AC 2011-2078: CATALYZING AND SUPPORTING MINORITY TALENT DEVELOPMENT IN STEM FIELDS: AN STRUCTURED MENTORING MODEL TO INSPIRE YOUNG ENGINEERING MINDS

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Catalyzing and Supporting Minority Talent Development in STEM fields: A Structured Mentoring Model to Inspire Young Engineering Minds

Abstract

The identification and development of science minority talent is important for the future vitality of scientific research. This development is essential because demographic trends show that in the next 20 years minorities will constitute an increasing portion of the US population, especially in the pool of potential college students. Despite the growing number of STEM careers in the American economy, education statistics suggest that far too few Hispanic students are being encouraged and enabled to take advantage of opportunities in technical disciplines. According to national statistics, Hispanics are not only the largest minority in the United States but also one of the fastest growing.

This paper describes the ***Catalyzing and Supporting Minority Talent Development*** model developed to attract and retain minority students in STEM related fields. The proposed model spans the educational engineering spectrum, impacting high school students and teachers, undergraduate and graduate students through structured education, research and mentoring activities. The main components of the present model are:

1) Teaching Teachers to Teach Engineering (T^3E) program
2) Peer Undergraduate Mentoring Program (PUMP)
3) Optimization Models for Engineering Research Class
4) Summer Research Experiences for Undergraduates in Engineering Optimization
5) Speaker Seminar Series & Graduate School Seminar

First, through the participation of high school teachers in the ***Teaching Teachers to Teach Engineering (T^3E) program***, teachers benefit by having a tested set of standards-based curricula to take back into their classrooms, coupled with the confidence of having learned how to teach engineering content. Secondly, through the ***Peer Undergraduate Mentoring Program (PUMP)***, sophomore students are able to be part of a supportive peer environment, in which a sense of belonging, and a exposure to role models facilitate their growth and development as engineers. Thirdly, through the development of the new ***Optimization Models for Engineering Research Class***, students are introduced to mathematical thinking and optimization modeling. A strong emphasis is given to learning optimization software. Additionally, a requirement for this class is that students are involved in research projects with applications in some of our College of Engineering strategic areas such as Sustainability Engineering, Border Security, Energy Sustainability, and Biomedical Engineering. Through the ***Summer Research Experiences for Undergraduates in Engineering Optimization***, students acquire a variety of research skills and participate in a research project. Finally, through attendance to the ***Speaker Seminar Series*** and the ***Graduate School Seminar*** students gain an understanding of the expectations, demands, role requirements, and necessary strategies within research as an academic profession. The ultimate goal of these structured seminar series is to generate student interest in graduate school.

Two main types of evaluations are used to ensure that the key objectives of this work are met: *1) formative evaluations* are used to provide continuous feedback on whether our initial stated objectives are met or not, and *2) summative evaluations* are used to measure how effectively the proposed model accomplished its stated goals.

1. Introduction

America has long been innovation's home, and its wellspring is education. To Americans, innovation means much more than the latest gadget. It means creating a more productive, prosperous, mobile and healthy society. Innovation fuels our way of life and improves our quality of life. Billions of new competitors are challenging America's economic leadership. In this competitive world, knowledge of math and science is paramount. According to the Bureau of Labor Statistics, jobs requiring science, *engineering* or technical training will increase by more than 24 percent by 2014 to 6.3 million [1]. U.S. manufacturing will no longer employ millions in lowskilled jobs. Tomorrow's jobs will go to those with education in science, *engineering*, and mathematics and to high-skilled technical workers. Such a workforce is an important key to future growth, productivity, and competitiveness [2].

The identification and development of science minority talent is important for the future vitality of scientific research. This development is essential because demographic trends show that in the next 20 years minorities will constitute an increasing portion of the US population, especially in the pool of potential college students. Furthermore, increasing the participation of minorities in the sciences, engineering and math fields is also a matter of fairness. Despite the growing number of STEM careers in the American economy, education statistics suggest that far too few Hispanic students are being encouraged and equipped to take advantage of opportunities in technical disciplines. According to national statistics, Hispanics are not only the largest minority in the United States but also one of the fastest growing [3-5].

