Targeted Infusion Project: Implementation of a Bioengineering Concentration in the Department of Chemical Engineering at Prairie View A&M University

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ABSTRACT

With the emergence of newer technologies, many of which are steeped deeply in chemical engineering principles, the chemical engineering profession has witnessed an increased decline in the number of students choosing it as a field of study. To address this issue, many chemical engineering programs have updated their curricula to reflect the emergence of biotechnology and nanotechnology, as chemical engineering is a natural fit. Hence, a number of chemical engineering departments have changed their names and curricula to reflect a shared focus on biology and chemistry, while others see fit to maintain their original name and have "bio-"concentrations/tracks or offer a biochemical degree within the chemical engineering department [1]. Consistent with these trends, the Department of Chemical Engineering at Prairie View A&M University has initiated steps to implement a bioengineering concentration as a option within its program. These efforts were supported using funding from the National Science Foundation HBCU-UP Targeted Infusion Program. This paper presents an overview of the accomplishment-to date of this project, future work and lessons learned.

INTRODUCTION & BACKGROUND

The engineering profession is currently facing an unprecedented array of external and internal pressures. It is becoming more complex, with traditional disciplinary boundaries blurring or disappearing; thus, graduates in any engineering discipline may find themselves working in emerging fields e.g. biotechnology and nanotechnology. As a result, graduates are under increasing pressure to have knowledge in these emerging areas. Engineering programs are in the precarious position of adapting to meet the continuously changing workforce needs in order to graduate students whose knowledge is relevant to the 21st century marketplace.

The demand for a continuous supply of highly trained scientists and engineers continues to serve as one of the most formidable issues facing our nation. Despite the increasing demand, the number of engineering degrees awarded over the next decade is projected to remain relatively stagnant [2], thus, severely hampering national efforts to meet the needs of the US technological workforce. Nationally, there is a growing consensus among leaders in the scientific and engineering communities that if we are to meet the ever increasing demand for a highly skilled workforce, it is necessary to tap the underutilized pipeline and increase the numbers of minorities who are interested in pursuing and graduating with degrees in engineering and technology.

With the daily advances in biotechnology, the increasing importance of nanotechnology and exponential demand for a more skilled biotech/nanotech workforce, many universities are updating their curriculum in order to graduate students better prepared to enter and compete in the new global marketplace. With the emergence of newer technologies, many of which are steeped deeply in chemical engineering principles, the chemical engineering profession has

witnessed a decline in the number of students choosing it as a field of study [1-3]. Whereas there are a number of factors that contribute to the enrollment decline, the shift of students who would normally pursue careers in chemical engineering degrees to bio-related departments (i.e. biomedical, biological, bioengineering, etc.) has had a significant impact [3]. To address this issue, many chemical engineering programs have changed their names and updated their curriculum to reflect the shared focus on biology and engineering. Hence, a number of prominent chemical engineering departments have changed their names and curricula, while others see fit to maintain their original name and have "bio-"concentrations/tracks or offer a biochemical degree within the chemical engineering department [1]. Previously, this list contained only one Historically Black College or University (HBCU) with a department name change and one with a bio-related track.

Worldwide, the fastest growing global biotechnology marketplace includes approximately 4300 companies in 25 nations with revenues estimated at over $40 billion [5]. The biotechnology industry clusters have identified workforce development as the second or third largest hurdle to commercialization and economic success [6]. Hence, the survival, maturation and success of the biotechnology industry is ultimately linked to the ability to not only hire and retain a workforce that possesses skills and fundamental knowledge in traditional areas of biochemistry, molecular biology, pharmacology, engineering and chemistry, but also the ability to apply this knowledge to solve fundamental nano-scaled and bioengineering problems. Given the daily advances in biotechnology, the increasing importance of nanotechnology and exponential demand for a more skilled biotech/nanotech workforce, it is imperative that university curricula are reflective of market shifts (while maintaining fundamental principles) in order to graduate students better prepared to enter and compete in the new global marketplace.

