AC 2008-2128: A COMPREHENSIVE AND INTEGRATED APPROACH TO INCREASE ENROLLMENTS IN ENGINEERING TECHNOLOGY

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A Comprehensive and Integrated Approach to Increase Enrollments in Engineering Technology

Abstract

The future of America's global competitiveness depends upon a well-educated, technologically literate workforce. However, if proactive measures are not taken in the near future, the United States will face a serious shortage of scientists, engineers, technologists, and mathematicians because high school students, especially those from underrepresented groups, are increasingly losing interest in these subjects. The key in reversing this trend lies in our ability to promote science, technology, engineering and math (STEM) subjects and professions in a more socially relevant, real-world context and to recognize the differences in learning styles and self-efficacy between males, females and minorities. In an effort to increase the number and diversity of students pursuing engineering related majors, the University of North Carolina at Charlotte has adopted a comprehensive and integrated approach involving three separate National Science Foundation (NSF) funded projects. Together, the projects are designed to raise the engineering awareness of middle and high school students, teachers and guidance counselors.

The central project is the Enhancing Diversity in Engineering Technology (EDIET) project which focuses on the establishment and support of North Carolina Junior Engineering and Technology (NCJETS) clubs at local area high schools. In order to receive project support, a high school club must have a population of at least 50% non-traditional engineering student types. The clubs compete in regional competitions such as balsa wood bridge building, trebuchets, robotics, and math tests, etc. The EDIET project also sponsors week long summer engineering technology camps hosted by the university.

To reinforce the impact of the EDIET project, the Teaching Engineering to Counselors and Teachers (TECT) project was developed to strengthen the way in which high school teachers and counselors approach the integration of engineering based materials into their courses and counseling. As STEM teachers and school guidance counselors will be the primary catalysts for introducing students to engineering and technology subjects and careers, the TECT project delivers week long professional development workshops that uses the well-established STEM model of hands-on activities as a tool to raise engineering awareness among the teachers and counselors. The TECT workshops have been closely integrated with the EDIET summer camps and makes use of the student camps to further promote best practices that reach across the diversity of student learning styles and interests.

Finally, in order to provide financial support for underrepresented students entering engineering technology majors, the Career Opportunities for Meritorious Engineering Technology Scholars (COMETS) scholarship program was created. The program awards scholarships to qualifying students with the goal of improving student retention by reducing the need for students to work and take classes at the same time. This paper discusses some of the results and findings of this comprehensive and integrated approach to increase enrollments in engineering and engineering technology majors.

1. Introduction

An essential component to the continued growth and stability of the American economy is a well-educated workforce able to create, develop and produce essential products, processes, and services[1]. However, it has become abundantly clear that the United States faces two significant challenges in that it has been unable to produce a sufficient number of domestic engineers[2], and it has been unable to produce a sufficiently diverse engineering workforce[3].

In 2003, Gibbons[2] reported that the demand for engineers is increasing, but the production of engineers in America is decreasing and the United States is facing an imminent shortage of scientists, technologists, engineers, and mathematicians[4.] The literature indicates that one of the reasons for this shortage is that high school students that are members of traditionally underrepresented in engineering and technology

show little interest in pursuing careers related to engineering[4] often because they are not aware of the opportunities and relevance of a technical career. Because these students are unaware of these career choices they are not taking appropriate classes in high school, and are therefore depriving themselves of many technical and scientific career choices, as well as access to high salaried occupations[5].

To address this lack of awareness of the technical professions on the part of students, parents, teachers and counselors, as well as stimulating the interest of high school students in engineering and technology, the University of North Carolina at Charlotte (UNC-Charlotte) has developed a sequence of projects that provide a holistic approach to increasing the number and diversity of students involved in engineering activities and studies. The relationship between the NSF programs administered by the Engineering Technology Department is illustrated in Figure 1. Each of these programs, which will be discussed in detail in the following sections, addresses a component necessary to facilitate and support the interest of students in the study of engineering and engineering technology disciplines. All programs operate synergistically to provide a comprehensive and cohesive approach to student, teacher and parent education and involvement. The final block in Figure 1 represents the support structure found in the college of engineering through the Office of Student Development and Success MAPS (Maximizing Academic and Professional Success) program. This nationally recognized program comprises services such as the college mentoring program, Supplemental Instruction, tutoring and workshops on personal and professional success strategies to help facilitate a successful transition to the departments and programs within the college of engineering.[6, 7,8] .