In the present paper, the ***Catalyzing and Supporting Minority Talent Development*** model is presented, it is based on an integration of proven engineering education models, undergraduate research experiences, and structured mentoring that will increase the number of underrepresented students that ultimately earn an engineering degree within our region students.

Specifically, **this model addresses four distinct engineering education goals**, namely

1. Teaching high school teachers to teach engineering
2. Providing sophomore students with the opportunity to be part of a peer support group
3. Increase the number of underrepresented students involved in undergraduate research experiences, and
4. Providing students with the tools to successfully complete graduate research by providing training during undergraduate research.

Addressing **these four goals should lead to four important outcomes**, as illustrated in Figure 1. First and foremost, through the participation of high school teachers in the ***Teaching Teachers to Teach Engineering (T^3E) program***, teachers will benefit by having a tested set of standards-based curricula to take back into their classrooms, coupled with the confidence of having learned how to teach engineering content. Once back in their individual classrooms, teachers will not only enhance learning but will be able to excite students and stimulate interest in engineering careers.

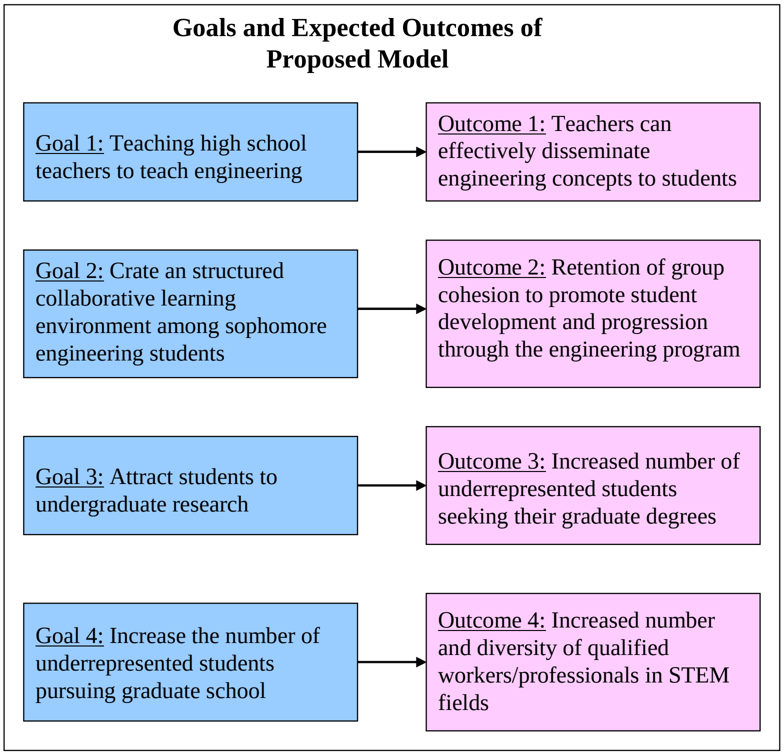

Figure 1. Goals and the Expected Outcomes for the *Catalyzing and Supporting Minority Talent Development* to promote an engineering continuum among underrepresented students

Secondly, through the ***Peer Undergraduate Mentoring Program (PUMP)***, sophomore students will be able to be part of a supportive peer environment, in which a sense of belonging, and a exposure to role models will facilitate their growth and development as engineers. Thirdly, through the development of the new ***Engineering Modeling Research class***, students will be taught several state-of-the-art mathematical and metaheuristic optimization approaches and will be trained in the use of optimization software. Optimization models can be applied in diverse STEM fields and thus, students will have the potential to participate in several projects requiring optimization methods to solve real life engineering problems. Additionally, through the ***Summer Research Experiences for Undergraduates in Engineering Optimization***, students will acquire a variety of research skills and experiences. Participants in this project will work directly with at least one existing research project. Lastly, students through attendance to the ***Speaker Seminar Series*** and the ***Graduate School Seminar*** will gain an understanding of the expectations, demands, role requirements, and necessary strategies within research as an academic profession. Ultimately, these structured seminar series will generate student interest in pursuing graduate studies.