HBCU's continue to contribute significantly to the overall number of minority students exiting the engineering pipeline despite limited federal support [7]. Often, they are unable to respond quickly and implement curriculum changes that focus on emerging technologies. Further, faculty at many HBCUs developed their research focus before the evolution of biotechnology and transitioning to new research areas, particularly with the high teaching loads and lack of facility infrastructure, can be quite challenging if not impossible. Currently, there are twelve (12) HBCUs that have engineering programs accredited by the Accreditation Board for Engineering and Technology (ABET), yet only six (6) have chemical engineering programs. With the ever growing emphasis on the synergy between biology and engineering and the recognized significance of HBCU's to the engineering pipeline, increasing the number of bioengineering programs at minority serving institutions is necessary if the science and technology community are to meet the ever growing needs of the biotechnology and nanotechnology workforce.

The National Science Foundation (NSF) has developed a cadre of programs to assist minority serving institutions to meet the scientific and technological needs of the US workforce. One such program is the Historically Black Colleges and Universities Undergraduate Program (HBCU-UP). "This program provides awards to enhance the quality of undergraduate science, technology, engineering, and mathematics (STEM) education and research at HBCUs as a means to broaden participation in the Nation's STEM workforce" [8] In 2005, The NSF expanded the HBCU-UP solicitation to include two additional funding opportunities: Education Research Project and Targeted Infusion Project (TIP). The TIP program provides awards to

"achieve a short-term, well-defined goal to improve the quality of undergraduate STEM education such as specialized accreditation or certifications, establishing new programs or concentrations, establishing collaborations between STEM disciplines and teacher education programs, and updating programs to reflect advances in the field and workforce requirements" [8].

The Department of Chemical Engineering at PVAMU is one of only six chemical engineering programs at an HBCU. The department offered a Bachelor of Science in Chemical Engineering (B.S.Ch.E.) degree. Of the six institutions, only two programs have updated their curricula to reflect the shared focus on biology and engineering. Florida A&M University (FAMU), a public institution, has changed its name to the Department of Chemical and Biomedical Engineering and Tuskegee University, a private institution, has added concentrations to its curriculum. For more than 20 years, PVAMU Chemical Engineering (ChE) has graduated students well-trained and prepared to enter the engineering workforce and/or pursue further studies in graduate school in the traditional areas of ChE. With the ever growing emphasis on the synergy between biology and engineering, it is paramount that PVAMU also update its curriculum in order to remain competitive and be a major contributor to the biotechnology workforce. Based on thoughtful consideration of the future technological and scientific needs of the department, US workforce, and the profession in general, the faculty concluded that it is paramount our educational efforts align with the skills and knowledge relevant to our nation's needs. If bio-nanotechnology is the way of the future then, the need to be prepared cannot be over emphasized.

Over the past seven years, the department has made strategic efforts to expand its capabilities in the bioengineering area. Prior to this period, the department was comprised of five (5) faculty members, whose area of expertise was tertiary oil recovery, engineering optimization, and process safety. In 2001 and 2003, two new faculty members were hired to support the department's shift in focus and expand the academic and research capabilities in biotechnology. With the addition of the new faculty members, the department was able to initiate curriculum updates and increase student interest in course and research opportunities in this area. However, to make the required academic modifications, the faculty quickly recognized that financial support was necessary to achieve any significant changes. In 2006, the department applied for and was subsequently awarded the NSF Targeted Infusion Grant to develop a bioengineering concentration in the Department of Chemical Engineering. The objective of this paper is to discuss the steps that guided the implementation of this award, developing a bioengineering concentration in the Department of Chemical Engineering.

GOALS AND OBJECTIVES

The overarching mission of the TIP is to: to provide an intellectually rigorous undergraduate educational program that emphasizes fundamental engineering and life sciences and that will prepare students to pursue further education in bioengineering or successful careers in businesses related to various bioengineering industries. To achieve our mission, the **goal** of this project is to *transform the chemical engineering program at Prairie View A & M University (PVAMU) in order to better prepare students for careers and/or graduate study in nanoscaled bioengineering.* The specific *objective* of the project is to: establish a bioengineering concentration within the Department of Chemical Engineering.