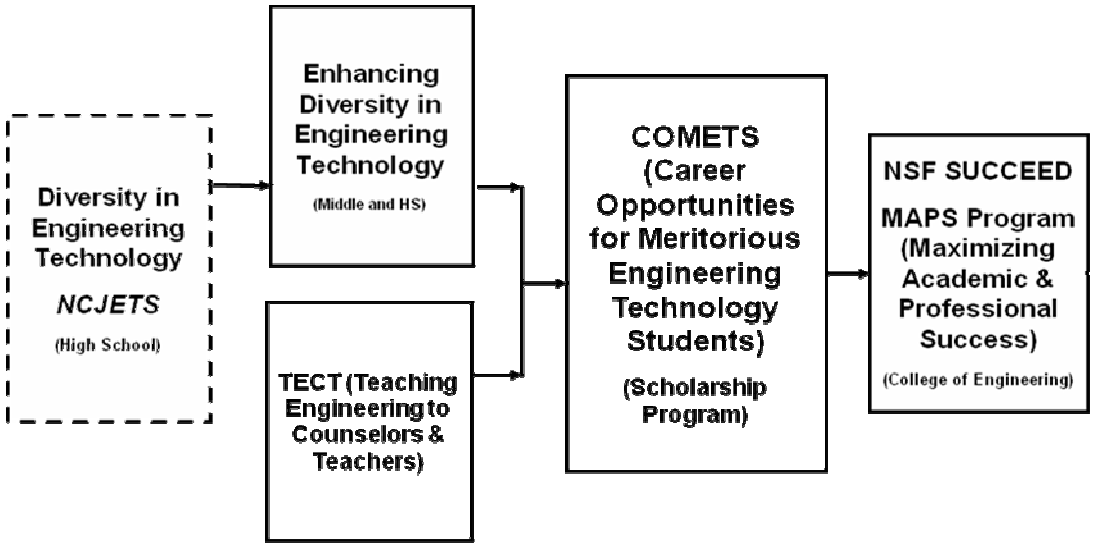

Figure 1: Relationship between Diversity Initiatives

2. Student-Oriented Efforts

The student-oriented aspect of the UNC-Charlotte's initiatives includes two NSF funded endeavors focused on encouraging traditionally underrepresented groups in engineering and engineering technology to pursue additional education in these fields through a series of interventions at the high school level. This has involved developing and implementing a model that:

- Increases the number and diversity of students pursuing traditional four-year studies in the engineering sciences and engineering technology disciplines.
- Increases the diversity of technically oriented students at the community colleges and, ultimately, at the university level in a 2+2 Associate of Applied Science (AAS) to Bachelor of Science in Engineering Technology (BSET) matriculation arrangement.
- Increases student, parent and teacher awareness of, and interest in, the career and educational opportunities for students with aptitudes in math, science, engineering and technology.

- Facilitates the development of pre-college STEM (Science, Technology, Engineering and Math) curricula at the secondary school level.

Phase I, which was the foundation of the current efforts, was laid through the *Diversity in Engineering Technology* (DiET) project (NSF #0302801), a proof of concept project in effect between 2003 and 2006 that primarily relied on anecdotal evidence of success. This project was extremely effective in creating sixteen NCJETS (North Carolina Junior Engineering and Technology Society) high school clubs in seven counties of the Central Piedmont region of North Carolina. Clubs were established with a math, science or tech ed teacher (or teachers) serving as club sponsor(s) and were encouraged to develop individual identities that best served their populations. DiET also established the basis for annual competitions held on the UNC-Charlotte campus, as well as offering high school summer camps through the UNC-Charlotte summer programs office.

Phase II of this effort, *Enhancing Diversity in Engineering Technology* (NSF #0603382), is operational between 2006 and 2009. In Phase II, the basic premise of Phase I with respect to unique club identities, competitions and summer camp offerings was maintained. The NCJETS program has been expanded to additional high schools and the first cohort of middle school clubs was brought on board in 2007. A major distinction between Phase I and Phase II is the incorporation of a formal assessment and evaluation component. This requirement, which supports NSF's emphasis on research in engineering education, provides measurable outcomes and demonstrates quantitatively the cost/benefit of the program. Assessment methods utilized in Phase II include the submission of a profile information spreadsheet from each club and annual student and teacher online surveys. The information on the spreadsheet is reported by a unique student identifier which is maintained by the club sponsor or the appropriate school system to maintain student anonymity.

Project goals are realized through a comprehensive collection of strategies designed to generate interest in, and excitement about, STEM related concepts. Research shows that social attitudes toward math, science, and technology become fixed in middle school and early high school, underscoring the importance of reaching out to underrepresented groups as early as possible[9]. Girls and minorities who develop negative attitudes during this time period are unlikely to pursue careers in technology. However, when introduced to engineering and technology through interesting and interactive activities, those students with abilities in math and science will be encouraged to pursue a career in a technical profession[10] which is multicultural and global in nature[11]. The primary mechanisms to achieve project goals involve: high school technology clubs that are active during the academic year; summer technology camps; student-to-student mentoring; and parental involvement, each of which is introduced in the following discussions.

2.1 NCJETS Clubs: NCJETS clubs established at public schools have proven to increase awareness and interest in technical careers and demonstrate the valuable contribution that diversity brings to the optimal solution of problems. Currently, 28 high schools in the region have established clubs that are focused on several activities during the academic year. These activities are designed to illustrate the STEM fields and the interdependence of multiple professions, while offering opportunities for students to participate in individual and team events. Specifically, academic year activities for NCJETS high school clubs involve:

1. Applied mechanical engineering principles through the design, analysis, simulation, construction, fabrication and testing of trebuchets, culminating in a competition on the university campus.
2. A career exploration contest which promotes student research of career / educational opportunities in STEM fields by addressing a specified open-ended problem with a specified theme that changes each year. Individual students write a paper of findings, which is evaluated by a judging committee. Top performers are invited to present their work in a conference format to their parents, teachers, peers and the general public.

