

Introducing Biomedical Engineering Content into Biological Engineering Courses

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Abstract

The Biological Engineering (BE) degree program in the Department of Biological and Agricultural Engineering at NC State University offers concentrations in Agricultural, Biomedical, Bioprocess, and Environmental Engineering. Enrollment in the BE degree program has grown markedly since it was introduced in Fall 1994 with students in the Biomedical Engineering Concentration now making up nearly 70% of the students. This broad range of concentrations and shift in student interests has resulted in several changes in course content. Many required courses now routinely include biomedical as well as agricultural examples. Future plans include the development of an ABET-accredited B. S. in Biomedical Engineering in addition to the B. S. in Biological Engineering so that the needs of the two student populations can be better served.

Introduction

In 1994, the Department of Biological and Agricultural Engineering at NC State University changed from offering a Biological and Agricultural Engineering (BAE) degree with concentrations in Biological, Environmental/Soil and Water, Food, and Power and Machinery, which was ABET-accredited under the guidelines for agricultural engineering programs, to a degree in Biological Engineering (BE) that followed the ABET guidelines for biological engineering. The revised curriculum offered students a choice of four concentration areas: Agricultural, Biomedical, Bioprocess, and Environmental Engineering. The revised degree program reflected the faculty's vision that biological engineering will play an important role in engineering activities in the 21st century and was also a response to declining enrollments that began in the late 1980s. The goal of the revised undergraduate curriculum was to provide students with a broad-based, biologically oriented education while training them to be competent engineers. The four concentration areas were selected based on faculty research

interests, student interest, and potential for employment.

All students following the BE degree program take a series of required courses. These include BAE 101: Introduction to Biological Engineering and Computing, BAE 202: Introduction to Biological and Agricultural Engineering Methods; BAE 235: Engineering Biology; BAE 315: Properties of Biological Engineering Materials; BAE 401: Bioinstrumentation; BAE 402: Transport Phenomena; and BAE 451/452: Engineering Design I/II. Students must also take several concentration-specific courses and other courses in engineering and biology in addition to courses in math, chemistry, and physics.

This paper will explore the effects of adding the Biomedical Engineering Concentration to the degree program offered by the BAE Department in terms of the required courses that existed before the BE curriculum was developed. BAE 235 and BAE 315 will not be discussed since both of these courses were developed specifically for the BE curriculum.

Effect on Courses

Undergraduate student numbers have greatly increased in the BAE Department since the BE curriculum was introduced in 1994 with 12 BE graduates in 1995-1997 and 41 on track to graduate in 1999-2000. This was a desired outcome since enrollment had previously been declining. Many of the required courses have more than doubled in enrollment from around 20 students to over 40. The increase in enrollment is due almost entirely to the addition of students who are following the Biomedical Engineering Concentration (BMEC) and now make up nearly 70% of the students in the BE degree program. This has caused two types of pressures on the courses. The first involves facilities, i.e. providing enough space in lectures and lab sections for the additional students. The second involves course content, which has had to change from being primarily agriculturally based to being biologically based with some examples from biomedical engineering.

BAE 101: Introduction to Biological Engineering and Computing
<http://www3.bae.ncsu.edu/bae101/>

BAE 101 differs from general introductory programming classes in that problems are selected which include biological content. To include biomedical engineering, faculty guests present overviews of biomechanics and bioinstrumentation with information about the biology that is involved and how it relates to engineering devices. For one assignment, students use spreadsheets and a Fortran 90 program to compare electrical signals acquired from swine hearts during normal sinus rhythm with those acquired during ventricular fibrillation, a life-threatening arrhythmia that kills over 100,000 people in the United States each year.

Since BAE 101 is the first course taken by students interested in the BE degree program and can be taken by students who have not yet met the minimum course requirements for matriculation, it has seen some of the largest increases in enrollment. The survey nature of BAE 101, overlaid on top of the introductory programming material, has made it one of the easier courses to adapt

to the new concentration areas and to accommodate the interests of BMEC students.

BAE 202: Introduction to Biological and Agricultural Engineering Methods
http://www.bae.ncsu.edu/bae/courses/bae202/home_page.html

In 1992, BAE 202 replaced BAE 151: Elements of Agricultural Engineering I, which was a first course in the department for students in the BAE curriculum. BAE 151 placed heavy emphasis on the basic skills of fabrication in a machine shop facility. In addition to fabrication, the course covered materials, stress-strain relationships, purchasing procedures, and engineering surveying methods and practice. BAE 202, now taken as a required course by all students in the BE curriculum, still includes a "shop" component which allows students to manufacture semester projects (see <http://www2.ncsu.edu/bae/courses/bae202/albidx3.htm>). However, the primary emphasis has shifted to the introduction of the design process, the basics of engineering graphics (with a text and workbook) and 3D visualization, and 3D solid modeling with CAD (ProEngineer) for parts, assemblies, and working engineering drawings.

