TEXAS ENGINEERING PARTNERSHIPS: EXPANDING OPPORTUNITIES FOR WOMEN

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Abstract

According to the Hudson Institute's report Workforce 2020: Work and Workers in the 21st Century, national demographic trends suggest that 62% of those entering the labor force will be women by the year 2005. However, women are not choosing to pursue careers in engineering. In fact, fewer than 20 % of the students studying engineering in college are women.

In response, Texas Woman's University (TWU), Texas Tech University (TTU), and Texas Instruments, Inc., (TI) have created a unique partnership to encourage members of traditionally under-represented populations to pursue graduate degrees in engineering. The partnership supports female and minority students by providing scholarship funds, mentors, internships, and research and travel opportunities. With funding from TI, TWU and TTU have established the Women In eNgineering (WIN) Program. TI currently provides scholarship and internship opportunities that support each WIN scholar through both a B.S. from TWU and an M.S. degree at TTU. In addition, TWU developed a Computer Science, Engineering, and Mathematics Scholars (CSEMS) Program, funded by the National Science

Foundation's Computer Science, Engineering, and Mathematics Scholarships Program (DUE – 0094823 and 0323921) and Texas Instruments, Inc.

Faculty members from TWU and TTU have worked together to develop a rigorous, yet manageable, curriculum that prepares mathematics and computer science undergraduates for a seamless transition into a graduate program in electrical engineering. This paper describes the activities undertaken to date, strengths and lessons learned, as well as future extensions to the partnership.

The Problem

Texas Senator Kay Bailey Hutchison[1] notes that only 62,500 American students graduated with an undergraduate degree in engineering in 2000, while American industry recruited 115,000 engineers from abroad. In fact, the Texas Higher Education Coordinating Board[2] concluded that "*the Coordinating Board and the Legislature should require Texas public colleges and universities to develop and implement plans that will double the number of engineering, computer science, math, and physical science degrees awarded by 2012.*"

According to the Hudson Institute's report[3] Workforce *2020: Work and Workers in the 21st Century*, the latest available national demographic trends suggest that 62% of those entering the labor force will be women by the year 2005. At the same time, the data also show that women are not choosing to pursue careers in engineering and other hard sciences.

In response to similar observations, the National Science Foundation's 2000 Congressional Commission on the Advancement of Women and Minorities and Science, Engineering and Technology Development[4] made the following statement:

> *As we enter the twenty-first century, U. S. jobs are growing most rapidly in areas that require knowledge and skills stemming from a strong grasp of science, engineering, and technology. In some quarters – primarily information technology – business leaders are warning of a critical shortage in skilled American workers that is threatening their ability to compete in the global marketplace.*
>
> *Yet, if women, under-represented minorities, and persons with disabilities were represented in the U. S. science, engineering, and technology (SET) workforce in parity with their percentages in the total workforce population, this shortage could largely be ameliorated*

The American Association of Engineering Societies[5] reports that females currently make up only 20% of students pursuing baccalaureate or graduate degrees in engineering. An abundance of research publications have suggested a variety of reasons for this phenomenon. Many studies, including [6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16], recognize the lack of contact with women and female role models in these disciplines as a barrier to female students. Other studies, including[10, 11, 14, 17, 18, 19], identify male domination of information technology fields and majors, such as engineering, as a factor in the under-representation of women. Others, including[20], stress the need to establish social relevance in order to capture female interest. Several studies, such as[12, 14, 21], suggest internship programs as an intervention and retention tool, while others[22] stress mentoring.

In spite of a wide variety of suggestions on re-mediation and several implementations thereof, the participation rate of women and minorities is not dramatically improving at the undergraduate or graduate level. Clearly there is room to pursue additional avenues. One such possibility is relevant to

TWU. Of particular interest is the fact that women's colleges and universities, and other small to mid-sized institutions, play an important role in the production of bachelor's degrees for this population. Most of these schools however, do not offer engineering degrees. Therefore, one important and almost unexplored way to encourage greater participation of women in graduate engineering programs is to establish a pathway into these programs for students in non-engineering undergraduate programs.