3. A poster session competition that provides an additional forum for student teams to address the same open-ended problem as the career exploration contest.
4. A civil engineering related project which has included a bridge building contest in which student teams design, analyze and construct bridges to given specifications and then test the bridges to destruction or a beam competition where student teams design to dimensional, weight, construction configuration, load and deflection specifications.
5. Competition in TEAM+S (Test of Engineering Aptitude, Mathematics, and Science: developed by the Junior Engineering Technical Society), a three-hour, team-based math and science test. To ensure maximum participation and a level playing field, the competition is separated into JV (9^{th} and 10^{th} grade) teams and varsity (11^{th} and 12^{th} grade) teams.
6. A competition using Legos MindStorm robot kits in which students are required to design, build, and test robots in a competitive situation. The format and specifications of the competition are also changed annually.
7. A Conference Day with concurrent sessions by COE students, faculty, alumni and industry representatives. Club members, sponsors and parents are able to interact with student organizations, partner educational institutions and a variety of industry representatives from throughout North and South Carolina through informational tables and booths. As mentioned earlier, one of the conference sessions contains the Public Speaking Competition of the career exploration contest.

Middle school clubs have been provided with balsa wood bridge and Legos MindStorm robot kits. Project personnel and NCJETS mentors are currently involved in developing a club and competition structure that will best serve middle school students, teachers and parents. It is anticipated that the middle school clubs will have a single event on the UNC-Charlotte campus in late spring 2008 that will involve a club showcase, poster session, as well as a robot and/or bridge competition.

The NCJETS clubs help overcome two recognized barriers to equal participation in math and science by underrepresented groups. The two barriers are:

1. Under-equipped schools. These schools, by necessity, offer less access to math and science activities. These schools are usually found in inner city and rural areas where a high proportion of economically disadvantaged and minority students are located[5].
2. Lack of role models. This is an especially critical issue, effectively preventing many capable students from entering technical disciplines[12]. Effective teachers from underrepresented groups are recruited to act as club coordinators and role models where possible. In addition, project leadership personnel, additional faculty and students, and industry volunteers (many of whom are members of underrepresented groups) serve as mentors and role models.

2.2 Mentoring: Mentoring programs are especially effective if they target individuals in underrepresented groups or groups of individuals who, statistically, are not likely to succeed. These programs are effective because the mentors provide protégés with a common community and help them anticipate future challenges[13]. Phase II has initiated the NCJETS Mentors, a group of college of engineering students that serve as a liaison between one or more NCJETS clubs and the project personnel at UNC-Charlotte. The NCJETS mentors attend club meetings on the high school campus, help with projects, provide a role model for club members and assist communication for the club sponsor(s). It is interesting to note that, of the eight NCJETS mentors currently employed by the project, six were members of NCJETS clubs in high school. In addition, student chapters of professional societies at UNC-Charlotte serve as speakers and mentors for high school students in the technology clubs as well as maintaining a visible presence as volunteers during all competitions and events. All mentors help students and sponsors get timely feedback to technical questions about current projects and provide information about the choices available in higher-level classes. A network of industrial and professional society

sponsors has also been developed to provide a resource for career guidance, professional development and practical advice.

2.3 Summer Engineering/Technology Camps: UNC-Charlotte has hosted resident summer camps throughout both phases of the project. Research shows that students develop the drive for pursuing a career in math, science, engineering or technology while in middle school or early in high school, and secondary school mathematics and science study is key to maintaining an interest in these careers[14].

Summer camp participants live in dorms on campus during the week. UNC-Charlotte has extensive experience in providing summer camps and monies from the project provide funding for student participation. Participants are selected through a formal process including recommendations from club advisors or math and science teachers and a demonstrated interest from the students using criteria to meet the project objectives. A focused effort is made to ensure participation by traditionally underrepresented and economically disadvantaged groups.

The middle school camp is focused on hands-on activities related to engineering/technology disciplines. Students work individually and in teams on a variety of projects including: trebuchets, robot kits (which they get to take home), and bridge building and testing. It was determined that more academic rigor should be brought into the high school summer camp offering, so in Phase II the high school camp is based on a COE freshman engineering course and is taught by freshman engineering instructors. The high school camp is designed to illustrate the different levels of abstraction and design in technical problems and ranged from the determination of appropriate resistor values for a defined voltage divider network, to a team-based discovery box project with outcome specifications, to a beam designed to specification using basswood. At each level, students used appropriate mathematical and simulation tools to develop optimal solutions. Laboratory experimentation or testing to spec was performed for each project during the week. The teacher and counselors participating in the concurrent TECT project also developed and delivered a module for the campers which will be discussed in the next section. At the end of the week, parents and families of the campers were invited to a showcase and luncheon. COE faculty, staff and administrators participated in the final beam testing and team-based poster competition, culminating in prizes and awards for student participants.