2. Model Description

The ***Catalyzing and Supporting Minority Talent Development model*** will be implemented at our university to ignite student's interest in the Engineering field more specifically in the application of optimization models. The project will build on the experience and the infrastructure surrounding undergraduate research participation and ongoing research to accomplish each of the aforementioned goals of this project.

As shown in Figure 2, the main components of the proposed model are *1*) Teaching Teachers to Teach Engineering (T^3E) program, *2*) Peer Undergraduate Mentoring Program (PUMP), *3*) Engineering Modeling Research class, *4*) Summer Research Experiences for Undergraduates in Engineering Optimization and, *5)* Speaker Seminar Series and Graduate School Seminar. A detailed explanation of each of the main components of the model are presented next.

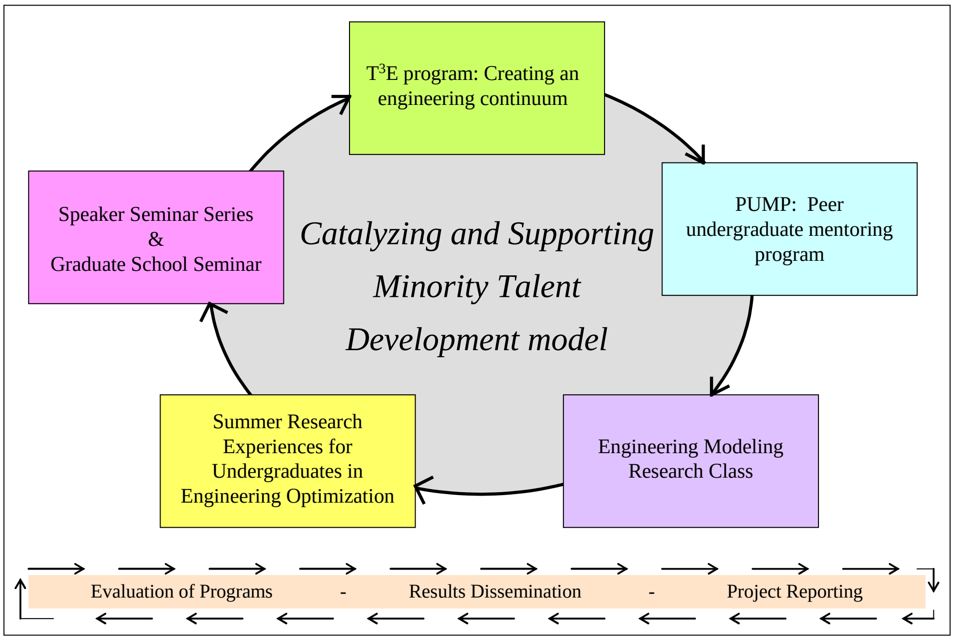

Figure 2. Main components of the *Catalyzing and Supporting Minority Talent Development* model

2.1. Teaching Teachers to Teach Engineering (T^3E) program: *creating an engineering continuum* **-** Previous research indicates that hands-on learning experiences for teachers as well as for students offer a valuable, real-life instructional method for learning engineering, especially when it imitates authentic engineering practice [6,7]. Therefore, in the present model a workshop for teaching high school teachers to teach engineering will be developed.

The workshop will be entitled: "*Practical Mathematical Models with Engineering Applications.*" This model will promote promising, research-based practices in engineering instruction and prepare students for more rigorous math course work at high schools. It will mainly focus in real-world engineering optimization applications and it will be designed to transmit teachers the knowledge they need to become classroom advocates of engineering fields. The products that will be developed under the present model are complete handouts including (*i*) student activities, (*ii*) classroom modules, extensions, and homeworks and, (*iii*) teachers handouts.

Every summer, 10 teachers will be selected to participate in the *Practical Mathematical Models with Engineering Applications* workshop; programs such as the T^3E provide an excellent opportunity for allowing high school teachers to benefit from institutions of higher education.

