TEXAS ENGINEERING PARTNERSHIPS: A MODEL PROGRAM

Melinda Miller Holt[1], Don Edwards[2], and Ron Cox[3]

Abstract *– Texas Woman's University has developed two exciting new opportunities for students interested in pursuing degrees in computer science, engineering, or mathematics. Along with Texas Instruments, Inc., Texas Tech University, Texas A&M University at College Station, and University of Texas at Dallas, TWU has established its Women In ENgineering (WIN) Program. TWU has also initiated its Computer Science, Engineering, and Mathematics Scholars (CSEMS) Program, funded by the National Science Foundation's Computer Science, Engineering, and Mathematics Scholarships Program and Texas Instruments, Inc. Each program is designed to encourage members of traditionally underrepresented populations to earn degrees in one of these fields. Students in both are matched with peer, faculty, and industry mentors. They are also eligible for a variety of industry internships and student assistantships related to their selected major field of study. A brief history of the development of these programs, their goals and objectives, as well as strengths, lessons learned, and plans for the future, will be addressed.*

Index Terms – Academic and industry partnerships, Scholarship programs, Mentoring, Curriculum development.

THE PROBLEM

According to Texas Senator Kay Bailey Hutchison [1], 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."

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 [3] 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.*
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> *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*

In fact, according to the Hudson Institute [4], while demographic trends suggest that 62% of those entering the labor force will be women by the year 2005, they are not choosing to pursue engineering and other sciences. The American Association of Engineering Societies [5] reports that females currently make up only 20% of students pursuing baccalaureate or graduate degrees in engineering. Many studies, including [6]-[16] have recognized the lack of contact with women and female role models in these disciplines as a barrier to participation. Previous studies have also identified male domination of information technology fields and majors, such as engineering, as a factor in the under-representation of women, including [10], [11], [14], [17]-[19]. References [12], [14], and [20] have suggested internship programs as an intervention. Reference [21] stresses the need to establish social relevance in order to capture female interest. In spite of the existence of many of these interventions, the participation rate of women and minorities is not dramatically changing at the undergraduate or graduate level. Clearly additional avenues must be pursued. 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 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 to such programs for students in non-engineering undergraduate programs.

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 of Dallas, Texas. The university serves approximately 9,000 students through a variety of baccalaureate, master's, and

[1] Melinda Miller Holt, Texas Woman's University, Mathematics and Computer Science, P.O. Box 425886, Denton, TX 76204-5886 mholt@twu.edu
[2] Don Edwards, Texas Woman's University, Mathematics and Computer Science, P.O. Box 425886, Denton, TX 76204-5886 dedwards@twu.edu
[3] Ron Cox, Texas Tech University, Electrical and Computer Engineering, P.O. Box 43102, Lubbock, TX 79409-3102 Ron.Cox@coe.ttu.edu

Ph.D. programs. Approximately 90% of these students are female, while females represent 78% of TWU faculty members and 57% of faculty members in the Mathematics and Computer Science Department. 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 to its students 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 provide the extra support many students need to complete their program of study at TWU.

Texas Tech University (TTU), TWU's primary partner in the current project, is a comprehensive state-supported university (including a Law School and Medical School) with approximately 25,000 students. The College of Engineering has 9 departments, a current enrollment of approximately 2300 undergraduate students, 500 graduate students, and 100 faculty. 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. Approximately 12% of the graduate students are female and about 13% are minorities. Over 70% of the graduate students are foreign nationals. Although the department 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 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. This Program for Semiconductor Product Engineering (PSPE) is funded by Texas Instruments, Inc. and has successfully produced a number of graduate engineers for the past 4 years.