2.4 Parental Involvement: High school students were asked what or who most influenced their career choices and, in order of importance, listed their own ideas, their mothers, and then their fathers[15]. This project provides parents opportunities to engage with their children during multiple events during the year, as well as with relevant and practical information that is intended to encourage students to 1) take science and math every year throughout high school, 2) become involved in technology clubs in school, and 3) participate in summer STEM camps by demonstrating that science and math are important parts of daily life.

As part of the awareness program, project personnel present and discuss these issues with parents at every opportunity. In the presentations, statistics are included about underrepresented groups in technical fields, the personal and professional rewards of a career in the STEM professions, and the career and salary opportunities for their children if they succeed in math and science courses. This information is also disseminated to teachers, the technology clubs and on the project website (http://www.ncjets.uncc.edu).

2.5 COMETS (Career Opportunities for Meritorious Engineering Technology Scholars)
To address the financial needs of students in programs in the Engineering Technology Department, the COMETS (NSF #0631038) scholarships were created. COMETS scholars must meet the criteria of full-time enrollment in an ET program at UNC-Charlotte, demonstrated financial need, commitment to participate in the MAPS program, and a minimum level of academic performance (although a formal recovery process has been identified for current scholars whose performance falls below this minimum).

A formal application process including a written statement of purpose and letters of recommendation are required for initial scholarship award.

The scholarship program has a two-tiered structure to accommodate the two distinct populations in the Engineering Technology Department. COMETS scholars that enter an ET program as freshman are eligible for scholarship renewal for up to four years, while students who enter the ET programs as AAS transfers are eligible for scholarship renewal for up to two years. All ET students are encouraged to apply for COMETS scholarships and students are identified through current diversity projects and department initiatives. The COMETS program is currently in the second of a four-year funding cycle. During the first year, fifteen scholarships were awarded, with 87% of these scholarships awarded to members of traditionally underrepresented groups in engineering and technology.

3. Teacher/Counselor Centered Efforts

For many students, the primary exposure to technical professions comes from their STEM classroom teachers and/or their guidance counselors. However, a study performed by Ferris State University indicated that 51% of high school students felt that ***no one*** within their high school had been helpful in providing career advice or guidance[16]. In fact, studies have shown that girls are actually "tracked away" from math and science careers by teachers and counselors[17, 18]. It has also been well established that teachers tend to have higher expectations for boys than for girls, especially in the area of math and science, which leads to less rigorous instruction for girls[19]. In addition, counselors tend to promote engineering only to their very best and brightest female students while at the same time encouraging academically average male students to consider engineering majors[20].

The **T**eaching **E**ngineering to **C**ounselors and **T**eachers (TECT, NSF #0554405) project is a three-year proof of concept project that works in conjunction with the middle and high school NCJETS program summer camps through a summer workshop for teachers and guidance counselors to address these problems. The TECT project incorporates the well-established STEM model that hands-on activities improve student learning and comprehension. Prior to the summer TECT workshop, teachers and counselors develop educational materials that focus on pedagogical methods for incorporating hands-on activities into STEM classrooms and classroom strategies for more effectively engaging women and underrepresented students in STEM-based subjects. Improved career guidance counselor training materials are also developed which are geared towards assisting counselors in promoting engineering careers to a wider audience of students. All materials developed are tested and evaluated during the week-long TECT summer workshop where TECT participants are observers of students, learners of new engineering and pedagogical content and participants in teaching the summer camp activities. The capstone practicum for the TECT workshop requires the teacher participants to prepare a lesson plan incorporating a hands-on engineering activity and delivering the lesson to the summer camp students while the counselor participants conduct a group career counseling session with the summer camp students.

3.1 The TECT Workshop Model

The first TECT workshop was held on July 23 – 27, 2007 at the UNC-Charlotte with 18 high school teachers and guidance counselors from nine local area high schools participating. Two additional workshops will be offered during the summer of 2008 (one each for middle school and high school teachers and counselors). The focus of the workshop is to teach the teachers and guidance counselors about engineering while training them in hands-on techniques and classroom practices that can be used to overcome latent gender and minority based biases that STEM teachers and counselors bring to the classroom[20, 21]. At the conclusion of the workshop, participants are required to develop formal work plans describing the engineering content and activities they intend to incorporate into their classrooms or counseling during the course of the next semester. A one day follow up meeting with all participants at

the end of the following semester in which participants are asked to report and critique their experiences in completing their work plans and incorporating TECT concepts into their classrooms.

The research hypothesizes that this mix of diversity awareness based teacher professional development training coupled with improved career guidance counseling training will provide a necessary foundation to increase the number and diversity of students entering STEM related fields. This is to be facilitated through the TECT project by providing teachers knowledge about technical areas, impacting information available to counselors and presenting the engineering profession and engineering topics in a socially relevant context to engage all populations[20,22,23,24] .