Such events are among the few channels through which educational research will transfer into the mainstream on a timely basis. Another advantage of this type of workshops is that by working with university faculty, the teachers will be able to use their own pedagogical knowledge to aid their content learning and overcome apprehensions associated with the prospect of teaching engineering in their classrooms. It should also be mentioned that all activities are designed to be exportable (inexpensive and simple) to facilitate the transfer.

2.2. Peer Undergraduate Mentoring Program (PUMP) - The objectives of the proposed Peer Undergraduate Mentoring Program are to create a supportive peer environment, a sense of belonging, and exposure to role models to facilitate their growth and development as engineers. PUMP is a pilot program for sophomore students enrolled in Industrial Engineering and Mechanical Engineering. This program consists of two key elements, *Sophomore Cohort* and *Senior-2-Sophomore Mentoring*, to provide resources, information, encouragement, and support. Each component is described below.

Sophomore Cohort – Students who have declared either Industrial Engineering or Mechanical Engineering as their major will be invited to participate in PUMP. There will be twenty slots for this pilot program every year. The students will be divided into cohorts of 5 students based on their major and other similarities in their background (age, work, family obligations, etc.). There will be a special emphasis on creating at least one all-female cohort. These cohorts will form an structured collaborative learning and support system that will meet throughout the academic year to further develop their math skills, communication skills, and team skills, which ABET wants instilled into students. Placing students in groups where others have similar academic and outside obligations will provide an environment that can truly understand the obstacles they are facing and provide encouragement and support to continue working on their studies.

The cohorts will also receive additional support through structured professional, educational, and developmental activities throughout the year. Most notable will be the *Senior-2-Sophomore Mentoring*, which is described in the next section. The cohorts will also be involved in case studies, resume writing, mock interviews, and advising for coop/internships, study abroad opportunities, and undergraduate research. Throughout the academic year, the students will be expected to have a minimum GPA of 2.5.

Senior-2-Sophomore Mentoring – The Sophomore Cohorts will be paired with a trained engineering minority senior, who will serve as a role model and as an information resource to help students take full advantage of our university's services and opportunities [8,9]. The senior student will meet with the cohort at least twice a month. During their meetings, seniors will work with students to develop their academic skills such as studying from class to class, prepping for lectures, effective use of professors, changing attitudes concerning asking for help and avoidance of areas of weaknesses [10,11]. The female cohort will receive additional mentoring from female faculty to address issues facing entering and succeeding in engineering as a woman while balancing professional interests, community engagement, children and partners, and time for themselves so that they can have it all.

Benefits of PUMP – This model is beneficial for both the mentees and the mentors. The mentees will develop a learning community of supportive fellow students, improved communication and teamwork skills, and will be ready to transition into their majors from their Basic Engineering courses. The mentors who will be trained by UTEP's Center for Effective Teaching and Learning (CETaL), will have increased confidence and experience in leading a team and improved communication skills [12].

2.3. *Curricula Development: Engineering Modeling Research class* - According to The Engineer of 2020 [13], to maintain the nation's economic competitiveness and improve the quality of life for people around the world, engineering educators and curriculum developers must anticipate dramatic changes in engineering practice and adapt their programs accordingly. This project will design new curricula based on the current national needs. Through this initiative, we plan to develop one new course to teach students the current state-of-the-art in mathematical optimization models applied to a broad range of engineering problems as well as the use of optimization software such as CPLEX® to solve them.

In the new class developed, computational implementation and experimentation which is an intriguing and challenging approach will be used extensively in teaching students important skills for solving real world optimization problems. Our students will experience that real problems are not in any single domain but they cross boundaries of several domains, not only among pure engineering disciplines but between engineering, business and science, etc. Thus, this project will cover material that demonstrates the intersection of design optimization, manufacturing, sustainability aspects, and biomedical engineering, among others. As a result, the students will be trained with such a rich multidisciplinary knowledge that will allow them to have excellent career opportunities.