In response to this challenge, Texas Woman's University (TWU), Texas Tech University (TTU), and Texas Instruments, Inc. (TI), have created a unique partnership. Its purpose is to encourage members of traditionally under-represented populations, i.e. females and minorities, to pursue graduate degrees in engineering, specifically electrical engineering. The partnership supports female and minority students by providing scholarship funds, mentors, internships, as well as research and travel opportunities.

A Brief History

Texas Woman's University (TWU), the nation's largest university primarily for women, is a comprehensive state-supported university, located approximately 30 miles north-west of Dallas, Texas. The university serves approximately 9,500 students through a variety of baccalaureate, master's, and Ph.D. programs. Approximately 90% of these students and 78% of the faculty are female. In the Mathematics and Computer Science Department, 57% of faculty members are female. Because TWU serves a primarily female population, it is uniquely suited and obligated to address the challenges of attracting and retaining females in computer science, engineering and mathematics careers.

Students at TWU that major in mathematics or computer science are typical of the university student population. Many are returning students with their associated special needs. Among currently registered undergraduate majors, approximately 82% are female and 44% are racial or ethnic minorities. To address the needs of its unique clientele, the department offers support through tutoring in the lower level mathematics and computer science courses, computer classrooms with appropriate hardware and software to support academic needs, small class sizes, and individual advising. Currently, the faculty to student ratio for the department is less than 20. The smaller classes and close faculty-student relationships provides extra support needed by many students to complete their program of study at TWU.

Texas Tech University (TTU), TWU's partner in the current project, is a comprehensive state-supported university with approximately 25,000 students. The College of Engineering has 9 departments, a current enrollment of approximately 2,300 undergraduate students, 500 graduate students, and 100 faculty members. The Department of Electrical and Computer Engineering currently has approximately 525 undergraduate (B.S.) students and 90 graduate (M.S. and Ph.D.) students, with 21 faculty, 6 staff, and approximately $3.7 million in funded research. About 12% of the graduate students are female and about 13% are minorities. Over 70% of the graduate students are foreign nationals.

Although the department of Electrical and Computer Engineering has been working hard to increase the enrollment of female and minority citizens, it is very difficult to attract these students from bachelor degree engineering programs since they are in great demand in industry. This need led to a joint industry/university program to bring in non-traditional students from other disciplines for a Master of Science in Electrical Engineering or a Master of Engineering degree. The Program for Semiconductor Product Engineering (PSPE), funded by TI, has been highly successful in preparing students from non-

engineering programs to be graduate engineers. More information about this program can be found at http://www.ee.ttu.edu/pspe/.

The current partnership between TTU, TWU, and TI was established in the summer of 2000. Since that time, 5 female students have successfully made the transition from a B.S. in mathematics or computer science at TWU to the M.S.E.E. program at TTU. Three of these students have completed the M.S.E.E. requirements at TTU and two are now employed by TI. Of special note is that three of these students were minorities. Student feedback and observations from faculty are used to identify curricular improvements to the TWU undergraduate program and the TTU graduate program to make the transition easier. Those have now become a primary focus of the TWU, TTU, and TI partnership. Materials developed at TWU will also be beneficial to other mathematics and computer science students, and even non-majors, at TWU.

The Program

The goal of this project is "to provide opportunities ensuring that all students have access to supportive, excellent undergraduate education in science, mathematics, engineering and technology, and all students learn these subjects by direct experience with the methods and processes of inquiry"[23]. The associated objectives of the partnership are

1. To establish scholarship programs to assist women and minority students with the expenses of college at both the undergraduate and graduate levels.
2. To establish mentoring, internship, and support programs that includes faculty members from both universities and industry professionals.
3. To provide a smooth transition from an undergraduate degree in mathematics or computer science at TWU to a graduate degree in engineering at TTU, including visits from TWU to TTU and visa versa, specially designed curriculum materials, and smooth admissions experiences.
4. To develop a model program for (i) undergraduate programs that are unable to offer engineering degrees but would like to offer students the opportunity to enter engineering graduate programs and (ii) for engineering graduate institutions interested in recruiting students from such undergraduate programs.