3.2 TECT Workshop Content

Studies have shown that any effective pre-college outreach program geared towards increasing diversity in engineering must [20, 21]:

- Promote awareness of the engineering profession;
- Provide academic enrichment to participants;
- Address teacher effectiveness; and
- Support the educational system of the participants.

The TECT project has been structured to meet these criteria through its integrated career guidance training, teacher development, and student summer camp activities. The learning objectives, describing what participants should be able to do by the end of the TECT workshop, are outlined in Table 1.

Table 1: ***Learning Objectives for TECT Workshop***

1. ***Articulate*** the importance of K-12 engineering education.
    a. Recognize the nation-wide shortage of engineers and technologists.
    b. Describe the overall decline in students entering engineering related majors.
    c. Characterize the demographics of students entering engineering related majors.
2. ***Explain*** engineering career opportunities within a global and societal context.
    a. Identify and contrast the engineering disciplines as outlined by ASEE.
    b. Relate the changing roles and skills of the engineer-of-the-future.
    c. Outline academic preparation requirements and available academic pathways.
3. ***Critique*** the impact of diversity in promoting engineering careers.
    a. Recognize student differences in career and identity development.
    b. Identify and evaluate differences in student learning styles.
    c. Assess the need to improve the self-efficacy of marginalized students.
4. ***Formulate*** lesson plans incorporating engineering content that support North Carolina Standard Course of Study objectives.
    a. Correlate specific academic discipline topics to related engineering content.
    b. Identify and access available K-12 engineering education resources.
    c. Evaluate the effective use of competitions and team building activities.
    d. Plan, complete and evaluate an assigned hands-on engineering activity.

To achieve these learning objectives, the workshop is presented in a series of modules covering the following topics:

- "Why K-12 Engineering Education?" Introduction
- Diversity in Student Learning Styles and Self-Efficacy
- Collaborative and Active Learning Strategies
- Engineering Profession Overview and Academic Pathways
- “A Day in the Life of an Engineer”
- Civil and Construction Engineering Discipline Overview and Activity

- Mechanical Engineering Discipline Overview and Activity
- Electrical and Computer Engineering Discipline Overview and Activity
- Biomedical and Biological Engineering Discipline and Activity
- Competitions, JETS clubs and Other Extracurricular Opportunities

Each module has been designed to be approximately one-half day long and includes opportunities for active individual and group participation, interaction with the student summer camps, and collaborative assessment of learning activities.

After the introductory overview of the importance of K-12 engineering education, the focus of the workshop is on the diversity in student learning styles and self-efficacy, effective collaborative and active learning strategies to address the range of diversity, the in-depth overview of the engineering profession, and the use of engineering related activities to strengthen STEM classroom instruction. In order to expand the diversity and number of students pursuing engineering related majors, teachers and counselors must be able to effectively recognize the diversity in how students learn and choose careers and adapt accordingly.

For example, studies have shown that girls tend to feel less confident, are less assertive and often feel that their comments are incorrect and, as a result, they feel they have little input to offer in groups and prefer same-sex groups over mixed group settings[25, 26]. They also prefer problem-centered and socially relevant topics and activities [20, 22, 23]. STEM students from traditionally underrepresented groups have identified cultural factors as having the greatest impact on their retention, a factor which indicates the need for enhanced cultural understanding by those responsible for supporting and mentoring students[17]. In the early 1990's multicultural competencies for human services were developed upon three cornerstones[27]:

1. Awareness of self,
2. Awareness of worldview of others, and
3. Awareness of culturally appropriate teaching or counseling.

Therefore, as part of the workshop, teachers and counselors are schooled in techniques that raise a student's self-confidence and self-efficacy beliefs and have been shown to be successful in encouraging female and minority students to enroll in more math and science courses. Techniques regularly used by teachers with the best record for encouraging more female and minority students to take more math and science classes and to participate in advanced placement math and science classes include[28,29] :

1. Cooperative learning strategies and individualized learning strategies rather than public drill and practice
2. More hands-on learning and more problems with practical applications and opportunities for creative solutions
3. More active, open-ended learning situations rather than drilling students on "correct" textbook answers
4. Active career guidance, stressing the importance and usefulness of math and science for the future career choices
5. Using multiple texts (or other sources of information) with information and pictures indicating the involvement of all races and both genders in math and science to avoid the use of racist or sexist materials
6. Rotating the leadership of teams, ensuring that all students have an opportunity to use the equipment.

As many of these practices have already been incorporated into the NCJETS summer camps, the camps are effective tools for demonstrating and reinforcing the concepts taught in the TECT workshop. The student summer camps use team-based, hands-on activities that culminate in low-key competitions in

order to introduce students to various engineering disciplines. Summer camps have been shown to be an effective tool for attracting minorities and women into engineering[30]. In a study of a girls-only camp, 50% of the participants went on to study engineering with 72% of those who did pursue engineering indicating that the camp experience was a deciding factor, with the experience of UNC-Charlotte being similar [31,32].

