2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33257

WIP: A New Undergraduate Biomedical Engineering Program: An Innovative Program in a Liberal Arts Institution

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Work in Progress: A New Undergraduate Biomedical Engineering Program: An Innovative Program in a Liberal Arts Institution

Key words: Biomedical Engineering, New Curriculum, Liberal arts

Abstract:

This paper describes a new biomedical engineering undergraduate program at a small liberal arts institution. The development of the program was initiated by a comprehensive feasibility report made in 2016 that included assessment of growth of the bioscience industry, cohesion with existing programs at the institution, potential students, and current trends and future needs. The program curriculum provides depth and breadth in the subject area with significant flexibility in course choices enriched by the liberal arts. The new biomedical engineering curriculum consists of 130 credit hours spanning a 4-year academic plan. The program curriculum consists of five integrated courses in biomaterials and biomechanics, three integrated courses in medical instrumentation and imaging, one course in design and development, two elective courses, and two capstone design courses, as well as courses in general engineering and basic sciences. Six biomedical engineering courses include laboratory components. A pre-med track is available for the students. The program is unique in that it shares a common first year with other engineering programs and that it merges with the institution's general education program using shared courses. Innovation lies in the program providing students with a required international global engineering experience and integrating engineering knowledge with essential business skills throughout the curriculum.

Introduction:

Program identity remains a significant challenge when developing new biomedical engineering programs due to the broad and interdisciplinary nature of the biomedical engineering discipline. Biomedical engineers need to acquire a diverse and comprehensive skillset to provide solutions for their clients, healthcare providers. This skillset could be obtained through extensive hands-on real-world engineering, international experience, integrated engineering knowledge with essential business skills, effective leadership and communication skills, and the opportunity to practice becoming catalysts for change through innovation and invention. Unlike vocational and technical academic institutions, liberal arts institutions provide diverse and comprehensive training ideal for broad and interdisciplinary programs. As of April 2021, there were 112 ABET accredited BS programs in Bioengineering/Biomedical Engineering worldwide [1]. The number of liberal arts institutions starting and/or exploring science, technology, engineering, and technology (STEM) programs is increasing every year. In 2016 and driven by the positive job outlook for biomedical engineers between the years 2012 and 2022 (about an increase by 27%) [2], our liberal arts institution initiated a comprehensive feasibility report for a new and innovative biomedical engineering program. The feasibility report included assessment of growth of the bioscience industry, cohesion with existing programs at the institution, potential students, and current trends and future needs. Based on the outcomes of the report, a new undergraduate biomedical engineering (BME) program was established with an innovative and unique curriculum. The innovative nature of the new program is demonstrated through the utilization of liberal arts pedagogical practices and interventions, 4 credit hours courses, the background and training of the programs 3 faculty members, a project-based curriculum, and the program emphases on analytics,

product development, a global engineering experience, and business skills. Each of these characteristics is designed to serve as a model to a much larger number of liberal arts institutions to follow. Here, we report on 3 years of our biomedical engineering program, its curriculum design process, and lessons learned.

Curriculum design process:

In addition to the core BME program courses, the program merges with the general education program at the institution, where students complete 4 foundational courses (16 credit hours), one of which is shared with the BME core, 2 foreign language courses (8 credit hours), 2 exploration courses (8 credit hours), which are part of the BME core, and a general education capstone course. Students select their foundational classes from a diverse collection of courses facilitated by the liberal arts nature of the institution, one of which is a required science course in biology, chemistry, or physics. A 4-credit hour course in electronics is the first exploration course for the BME students. The second exploration course is Global Engineering.
Two engineering programs (Civil and Mechanical Engineering) existed in our institution prior to establishing the biomedical engineering program. The curriculum design process started by reviewing the mechanical engineering curriculum for general guidance. The BME curriculum capitalized on courses offered by other academic departments at the institution. The lead biomedical engineering faculty and the director of the school of engineering engaged with the chairs of the chemistry, biology, physics, and math departments to identify required courses and the logistics of course scheduling, as many courses are only offered once during the academic year. Meetings were also held with the director of the pre-medical program to identify required courses for a pre-med track for the BME students. This collaborative approach was instrumental in creating a new program curriculum which is heavy in pre-requisite courses. Seven general engineering courses (22 credit hours), two chemistry courses (8 credit hours), two biology courses (8 credit hours), three physics courses (12 credit hours), four math courses (14 credit hours), and one project management course (2 credit hours) were incorporated in the BME curriculum. Additional courses (15 credit hours) were incorporated for students pursuing a pre-med track. BME students are able to pick a course of their choice for a minor in math, physics, or chemistry (if going through the pre-med track). Two categories of biomedical engineering topics were identified for the program core courses; (1) Biomaterials, Biomechanics, and Tissue Engineering and (2) Medical Instrumentations and Imaging.