Objectives #1 and #2 are currently being met through two scholarship programs. In partnership with TI and TTU, TWU has established its **Women In ENgineering (WIN) Program**. TI provides scholarships to each WIN Scholar, as well as internship opportunities while they pursue a B.S. from TWU. It is anticipated that they will continue such funding for them through an M.S.E.E degree. Eight young women are currently in this program at TWU, and three have graduated from the program. Three TWU graduates are receiving funding for advanced engineering studies at TTU. TWU also offers a **Computer Science, Engineering, and Mathematics Scholars (CSEMS) Program,** funded by the National Science Foundation's Computer Science, Engineering, and Mathematics Scholarships Program (NSF DUE #0094823 and #0323921), and with added funding from TI. The CSEMS program is designed to support low-income, academically talented students majoring in any of the three areas at either the undergraduate or graduate level. Thirty-two students are currently funded through this program. Twenty-five (78%) of the CSEMS participants are women, and thirty are undergraduates, with 7 interested in graduate degrees in engineering.

Both scholarship programs provide female mentors and internships through TWU, TTU, TI and the on-line program MentorNet. The programs also provide individual tutoring, career counseling, training in job search skills related to technical careers, and assistance in applying for graduate study. WIN and CSEMS students are required to join departmental student organizations and to attend professional symposiums and conferences. They are also provided organized opportunities to visit industry and academic partners.

The Future

TWU and TTU are currently pursuing Objectives #3 and #4. In order to achieve Objective #3, faculty members from TWU and TTU are working together to develop self-contained engineering tutorial modules designed to supplement traditional courses offered in mathematics and computer science departments. Courses that are standard to most programs in mathematics and computer science programs include Calculus I (Cal I), Calculus II (Cal II), Differential Equations (DE), Digital Logic (DL), and Probability and Statistics I (PS). Self-contained modules will be developed for each of these courses, and will be offered in 2 formats, (i) as in-class material, integrated with and delivered as part of the regular curriculum, or (ii) as on-line student centered, interactive tutorial modules. They will be designed to introduce engineering terminology, concepts, applications and problems within the context of the classroom course. Students will thus have the opportunity to supplement the traditional courses with materials that prepare them for a graduate degree in engineering.

To make the on-line modules as effective and flexible as possible, a variety of approaches are used; most modules include the following elements:

- A concise presentation of the appropriate materials.
- Examples from real life.
- Interactive comprehension questions with immediate feedback interspaced in the text to continuously check the level of understanding.
- Interactive applets to illustrate and/or demonstrate concepts. Appropriate pre-existing applets will be used if possible.
- Comprehensive testing modules.
- Other features include, glossary of terms, frequently asked questions, contact information, links, and instructor feedback.

The rationale for and the design of these modules is based on previous research by Holt and Demuynck [24] of TWU in the context of statistics education (NSF DUE #9972494). Because the modules will be web-based, advantages and disadvantages of using this medium have been considered. References[19, 23, 24, 25, 26, 27, 28] and others, discuss a number of ways in which reaching students through the Internet may enhance the educational process. Initially, two web-based modules will be developed for each course listed above.