Beyond the diversity based learning styles and self-efficacy training, TECT workshop participants also receive in-depth instruction concerning the engineering profession and its various disciplines. Participants are given an overview of the engineering profession as a whole with all of its various disciplines and possible academic pathways. Additional emphasis is given to four of the disciplines: civil and construction engineering, electrical and computer engineering, mechanical engineering, and biomedical and biological engineering. The first three were chosen because they correspond with the engineering disciplines currently offered at UNC-Charlotte in both the engineering sciences and engineering technology departments. Biomedical and biological engineering was chosen as a fourth emphasis because it is a field that tends to attract a larger percentage of female students and it provided a ready vehicle for adding content to the workshop that would better address the needs of life science teachers that may be in attendance. Throughout the workshop, the societal context, prevalence and impact of the engineering professions are emphasized. In order to bring a "real-world" perspective into the workshop, a practicing engineer from industry is invited from industry to talk about their career and to present a typical "day in the life of an engineer." In the initial workshop, a female civil engineer working in the area of concrete materials, inspection and forensic engineering was invited and she provided her perspective of the rewards of an engineering career and the challenges of working in a male dominated profession.

Each of the discipline specific modules contains one or more discipline related hands-on activities that participants complete. Low cost projects utilizing common supplies and materials were deliberately chosen to ensure that cost was not a barrier to implementation into the normal public school classroom. Projects include bridges made from file folders, windmills made from drinking straws, dismantling discarded cell phones, electronic bread boards, and rubber bands and springs to demonstrate the elasticity of skin. Participants learn some of the basic math and science concepts behind the activities (and actually perform some of the calculations) and how to make connections between the activities and specific classroom topics and content tied to the North Carolina Standard Course of Study.

The last part of the workshop focuses on available extracurricular activities and resources for promoting engineering within the schools. Information will be provided concerning the NCJETS club program and the process of establishing such clubs within their own schools. In addition, as the summer camps utilize competitions, strategies for the effective use of competitions within the classroom and clubs will be presented. Although the research literature is mixed concerning the effectiveness of competitions as an educational tool, competitions have been shown to be useful in promoting student interest in engineering and science[33, 34]. An NSF report examining competitions indicated that the participation rate of girls in competitions was comparable to that of boys[34] and other studies have noted that both genders felt that competitions were enjoyable and integral to the class atmosphere and that competition competency between males and females was similar[35]. Our observations of the summer camps have indicated that coupling collaborative teamwork with the competitions effectively engages all participants in the activities regardless of gender or race.

3.3 Lessons Learned from the 2008 TECT Workshop

The first TECT workshop was held on July 23 -27, 2007 on the campus of the UNC-Charlotte. Eighteen teachers and counselors representing nine high schools from four school districts attended the workshop. The group included four science teachers, four math teachers, four technology education teachers, and six guidance counselors. Participants for the workshop were randomly solicited via an email announcement sent to all STEM teachers and high school guidance counselors in the local area. Nineteen individuals

responded expressing interest in attending the workshop from which the 18 participants were selected. Table 2 provides a breakdown of the group demographics:

Table 2: ***2007 TECT Participant Demographics***

Female	61%
Male	39%
White	56%
African-American	44%
Tenure of service:	2 years to 23 years (median 6.5 years)

To evaluate the effectiveness of the workshop materials, two surveys were administered to the workshop participants. The first was a multi-cultural awareness survey and the second was a perception of engineering survey. The surveys were administered both prior to and at the completion of the workshop in order to assess any changes in attitudes or perceptions created by the workshop. The same surveys were also administered during the one-day workshop follow up meeting held on December 8, 2008 in order to provide a longitudinal perspective of the impact. Preliminary analysis of the survey results indicate that participants' level of awareness concerning engineering was clearly raised, which confirmed anecdotal observations. The guidance counselors in particular reported an increased awareness concerning engineering as most acknowledged having only limited knowledge of the engineering profession and reported being unaware of the breadth of the engineering profession and the many available engineering disciplines. The counselors were especially appreciative that a professional development workshop had been developed addressing the needs of school counseling profession as most workshops are geared exclusively towards STEM teachers.

The teachers were excited about having someone demonstrate the actual math and science behind the engineering activities and many were able to make immediate connections to classroom topics. However, the counselors were much less enthusiastic about the technical content. Although they appreciated the engineering discipline overviews presented and enjoyed the group participation on the projects, they found the rigorous math and science to be overwhelming and irrelevant to their jobs. As a result, the workshop was modified on-the-fly and counselor specific modules developed and delivered that allowed the counselors to break out during the more technical components of the hands-on activities.

All of the participants reported enjoying the hands-on activities, even the counselors who were less interested in the technical content behind the activities. The activities not only helped expose the participants to engineering but created a positive cohesiveness and team synergy among the participants. As the activities were also used to demonstrate effective collaborative learning strategies and practices, participants were divided into groups of three individuals for each of the activities. A deliberate and concerted effort was made to mix and rotate the individuals into different groups for each activity while ensuring that each group contained at least one teacher and one counselor.

The participants enjoyed the opportunity to interact with the students from the summer camps and the teacher practicum with the camps was well received by both TECT participants and summer camp students. TECT workshop participants recommended that even more interaction with the students be planned for future workshops. They suggested holding a joint engineering activity with groups consisting of teachers and students.