During the fall 2010 semester, the team will develop the new course where different topics related with mathematical optimization such as linear programming, integer programming, decision making and metaheuristic optimization will be covered. The course is intended to be offered as a technical elective course for junior/senior year students. The undergraduate course is expected to be taught for first time in spring 2011 semester and then offered every other semester. The newly developed undergraduate course will be offered as a technical elective course to all engineering students.

***2.4. Research Experience for Undergraduates* –** Recent studies have demonstrated the importance of undergraduate research [14,15] in the retention of diverse students in fields in which they are underrepresented and in students' pursuit of graduate education [16,17].

The students in this program will be recruited from those in the *Optimization Models for Engineering Research course*. The summer research will provide undergraduate students an opportunity to conduct full-time research under the supervision of a faculty member from the Industrial or Mechanical Engineering Departments. The experiences will:

- Provide mentoring to participating students and encourage their enrollment in graduate school;
- Improve student confidence and communication skills through oral and written presentations of project results;
- Encourage student participation at national and regional conferences

The research program will sponsor fifteen students every summer who will work full-time over a six-week period. Each PI will open their laboratory to the undergraduates during the summer. The students will be divided into teams and split into the different laboratories. In the laboratories, the students will be paired with a graduate student following the Pair-2-Learn (PAL) model.

Pair-2-learn (PAL) model - Four undergraduate students will be “paired” with one graduate student to work in a research project; the graduate students will be trained by the Center for Effective Teaching and Learning (CETaL) at UTEP before they start working with undergraduate students. The graduate student will be the project leader while the undergraduate students will help in achieving the research tasks. The students involved in the research will participate in conferences, give poster presentations, and publish conference papers. This will instill a sense of pride and will engage them in graduate studies. In addition, they will have the opportunity to network with students from other academic institutions.

***2.5. Seminar Series* -** This component will consist of three types of seminars, research presentations from outside researchers, research presentations from UTEP graduate students, such as the ones depicted in Figure 4, and graduate information presentations given by the PIs. The objectives of these seminars are to increase the number of underrepresented students 1) seeking to participate in undergraduate research experiences, 2) applying for graduate studies and fellowships, and 3) pursuing careers in STEM research fields.

3. Evaluation Plans

Three types of evaluations will be performed during the present project to ensure that we are meeting the key objectives of this project: *1) formative evaluations* which will be used to provide us with continuous feedback on whether we are meeting our objectives and *2) summative evaluations* will be used to measure how effectively the program has accomplished its stated goals, and *3) Performance Measures* to assess student retention and changes in the number of full-time, degree-seeking minority undergraduate students in the Industrial Engineering and Mechanical Engineering department.

The main components of the proposed model [*a)* teaching teachers to teach engineering program, *b)* peer undergraduate mentoring program, *c)* a new engineering modeling research class, *d)* seminar series and *e)* summer research experiences for undergraduates] will be evaluated using formative and summative evaluations to assure that we are achieving the stated goals in each of the different components.

1) Formative Evaluation - Qualitative research techniques (peer review of curriculum materials, student interviews and student group interviews) will be used for formative evaluation purposes. These techniques have the advantage of providing detailed descriptive information which is useful for project improvement purposes.

<u>*Peer review of curriculum materials*</u> - This project will result in the development of diverse curricular materials (class modules, laboratory exercises, and research projects). At least two external experts in the field of Engineering Education from the Center for Effective Teaching

and Learning at UTEP will review the developed materials and revisions will be made based on their recommendations.

<u>*Individual interviews*</u> - The instructional materials developed will be pilot-tested in the Spring 2011 semester. At the end of the semester, ten randomly selected students will be interviewed. This interview will focus on their experiences with the instructional materials and how these experiences influenced their future educational goals and decisions. The individual interviews will allow the investigators to acquire a detailed understanding of students' experiences with the instructional materials.

<u>*Group interviews*</u> - Students not selected for individual interviews will participate in student focus group activities. Questions asked in the focus groups will be the same as those asked during the individual interviews. The focus group activity will ensure every student has an opportunity to express his/her viewpoint.