PROJECT ACTIVITIES

Prior Works

In the five years prior to the TIP funding, the department had initiated several key steps to facilitate the transition into this new emerging technology. The initiatives included: (1) strategic recruiting of faculty whose area of expertise was in biotechnology, (2) providing start-up funds, although very limited, to support their research activities, and (3) introduction of a new course under the "Special Topics" label aimed at increasing student interest. The facility infrastructure to conduct biotechnology research was limited. To increase research capabilities in this area, the faculty applied for external financial support through the National Science Foundation Major Research Instrumentation Program. In 2005, a the department was awarded a MRI: Award Abstract #0421287 entitled: *Acquisition of Research Instrumentation for Applied Research and Training in Biotechnology and Bioprocess Engineering* , A special topics course, Introduction to Biotechnology and Bioprocess Engineering, was developed and first offered as a technical elective in 2002. Table 1 outlines the growth in student interest as reflected in the continued growth in student enrollment in the semesters the course was offered.

Table 1. Course Enrollments

Activity	Course Number	2007	2006	2005	2004	2003	2002
Intro to Biotechnology & Bioprocess Engineering*	CHEG 4103	-	-	13	9	-	10
Bioengineering	CHEG 4153	10	N/A	N/A	N/A	N/A	N/A

The equipment purchased with the MRI grant allowed the department to increase the number of undergraduate research opportunities and thus increase student interest in bio-related topics as demonstrated in Table 2. Additionally, the increased infrastructure positioned the department to partner with other larger institutions (i.e. University of Kansas, University of Iowa, University of California-Berkeley, Harvard, etc.) and successfully secure NSF funding of two (2) Engineering Research Centers: the Center for the Environmentally Beneficial Catalysis (CEBC) and the Synthetic Biology Engineering Research Center (SynBERC).

Given these strategic moves, the department began to examine the chemical engineering curriculum to assess how to implement further expansion of the curriculum in support of biotechnology. The following descriptions show how the department was able to build on prior success coupled with the TIP award to successfully implement a "new" bioengineering option within the Department of Chemical Engineering.

Proposed TIP Activities

The project activities that were proposed for the TIP project were designed to allow the department to strategically analyze its current curriculum and craft a bioengineering concentration that would provide the theoretical background students would need in order to be successful and to compete in the current biotechnology marketplace. The project activities included the following.

1. Petitioning for course and curriculum approvals.

2. Restructuring of the chemical engineering curriculum to reflect the bioengineering option.
3. Development of new courses and laboratory experiments.
4. Development supplemental materials for existing chemical engineering course.
5. Increased research opportunities and exposure to bioengineering principles for undergraduate.

Restructuring of Chemical Engineering Curriculum

The current chemical engineering curriculum is designed to prepare engineers who are well qualified to design and operate chemical processes. The undergraduate baccalaureate degree required that students complete 135 hours, of which 20 hours of chemistry and 41 hours of chemical engineering specific courses. The bioengineering option requires that students complete 20 hours of course materials, of which 17 hours are integrated into the current curriculum, specific to bioengineering concepts, which are spread amongst the current chemistry and chemical engineering requirements, as detailed in Table 3 below. The courses were selected to build the students knowledge, skills, and expertise in basic fundamental bioengineering concepts. Students choosing the bioengineering option will thus complete 138 hours for the B.S.Ch.E degree. Additionally, bioengineering concepts are being vertically and horizontally integrated throughout the chemical engineering curriculum. The concentration requirements were constructed by examining other programs with bio-related options [9-10]. Hence, the requirements are aligned with programs at other national and regional universities of similar and larger size and comparable mission statements. The course requirements are as follow (Table 3).

Table 3. Course Requirements for Bioengineering Option

Courses	Hours
Biology	**3**
Biochemistry	**3**
Biochemistry Lab	**2**
Bioengineering Technical Elective (2 courses)	**6**
Senior Design I & II (Bioengineering project)	**6**
Total Hours	**20**

Concentration Approval

Once the above curriculum requirements were outlined and received approval from its entire faculty, the department moved forward to secure approval of the concentration through the process outlined by the university. To establish a concentration at PVAMU, the department must first receive approval of any curricula changes from the requesting College Curriculum Review Committee (CRC). Once approved by the CRC, the department must then submit necessary paperwork for review by the University Academic Council (UAC). Once this process has been approved, paperwork is submitted to the Texas A&M University System Coordinating Board for final approval. The department was able to successfully navigate the outlined procedures and receive subsequent approval of the concentration. Effective fall 2008, the Department of Chemical Engineering will offer a concentration in bioengineering as an option under the B.S.Ch.E. degree program.