Participants were extremely complimentary about the invited industry speaker and the "day in the life of an engineer" presentation. They felt it provided a real life perspective that they could easily relate to. They recommended that an effort be made to include more industry speakers in future workshops, particularly individuals from underrepresented groups that could serve as role models for success.

During the post-workshop follow up meeting, participants returned and reported on their efforts to incorporate engineering related content into their classroom activities. A total of 14 of the original 18 participants were able to return and report. Of the four not attending, two had legitimate excuses, therefore, the effective non-participatory withdraw rate from the project study was 11%. Teachers' reports revealed a wide range of efforts to incorporate engineering in their classrooms. Some attempted extensive hands-on activities either borrowed from the workshop or developed independently while others limited their efforts to discussing engineering ties to classroom topics.

Counselor efforts focused primarily on upgrading their office bulletin boards and resources to include engineering career information. Some made attempts to direct students, particularly females, towards consideration of engineering majors. One example provided was the case of a female student who expressed interest in studying medicine but after learning about biomedical engineering from the counselor, decided to pursue engineering as a major instead. Without the TECT workshop, such an occurrence would have been unlikely as the counselor admittedly knew little about bio-medical engineering prior to attending the workshop.

4. Future Work

Two additional TECT workshops are scheduled for the summer of 2008, one associated with each of the middle school and high school NCJETS summer camps. Prior to the workshops, workshop materials will be revised to reflect the feedback and results generated for the recently completed 2007 workshop. As a proof-of-concept project, the TECT project will be evaluated to determine its potential effectiveness and long-term viability. If the workshop proves effective, strategies for expanding the project and developing its sustainability after NSF funding has expired will be explored. However, pending the results, we believe the integrated mix of diversity awareness based teacher and counselor professional development training and the summer engineering camps will provide a necessary foundation to increase the number and diversity of students entering STEM related fields.

Several initiatives have also been implemented in Phase II to provide additional support to the NCJETS clubs and/or begin the process of anticipating the expiration of external funding and the institutionalizing the program concepts. Specifically,

- The NCJETS website (http://www.ncjets.uncc.edu) has undergone a complete overhaul to make it more user friendly and provide a means by which students and sponsors can get details of competitions, submit required information and forms and keep track of the championship point standing. In addition, a wealth of information is provided for parents and the general public.
- The NCJETS Mentors program will be expanded to provide additional resources and support for middle and high school clubs.
- Corporate sponsorship is currently being sought to ensure institutionalization of the NCJETS program after NSF funding expires. Project personnel are working with the University Development Office to identify sponsors and engage local industry in several aspects of program delivery and funding, as well as ensuring the continuation of the COMETS program.
- Recognition of students and sponsors has been formalized through commendation letters and providing honor cords to all student members to recognize graduation.

The complementary and cohesive natures of the projects at UNC-Charlotte address many concerns with the pursuit of engineering and technology professions and actively engage all stakeholders in the process. Best practices and lessons learned will be incorporated into the expansion of all program concepts into additional rural and inner city high schools, as well as implementing innovative facets of middle school student, parent, teacher and counselor/advisor involvement. In addition, further expansion and solidification of the professional and industry alliance is of utmost importance to ensure sustainability of the projects and institutionalization of project concepts beyond the periods of NSF funding.

5. References

[1] National Science Board, *Science and Engineering Indicators*—2002, http://www.nsf.gov/sbe/srs/seind02/toc.htm

[2] Gibbons, Michael T., "ASEE Profiles of Engineering and Engineering Technology Colleges, 2003 Edition", Downloaded from *http://www.asee.org*

[3] Chubin, D., May, G., and Babco, E., "Diversifying the Engineering Workforce," *Journal of Engineering Education*, Vol. 94, No. 1, pp. 73–86, January 2005

[4] Clark, J.V., *Minorities in Science and Mathematics: A Challenge for Change,* Virginia Parent Information and Resource Center, 2000

[5] Clark, J. V., *Minorities in Science and Math,* ERIC Clearinghouse for Science Mathematics and Environmental Education, ED433216, May, 1999

[6] Blat, C. M. and Tolley, P. A., "Maximizing Academic and Professional Success: Building Student Learning Communities that Lead to Engineering Excellence," *Proceedings of the American Society for Engineering Education National Conference*, Session 3453, Salt Lake City, UT, 2004

[7] Blat, C. M. and Tolley, P. A., "Improving Retention Using Student Learning Communities for Maximizing Academic and Professional Success (MAPS)," American Society of Engineering Education National Conference NSF SUCCEED Pre-Conference Workshop, Albuquerque, NM, 2001

[8] Tolley, P. A., "UNC Charlotte MAPS Program," NSF SUCCEED Best Practices in Mentoring Workshop, Charlotte, NC, 1999

[9] Milbourne, L. A., "Encouraging Girls in Science and Math," *The ERIC Review*, Vol 6, Iss. 2