As developing engineers, students need opportunities to experience the design process early in their education to acquire some of the skills necessary for the hands-on application of engineering knowledge. Early design experience also serves to illustrate the importance of the engineering sciences and to focus the student on the role of engineering in our economy and our society. Improvements in the student's self-confidence in problem definition and solving, idea generation, idea communication, and idea implementation are necessary for continued development as a competent engineer. Computer-aided engineering graphics, material properties, the design process, fabrication, and tool processes are vehicles for effecting these improvements. This emphasis is well suited for students in all concentration areas and serves the needs of those in the biomedical areas even though the emphasis is on "hard" engineering with little explicit biomedical content. It is believed that basic design competencies with some understanding of basic manufacturing processes will serve as a foundation for the development of more sophisticated engineering competencies in upper level courses.

BAE 401: Bioinstrumentation
http://www.bae.ncsu.edu/bae/courses/bae401/home_page.html

During 1998, two major equipment purchases were made which affected the content of BAE 401 in the fall semester of 1998. The first of these was the addition of LabVIEW[®] from National Instruments to the software capabilities of the PCs used for the BAE 401 lab. The second purchase involved Lionheart II simulators. Since the Lionheart simulators were developed to test ECG machines, they could output a variety of ECG and blood pressure signals. These signals were used by students as inputs for the data acquisition systems that they designed and built using LabVIEW[®].

BAE 402: Transport Phenomena
http://www.bae.ncsu.edu/bae/courses/bae402/home_page.html

BAE402 has traditionally been a course that covered the basic concepts of fluid flow, pumps and fans, heat transfer, and psychrometrics. It has changed during the past two years to increase the application of basic principles of fluid and heat transfer to biomedical applications and consequently to reduce the application of these same principles to agricultural situations. This has primarily been accomplished through the semester long special projects rather than with changes in the organization of the lectures or laboratory periods.

Prior to 1997, special projects were assigned which integrated the concepts of resistance to flow through a system, performance of pumps or fans, heat transfer, and psychrometrics through a problem involving a batch grain drying system. Beginning in 1997, the emphasis of the special problem was shifted to a study of the flow of blood through the human vascular system, the performance of the heart (pump) on the system, and the effects of various heart or vascular system maladies on blood volumetric flow rate and pressures. This choice of projects has resulted in more in-depth study of the interactions between pump and system but no longer also incorporates heat transfer and psychrometric principles. It has also led to more independent study by the students into the human cardiovascular system. On the other hand, it has considerably reduced the opportunity for agriculturally based students to apply these same principles to problems that have traditionally been studied by the agricultural process engineer.

BAE 451/452: Engineering Design I/II

http://www.bae.ncsu.edu/bae/courses/bae451/home_page.html

The large increase in the number of students following the Biomedical Engineering Concentration meant that a large number of projects needed to be found which emphasized biomedical engineering topics and that funding needed to be found to support those projects. A grant from NSF (Senior Design Projects to Aid the Disabled) was awarded in September 1996 and provides funds to design and build projects for physically and mentally disabled clients. Three 2-person teams of students completed projects for clients at the Tammy Lynn Center for Developmental Disabilities during the 1996-1997 academic year. During the 1997-1998 academic year, three 2-person teams did WWW-based computational biology projects that are now available to the world from the web at The Shodor Foundation (<http://www.shodor.org>) and two other teams (5 students total) completed NSF-funded projects for disabled clients. Nine projects are currently being funded from the NSF grant for the 1998-1999 academic year, and more projects will be initiated during the spring semester of 1999. Additional projects in biomedical engineering are also being done in collaboration with faculty from the NC State College of Veterinary Medicine.

Conclusion

Introducing the Biomedical Engineering Concentration has had a major effect on the content of several required courses in the undergraduate degree program offered by the BAE Department at NC State. Biomedical, as well as more traditional agricultural, engineering topics are now covered in most of the required courses. The BAE Department is currently exploring separating its undergraduate program into two ABET-accredited degree programs, Biological Engineering

and Biomedical Engineering. With the addition of a new degree program and new faculty to support the large number of BMEC students, many of the required courses could be split into two sections with one section emphasizing more agriculturally based examples and another section emphasizing more examples from biomedical engineering. This outcome would better serve both populations of students.

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