements: ***Because of the club:***	Female	Male	African-Am.	Asian	Hispanic	White	Other
I have been working harder in math	55.6%	65.1%	83.3%	42.9%	85.7%	61.8%	53.3%
I have been working harder in science	48.1%	58.7%	66.7%	28.6%	85.7%	56.4%	46.7%
I have more interest in science	66.7%	57.1%	50.0%	28.6%	71.4%	60.0%	73.3%
I have more interest in math	55.6%	66.7%	50.0%	28.6%	42.9%	69.1%	73.3%
I know more about the university and community college programs	48.1%	47.6%	50.0%	14.3%	57.1%	50.9%	46.7%
I plan to go to a CC for an ET degree	3.7%	28.6%	16.7%	0.0%	0.0%	27.3%	20.0%
I plan to go to UNC Charlotte	11.1%	31.7%	16.7%	0.0%	42.9%	27.3%	26.7%
I plan to get an engineering degree	11.1%	65.1%	66.7%	28.6%	71.4%	47.3%	46.7%
I plan to get an ET degree	7.4%	41.3%	33.3%	14.3%	28.6%	34.5%	26.7%

Many students are working harder in math and science and have more interest in math and science. Fifty-five percent of the female, eighty-three percent of the African-American, forty-three percent of the Asian, and eighty-six percent of the Hispanic students indicated that they were working harder in math because of the clubs. A similar percentage of the students indicated they were working harder in science. Another encouraging statistic is the numbers and percentages of students that are demonstrating an increased interest in math and science because of the clubs.

When we began this project, most students knew of one school in North Carolina in which they could pursue an engineering degree. They were not aware of the technical programs at the community colleges or the engineering technology degree at UNC Charlotte. In fact, many teachers told us that they were not even aware that UNC Charlotte had a College of Engineering. The students now tell us that they know more about the community college and university programs, plan to go to their local community colleges or UNC Charlotte, and many students plan to enroll in engineering or engineering technology programs. However, it is our goal to increase the number of capable students, particularly underrepresented minorities, in the STEM professions. For this reason, any student who chooses to study in a STEM field is considered a success of the program, whether or not they choose to attend UNC Charlotte.

We realize that these are preliminary statistics. As more meetings are held with parents, teachers, and career counselors, more discussions are held with high school students, and more activities are held for the high school students the statistics are expected to get better.

A Success Story

One of the competitions hosted by UNC Charlotte for the engineering clubs this year was a trebuchet competition. The students had to build and fine-tune a trebuchet that would out-

perform others in distance and accuracy. One of the high school teachers (a sponsor for one of the clubs attending the competition) told us:

> "These students have never shown much interest in math or science. As they were testing and adjusting their trebuchet one Saturday morning, a parent volunteer (who has designed and built trebuchets as a hobby) came over and asked to see their calculations. The students responded, asking 'calculations?' The parent showed them some of the calculations he used to help fine-tune his trebuchets. The students immediately gathered round to look. Before long, these students, who have never shown much interest in math and science, were spending their Saturday morning working math problems, out in a field, to help fine-tune their trebuchet. That is a direct outcome of the project! This activity has shown these students an application for math and science that interests them. They are now showing a much greater interest in math and science, and are performing better in their math classes."
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> ***Ken Stoltzfus, North Iredell High School***

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Biographical Information

Stephen Kuyath is an Assistant Professor of Engineering Technology at the University of North Carolina at Charlotte. He has taught engineering technology courses at the college level for over 22 years. He has a strong interest in and dedication to improving both traditional and distance engineering education and to encouraging those students typically underrepresented in STEM fields to consider engineering technology as a career.