[10] Symans, M. D., "Introducing Middle School Students to Engineering Principles Using Educational Bridge Design Software, *Journal of Engineering Education*, July 2000

[11] Foundation Coalition, "Women and Underrepresented Minorities," http://coalition.tamu.edu/Zope/wum

[12] Abbitt, J. D. III, and Carroll, B.F., "Applied Aerodynamics Experience for Secondary Science Teachers and Students," *Journal of Engineering Education*, Vol. 82, no. 3, July 1993

[13] Wadia-Fascetti, S. And Leventman, P.G., "E-Mentoring: A Longitudinal Approach to Mentoring Relationships for Women Pursuing Technical Careers," *Journal of Engineering Education,* July, 2000

[14] Adleman, C., *Women and Men of the Engineering Path: A Model for Analysis of Undergraduate Careers,* National Institute of Science Education, May, 1998

[15] The Maui County High School Technology Survey, *Women in Technology,* Maui Economic Development Board, 2001

[16] Career Institute for Education and Workforce Development, *Decisions without Direction: Career Guidance and Decision-Making Among American Youth*, Hurley, D. and Thorp, J. editors, Ferris State University, 2002. http://www.constructmyfuture.com/pdf/dwd_report.pdf

[17] American Association of University Women Educational Foundation, "Shortchanging Girls, Shortchanging America", Washington, D.C., 1991

[18] National Research Council (NRC) Center for Education (CFE); NRC Committee on Science and Mathematics Teacher Preparation (CSMTP), *Educating Teachers of Science, Mathematics, and Technology: New Practices for the New Millennium,* National Academy Press (NAP), 2001

[19] Sadker, M. and Sadker, D., "Failing at Fairness: How America's Schools Cheat Girls", New York: Scribner, 1995

[20] Baum, Eleanor, "Recruiting and Graduating Women: The Underrepresented Student", *IEEE Communications Magazine*, December 1990, pp. 47-50

[21] May, G.S. and Daryl, E.C., "A Retrospective on Undergraduate Engineering Success for Underrepresented Minority Students", *Journal of Engineering Education*, Vol. 93, No. 1, 2003, pp. 1-13

[22] Extraordinary Women Engineers Project, "Extraordinary Women Engineers Final Report, April 2005", National Science Foundation Grant No. EEC-0438810
[23] Zuga, K.F., "Addressing Women's Ways of Knowing to Improve the Technology Education Environment for All Students," *Journal of Technology Education*, Vol. 10, No. 2, 1999, pp. 57-71.
[24] Abbitt, J.D. III, and B.F. Carroll, *Applied Aerodynamics Experience for Secondary Science Teachers and Students,* Journal of Engineering Education, Vol. 82, no. 3, July 1993
[25] Guzzetti, B. and Williams, W., "Gender, Text, and Discussion: Examining Intellectual Safety in the Science Classroom", *Journal of Research in Science Teaching*, Vol. 33, 1996, pp. 5-20
[26] Shakeshaft, C., "Reforming Science Education to Include Girls", *Theory into Practice*, Vol. 34, No. 1, Winter, 1995
[27] Sue, D.W., Arredondo, P., McDavis, R.J. Multicultural Counseling Competencies and Standards: A call to the Profession. *Journal of Counseling and Development, 70*, 477-486, 2002
[28] Busch-Vishniac, I.J. and Jarosz, J.P., "Can Diversity in the Undergraduate Engineering Population be Enhanced through Curricular Change?" *Journal of Women and Minorities in Science and Engineering*, Vol. 10, 2004, pp. 255-281
[29] Eccles, J., "Bringing Young Women into Math and Science," In M. Crawford and M. Gentry, eds, *Gender and Thought: Psychological Perspectives*, New York, NY: Springer-Verlag, 1989
[30] Bottomely, L.J. and Parry, E.A., "Assessment of an Engineering Outreach Program: Hands on Engineering", *Proceedings of the 2002 American Society for Engineering Education Annual Conference and Exposition*, Toronto, Canada
[31] Gilbride, K.A., Kennedy, D.C., Waalen, J.K, and Zywno, M.S., "A Proactive Strategy for Attracting Women into Engineering", *Canadian Journal of Counseling*, Vol. 33, No. 1, 1999, pp. 55-65
[32] Kuyath, S. and Sharer, D., "Summer Camps in Engineering Technology: Lessons Learned", *Proceedings of the 2006 American Society for Engineering Education Annual Conference and Exposition*, Chicago, IL, June 2006
[33] Kimmel, H., Burr-Alexander, L.E., and Bloom, J., "Engineering Design Competitions: A Motivating & Learning Experience", *International Conference on Engineering Education*, October 16-21, 2004, Gainesville, Florida
[34] Somers, L. and Callan, S., "An Examination of Science and Mathematic Competitions", National Science Foundation Grant Report, June 1999
[35] Milto, E., Rogers, C., and Portsmore, M., "Gender Differences in Confidence Levels, Group Interactions, and Feelings about Competition in an Introductory Robotics Course", *32nd ASEE/IEEE Frontiers in Education Conference*, November 6-9, 2002, Boston, MA.

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