Curriculum goals, objectives, and students outcomes:

In light of the institution's mission and vision statements, six educational objectives of the new BME were articulated with the help of the program's engineering advisory board. These objectives are: (1) Graduates will be able to pursue fulfilling professional lives by integrating their Biomedical Engineering expertise with business and communication skills, (2) Graduates will be able to create value and meaningful work in the field by meeting the expectations of employers of Biomedical Engineers, (3) Graduates who are interested will be able to pursue meaningful work through advanced study or alternate career paths, (4) Graduates will be empowered to take control of their careers and to engage in responsible citizenship through dynamic roles in their local, national, and/or international communities, (5) Graduates will be able to integrate their fundamental knowledge of sciences, mathematics, liberal arts, and engineering analysis in

meaningful work to solve challenges related to medicine and biology, and (6) Graduates who are interested will be catalysts for change who excel in entrepreneurial or start-up situations and innovate and invent to shape the future. The developed objectives were presented and discussed with the BME students in a special meeting for the purpose of receiving feedback. The students were offered the chance to provide written feedback about the presented educational outcomes which was positive.

The BME program utilizes the existing ABET student outcomes (SO's) (1)-(7) to assess the educational objectives. The performance indicators for SO's (2)-(5) are shared with the other engineering programs at the institution. The performance indicators for SO's (1), (6), and (7) are unique to the new BME program and are specifically designed to address the ABET BME program criteria.

A diverse group of direct assessment tools are utilized for course assessment. Examples of these tools include exam problems, homework problems, lab report sections, and design report sections. In addition, assessment using surveys is used as an indirect tool of the SO's.

Teaching laboratories, course projects and clinical exposure:

BME students have access to three BME teaching laboratories; two new laboratories; (1) Biomaterials & Tissue Engineering Lab and (2) Medical Instrumentation and Imaging Lab, and one lab that existed prior to the establishment of the program; the Human Motion Analysis Lab.
All BME courses have a project component in their design. At the beginning of each course, students interests and aspirations are gaged by providing students with a list of biomedical engineering projects and challenges. Students were asked to select and rank their top choices. Early on, students were encouraged to identify a medical/clinical disease/challenge, and to focus their efforts on projects related to that specific medical/clinical disease/challenge in multiple courses. This way students could start a project that spans the course of multiple academic years building students' knowledge and capacity in a specific area of interest related to a specific medical/clinical disease/challenge.

A unique laboratory in the program is the Biomaterials & Tissue Engineering Lab. Such labs are not usually part of an undergraduate BME program. The lab is designed to offer students with the opportunity to operate research grade equipment and tools preparing them to pursue post-graduate research and development opportunities.

Clinical experiences among biomedical engineers are currently limited by access and exposure. Starting a BME in an institution with existing healthcare programs like nursing, exercise sciences, and physical therapy is valuable in terms of offering BME access to clinical experiences through collaboration and joint projects. Our new BME program is developing collaboration with the nursing program in the form of a Biomedical engineering and Nursing Clinical Immersion Program. In this program, BME students shadow nursing students in their clinical rotations as observers. The goal of the project is to investigate the factors that affect BME students' readiness and ability to identify healthcare providers clinical needs and to develop solutions/products that address those identified needs.

Global engineering experience and building business skills:

Global engineering is a required exploration course for all engineering students including BME students. The global engineering course is a semester long course designed to provide students with the theory and field experience to be successful global engineers. Students acquire the knowledge, ability, and predisposition to work effectively with an international entity and/or client who define and solve problems differently than they do. Students work in multidisciplinary engineering groups. The field experience component of this course provides students the opportunity to experience engineering within another culture and requires international travel for about one week. The successful completion of all four foundation courses as well as demonstrating world language proficiency are prerequisites for the global engineering course.

BME students learn essential business skills throughout the curriculum in multiple setups. Students are required to complete a 2-credit hours project management course offered by the institution department of business. Students also learn essential business skills in the Product Design and Development course. The course presents content from business and engineering with an emphasis on the process of product development. The steps in the product development process are presented to give shape to a design idea and to make a commercially viable product. Students teams identified needs, designed products, constructed alpha prototypes and presented their prototypes with business cases in support of the product.

Lessons learned from our first cohort:

Students expressed their appreciation to the utilization of service courses from other departments in the school. Specifically, the following courses; anatomy and physiology offered by the biology department, organic chemistry offered by the chemistry department, and electronics offered by the physics department. BME students also expresses their excitement about collaborating with nursing students in the proposed clinical immersion experience.

Reference:

[1] www.abet.org
[2] Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2014-15 Edition*, Biomedical Engineers, on the Internet at http://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm (visited *October 06, 2015*).