2) Summative Evaluation- The Kirkpatrick Model [18-20] as shown in Figure 5, will be used for the summative evaluation. It is a four-level model of evaluation. Level one measures participant reaction. Level two measures new learning. Level three measures behaviors in the real world and, level four measures the results.

<u>*Level One: Reaction*</u> – Participating undergraduate students at the beginning and end of the semester will complete an attitudes survey. This survey will help to determine whether students' participation in their engineering modeling research has further stimulated their interest in pursuing a higher degree in engineering.

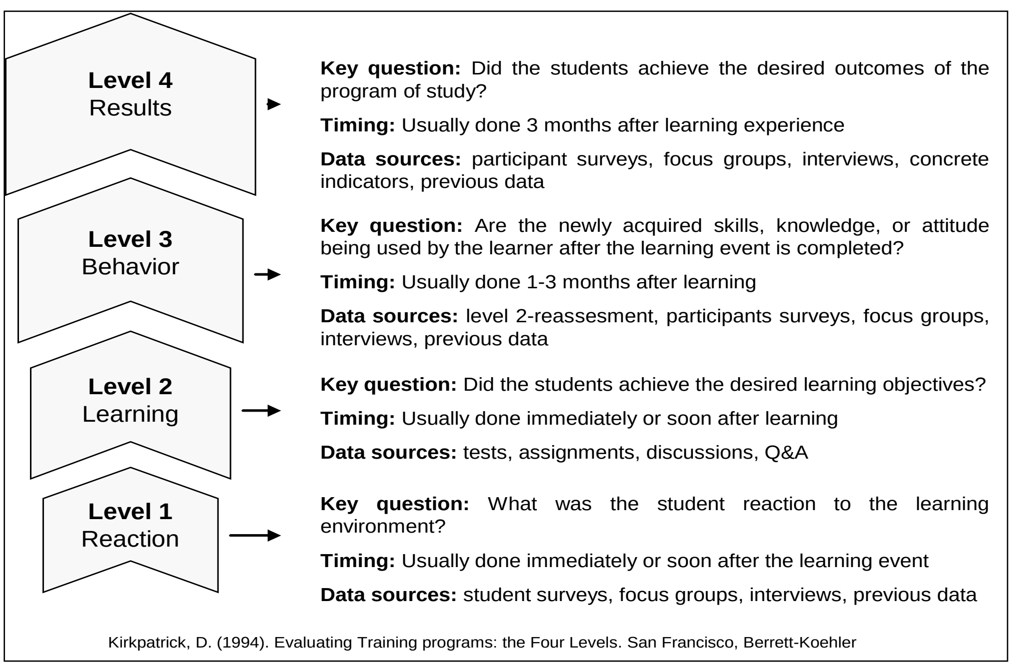

Figure 5. Kirkpatrick's Four Levels of Evaluation

Level Two: Learning - Through a collaborative effort between the investigators a pretest/posttest assessment instrument will be developed. The resultant instrument will be included in the expert review that was described in the formative section of this proposal.

Level Three: Behavior - This measure will evaluate student retention of research skills covered in the new engineering modeling research. This evaluation will be completed three months after the course, specifically during the summer research experience.

Level Four: Results (Retention statistics) - The number of students that select to continue to pursue an Engineering graduate degree will be recorded. This data will suggest whether the newly developed course contributes to student retention.

4. Conclusions

This paper presents the deveopment of "The Catalyzing and Supporting Minority Talent Development" model which is to be implemented over the course of a three-year period at our university. The main components of the proposed model are (*1*) Teaching Teachers to Teach Engineering (T^3E) program, *2*) Peer Undergraduate Mentoring Program (PUMP), *3*) Engineering Modeling Research class, *4*) Summer Research Experiences for Undergraduates in Engineering Optimization and, *5)* Speaker Seminar Series and Graduate School Seminar). The model is to be evaluated using different formative and summative evaluations, results will be documented and presented in forthcoming conferences.

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