TWU's Department of Mathematics and Computer Science has established partnerships with Texas A&M University (TAMU) at College Station and with the University of Texas at Dallas (UTD), through 3+2/Dual Degree Engineering Programs. The 3+2 program with UTD was established in 1988. Students completing this program received a bachelor's degree in mathematics from TWU and a bachelor's degree in electrical engineering from UTD. Several students have completed the program and there are two students who should complete the program in the next year. The Dual Degree program between TWU and TAMU was established in 1996 at a time when both universities were participating in the NSF sponsored Foundation Coalition. The program was modeled after the TWU-UTD 3+2 program. The realization that students would have difficulty in completing the program in five years was the rational for calling it a Dual Degree and not a 3+2 program. Many TWU students have entered the program, but only one has actually moved from TWU to the TAMU campus. The other students entering the program have elected to stop their studies after completing the degree at TWU in mathematics or computer science. Both TAMU and UTD have committed to establishing distance-learning relationships to complement the course offerings at TWU. In addition, each involved university has agreed to host campus visits from TWU students who are considering further education at that institution. Recently these partnerships were extended to include Texas Tech University (TTU). All parties involved in the 3+2/Dual Degree Engineering Program met at the Dallas headquarters of Texas Instruments, Inc. (TI) on July 28, 2000 to design a plan for further expansion and collaboration among university faculty and students. Preliminary discussions focused on areas of concerns with 3+2 programs. Many of these programs seem to become 3+3 programs and it was noted that six years of study leading to a bachelor's and master's degree would better serve the student than two bachelor's degrees. Representatives from TTU described their efforts to provide leveling courses for students with a strong background in mathematics and science that would enable the student to complete a master's program in engineering in two years. It was agreed to explore these possibilities more fully, and this resulted in funding for undergraduate students at TWU interested in the engineering graduate program at TTU. In June 2001, a recent mathematics graduate from TWU entered the TTU graduate engineering program. In September 2001, the first WIN (Women In Engineering) scholars began studies at TWU with financial support from TI. In January 2002, two fall graduates from TWU entered the graduate program at TTU. Input from these students and observations from faculty were used to identify curricular improvements to the TWU undergraduate program and the TTU graduate program, which have now become a primary focus of the TWU, TTU, TI partnership. Materials developed will also support the partnerships with TAMU and UTD.

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 [22]." 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 include 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 undergraduate programs that are unable to offer engineering degrees but would like to offer students the opportunity to enter engineering graduate programs and for engineering graduate institutions interested in recruiting students from such undergraduate programs.

With funding from Texas Instruments and the National Science Foundation's CSEMS program, objective #1 is being met. In partnership with Texas Instruments, Inc. and Texas Tech University, TWU has established its **Women In ENgineering (WIN) Program**. Texas Instruments, Inc. provides scholarships and internship opportunities to each WIN Scholar through a B.S. from TWU and it is anticipated that they will continue such funding through an M.S. degree. Ten young women have now been accepted into this program at TWU. Three TWU graduates are receiving funding for advanced engineering studies at Texas Tech.

TWU has also recently initiated its **Computer Science, Engineering, and Mathematics Scholars (CSEMS) Program**. Twenty-three students are now funded by the National Science Foundation's Computer Science, Engineering, and Mathematics Scholarships Program (NSF DUE #0094823), with matching funds from Texas Instruments, Inc. This program is designed to support low-income, academically talented students majoring in any of the three areas at either the undergraduate or graduate level. Twenty-two of the CSEMS participants are women. Twenty are undergraduates, with 5 interested in graduate degrees in engineering.

Objective #2 is also being met by both scholarship programs through mentors and internships provided by TWU, TTU, TI and the on-line program MentorNet. Students are eligible for a variety of internships and student assistantships related to their selected major field of study. 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 strongly encouraged 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 will work 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). Student centered, interactive tutorial modules will be developed for each of these courses. They will be designed to introduce engineering terminology, concepts, and problems within the context of the classroom course. Students will then have the opportunity to supplement the traditional courses with materials that prepare them for a graduate degree in engineering. Each module includes 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 check the level of understanding.
- interactive applets to illustrate and/or demonstrate statistical concepts. Appropriate pre-existing applets will be used. However, indications are that there is a limited number of applets appropriate for this project; in addition, links to such sites may become invalid at any time. Thus new applets will be developed as needed.
- other features include comprehensive testing modules, glossary of terms, frequently asked questions, and instructor feedback.

As stated above, the modules will provide students with immediate corrective feedback. In addition, feedback will be provided to the instructor in the form of progress reports and results. The project will not include other types of online interactions between students and instructors, such as email, communications on-line chat rooms, etc., since those are already provided at TWU through Blackboard, distance-learning software held by the university. Students will be given the opportunity to contribute and comment on the modules through suggestions, feedback on problems they encounter, news links and examples, and so on. Student employees will be involved in all phases of research, design, development, testing, evaluation and management issues of the project.

The rationale for and the design of these modules is based on previous research by Dr. Holt and Dr. Marie-Anne Demuynck 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] and [23] and others discuss a number of ways in which reaching students through the Internet may enhance the educational process. Some interesting observations and speculations include:

- *Increased independence:* The proposed modules will afford the students a measure of geographical and temporal independence. That is, students will be able to access the modules from any location with an Internet connection and at any time convenient to them. The researchers will carefully design the modules to ensure that students also have a good measure of platform independence; thus, access is not limited to just one type of hardware or software environment.
- *Increased learner control:* Accessing the modules at their own time and at their own convenience gives the students increased control over their learning environment, leading to increased motivation. In addition, the objective of the proposed modules is to leave the student a substantial amount of choice in how to proceed or where to go next. They also will have the opportunity to repeat a module or any section of it as often as they need to without any negative feedback.
- *Increased expectations:* Today's students expect more attention, learning resources, feedback, etc., from their instructors. Interactive web-based modules help in this respect as they provide a student with an additional learning resource and feedback through the interactive testing and frequently asked questions sections. Larger class sizes and higher student-to-teacher ratios decrease the level of interaction between students and teachers, while educational research shows that students, especially females and minorities, learn better with more attention and encouragement from the teacher ([11] and [24]).
- *Increased interest and participation:* There is ample anecdotal evidence to suggest that young students of all backgrounds really enjoy working and learning with computers. As reported by [25], using interactive applets seems to generate a positive reaction from students and result in increased attentiveness, enthusiasm and participation.
- *Increased exposure* to computer applications leads to increased access to careers in high technology, mathematics and science. As [19] strongly recommends, computer science through the curriculum should be used to introduce women and minorities to IT, mathematics and science related career options, instead of the traditional computer games that hold very limited appeal for this population ([19] and [26]). The evidence suggests that increased exposure to computers leads to increased confidence and comfort with computers, and consequently leads to more interest and success in the pursuit of high tech and science careers.
- *Increased flexibility:* is necessary as more and more mature students are returning to college; this population is well represented at TWU. They often have family or work obligations and need to find study time at non-traditional hours. The web-based modules proposed in this project are accessible at any time and thus fit more easily in busy schedules.
- *Increased variety:* Increased participation by traditionally under-represented populations demands more diverse approaches in teaching and learning to accommodate the wider variety in cultural and economic background of the students.

Initially, two web-based modules (Mod 1 and Mod 2) will be developed for each course listed above. A more detailed schedule is presented in Table I below.

TABLE I
TIMELINE – OBJECTIVE #3

Semester	Develop	Evaluate
Fall 2002	Cal I, Mod1	
Spring 2003	Cal I, Mod2	Cal I, Mod1
Summer 2003	Cal II Mod1; Cal II, Mod2	Cal I, Mod2; Cal II Mod1
Fall 2003	DE, Mod1	Cal II, Mod2
Spring 2004	DE, Mod2	DE, Mod1
Summer 2004	DL, Mod1; DL, Mod2	DE, Mod2; DL, Mod1
Fall 2004	PS, Mod1	DL, Mod2
Spring 2005	PS, Mod2	PS, Mod1
Summer 2005		PS, Mod2; Overall

The following paragraphs describe another approach that will be taken in order to support the achievement of Objective #3. Participating as part of a fifteen member consortium of Texas universities, TWU recently received a Texas Technology Workforce Development Grant titled ***Launching the Texas Engineering Education Pipeline: Deploying The Infinity Project Statewide.*** 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 Texas Instruments, 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 that 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 Texas Instruments 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 ordered twenty of these kits, which will be 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 will formally analyze curriculum offerings and suggest 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. This program will be designed to be applicable to other undergraduate institutions that prepare traditionally under-represented groups and other graduate programs interested in admitting students with undergraduate degrees outside of engineering. This objective means establishing a leveling program that utilizes the background from the modules developed in Objective #3 with minimum additional graduate course work that will allow non-traditional students to enter into a specific graduate engineering program.

Two graduate level electrical engineering courses will be developed as a test case. These courses must meet the requirements of the engineering departments and be within the capabilities of the prospective students. Each course will be divided into 3 separate sections, roughly corresponding to an undergraduate engineering course. Specifically, the first course will include 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. However, simply covering the material one time is not enough to provide the necessary learning experience. The classes will also 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 will be tailored to fill in any gaps in the required engineering background. Table II contains the timeline for achieving objective #4.

TABLE II
TIMELINE – OBJECTIVE #4

Semester	Course 1	Course 2
Fall 2002	Sec 1, Sec 2	
Spring 2003	Sec 2, Sec 3	
Summer 2003	Teach (1st time)	
Fall 2003	Evaluate/refine	
Spring 2004	Evaluate/refine	Sec 1, Sec 2
Summer 2004	Evaluate/refine	Sec 2, Sec 3
Fall 2004	Evaluate/refine	Teach (1st time)
Spring 2005	Evaluate/refine	Evaluate/refine
Summer 2005	Evaluate/refine	Evaluate/refine

A very important part of the program is an internship, in industry whenever possible. During these first semesters, the student will work in an engineering environment as an engineer. While interning, the student, along with the industrial sponsor and the faculty at TTU and TWU, will begin the development of a thesis project that 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. There is an existing course, focused on women's issues, that provides an introduction to engineering. Students in the program are expected to take this course to satisfy their TWU women's studies core curriculum requirement.

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 MSEE program at TTU can expect to complete the degree, including a 6-hour leveling sequence and an internship at Texas Instruments, 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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