Course Approval

Given the increased interest among students for topics in area of biotechnology and to support the "new" concentration, two courses were updated. The technical elective CHEG 3153, Special Topics: Introduction to Biotechnology and Bioprocess Engineering was originally introduced as a Special Topics course in 2002 and has experienced growth in enrollment during the three semesters offered. CHEG 4153, Bioengineering, is a course that is in the course inventory but had not been taught for several years. Enrollment figures for both courses are listed above in Table 2. These courses status were modified using the same approval process outlined above. The CHEG 3153 course was renamed, its description updated, and it was requested to be added as a stand-alone course to support the new bioengineering option. The CHEG 4153 course description was also updated. Effective fall 2008, CHEG 3153 (formerly CHEG 4103), Introduction to Biotechnology and Nano-Scaled Processes was successfully added to the curriculum and will be offered for the first time under the new name and description in the spring 2009 semester.

Increased opportunities for Undergraduate Research

Research opportunities for both graduate and undergraduate students have increased with the hiring of the new faculty, improved academic and facility infrastructure, and financial support from the TIP as shown in Table 4. Notably, the students conducting undergraduate bio-related research represent approximately 80% of the undergraduate students conducting research in the Department of Chemical Engineering.

Table 4. Research Participation in Biotechnology

Activity	2008	2007	2006	2005	2004	2003	2002
Undergraduate Research in Bioengineering	10	8	12	12	8	4	1
Graduate Research in Bioengineering	1	1	2	2	1	1	-

The students have been actively involved in conducting authentic, publishable research. These research accomplishments have been presented at both regional and national conferences. Two students have received partial travel support to the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCCHE) annual conference. Two supplemental awards have been approved to support a Faculty and Student (FaST) research team. One faculty and 5 student researchers spent 10 weeks at Oak Ridge National Laboratories in Knoxville, TN in summer 2007 and 2008 in the FaST program. Additionally, one of the undergraduate research students received an internship with Eli Lilly during summer 2007, a first for the department with this company; the student was subsequently hired by a company to do bio-related work. Also, four (4) of undergraduate research students received a Research Experience for Undergraduates at Texas A&M University (College Station) during summer 2007.

Development of Laboratory Experiments and Supplemental Materials

During the spring 2008 semester, a lab manual was developed for implementation of the new experiments in the Chemical Engineering Lab 1 and Chemical Engineering Lab 2

courses. To support these experiments, the undergraduate lab was furnished with state-of-the-art **new instrumentation**. Bio-related material and problems have been introduced in the following courses: (1) Equilibrium Staged Separation Processes, (2) Kinetics and Reactor Design, (3) Heat, Mass, Momentum Transport, (4) Introduction to Engineering Course (freshman level), and (5) Senior Design & Professionalism I and II. The faculty anticipates developing formal supplemental documentation that can be used by all faculty for the above listed courses and other courses.

CONCLUSION AND DISCUSSION

The Department of Chemical Engineering was successful in their efforts to develop a bioengineering option. Awarding of the Targeted Infusion Project by NSF provided the last integral piece in order for the department to move forward and expand its academic and research capabilities in this area. The department is moving forward to recruit students, develop additional courses, and seek research funding.

Lessons Learned

One of the most important lessons learned was that we did not adequately anticipate the amount of time and human resources that would be needed in order to implement the bioengineering concentration. For this reason, it took longer than originally estimated to accomplish the measures that have been completed to date. PVAMU is primarily a teaching institution, hence our normal teaching load is four course (or 12 credit hours) per semester. However, there is a focus on increasing the amount of research conducted by faculty within the College of Engineering. Additionally, maintaining student interest and being able to recruit new students has become challenging. Although we are able to introduce the concepts in new courses and existing courses, it is often difficult to keep up with the expanding interest of the students and very challenging to do any active recruiting of new students. Given these factors combined with the fact that the new faculty hired to develop the bioengineering program are Assistant-level faculty, additional human resources were needed to meet the tasks associated with the new concentration.

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