In addition, TWU participates in a 15 member consortium on "*The Infinity Project*," funded by a Texas Technology Workforce Development grant. The Infinity Project was established in the fall of 1999 as an innovative national program aimed at increasing the quantity, quality, and diversity of students pursuing engineering and technical degrees. Based at Southern Methodist University (SMU) in Dallas, Texas and supported by TI, the National Science Foundation, and school districts from across the nation, the Infinity Project has created an award winning comprehensive program for grades 9-13 and

has achieved notable success in recruiting and retaining students in electrical engineering (EE) and computer science (CS) programs. A major strength of the program is its innovative curriculum, designed by leading EE and CS faculty from SMU, University of Illinois, Rose-Hulman Institute of Technology, Rice University, Santa Clara University, and George Mason University. This curriculum is based on state-of-the-art classroom technology. University engineering faculty working closely with professional engineers from TI and Hyperception have designed and manufactured the Infinity Technology Kit. This kit converts standard PC's into state of the art engineering design and implementation platforms, and allows students to undertake a wide range of design problems contained in the curriculum – such as the creation of new digital musical instruments, cell phones, and real time video special effects for movies.

TWU has twenty of these kits installed in a computer lab dedicated to students in the department. TWU faculty, in consultation with TTU faculty, will integrate appropriate material from the Infinity Curriculum into existing courses taken by students preparing for graduate studies in engineering as well as other departmental majors. It is anticipated that this material will strengthen those courses, thereby better serving all students in the program. The resulting curriculum will be a part of the model program described in the following discussion of Objective #4.

To achieve Objective #4, faculty members from both universities have begun to analyze curriculum offerings to develop a program design that takes advantage of courses that currently exist at TWU and TTU but offers options that make a smoother transition possible for students entering an engineering graduate program. The final program design will be flexible enough so that it can be adapted and adopted by other teams of graduate and undergraduate institutions interested in admitting students with undergraduate degrees outside of engineering into graduate engineering programs. To best achieve this objective, a leveling program that utilizes the background from the modules developed in Objective #3 with minimum additional graduate course work is needed at the graduate institution.

Faculty members at TTU have developed two graduate level electrical engineering courses used for leveling. These courses meet the requirements of the engineering departments and are within the capabilities of the prospective students. Each course is divided into 3 separate sections, roughly corresponding to an undergraduate engineering course. Specifically, the first course includes basic electric circuits, electronics and digital systems. The second course includes linear circuits and systems, advanced electronics and basic communications. These 2 graduate courses can cover most of the material in 6 undergraduate courses if students have strong mathematics and physics backgrounds. The classes use "hardware homework" to give the students a better understanding of the physical nature of engineering and reinforce basic principles. Of course, 2 graduate level courses are not enough even with the addition of hardware homework. The additional graduate courses the students take are chosen to solidify their engineering background and assure they use basic concepts many times. Thus, in addition to the course development, the curriculum for the Master's degree is tailored to fill in any gaps in the required engineering background.

Industry internships are a very important part of the program. Early in their graduate program, the students work in an engineering environment as an engineer. The student, along with the industrial sponsor and the faculty at TTU and TWU, begin the development of a project they will bring back to school for their Master's thesis.

It is anticipated that enhancements to the undergraduate curriculum described earlier for Objective #3 will provide students at TWU with the knowledge and experiences needed to succeed at TTU. These enhancements will be made to existing courses. At this time, no new courses are planned, but some may be developed in the future as the program is evaluated and refined. TWU students will complete a

standard B. S. degree requiring 124 hours. These students will either major in mathematics with a strong computer science minor or major in computer science with a strong mathematics minor. Students must complete at least 36 hours in the chosen major and 18-24 hours in the minor area. Internships at the undergraduate level may be undertaken in the summer terms after the sophomore year. The program with internships can be completed in four years. Students entering the M.S.E.E. program at TTU can expect to complete the degree, including a 6-hour leveling sequence and an internship at TI, within two years.

Conclusions

TWU and TTU are actively pursuing the objectives described in the previous pages. Faculty members at both institutions are committed to the success of this program. The students from TWU that have begun graduate engineering studies at TTU are providing valuable insights into areas that need to be strengthened so that the students following them will be insured of success. At the conclusion of current activities, the engineering tutorial modules developed will be made available online to any other school that wishes to utilize them. Course materials and the programs designed to support both undergraduate and graduate needs will be published and available to serve as a model for others to follow.

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