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Louisiana State University's Biological Engineering Program*

RICHARD L. BENGTSON
Biological and Agricultural Engineering, Louisiana State University, Baton Rouge LA 70803, USA.
Email: bengtson@bae.lsu.edu

In the mid 1980s, undergraduates entering Louisiana State University from rural backgrounds seeking to enter agricultural-related industries were replaced by students from urban settings seeking careers in biological, environmental and medical professions. In response to this, LSU developed an engineering curriculum explicitly integrating the biological sciences. This Biological Engineering curriculum is uniquely applied to develop engineering solutions to problems that affect plants, animals and the natural environment. It is a unitary program without any specialties. The students complete a 107 semester hours core curriculum plus 9 hours of design electives, 18 hours of general education electives, and 3 hours of free elective. The enrollment increased from 2 students in 1988 to 160 in 2003. The annual number of graduates increased from 0 in 1989 to 33 in 2003 with 188 total graduates as of 2004. Twenty-nine per cent of the graduates attended graduate school, 22% have gone to work in environmental consulting, 12% in manufacturing, and 10% have gone to medical school. This program has been very successful and provides needed biological engineers for the Louisiana and regional economy.

Keywords: Biological engineering: curriculum

INTRODUCTION

NATIONALLY, change has taken place to increase and emphasize formal training in biology within engineering curricula. These changes have resulted in the fundamental redefinition of coursework and the development of an integrated curriculum in Biological Engineering. Undergraduates entering Louisiana State University from rural backgrounds seeking to enter agriculture-related industries were replaced largely by students from urban settings seeking careers in biological, environmental, and medical professions. Many undergraduates have the explicit goal of furthering their education with graduate or professional training in specialized fields of engineering, medicine, and science. All students entering Biological Engineering expect an engineering curriculum explicitly integrating the biological sciences.

The objective of this paper is to describe the contemporary vision of Biological Engineering at Louisiana State University. In so doing, a definition of biological engineering, an explanation of the scope of the curriculum, and a discussion of the skill competencies of graduates were developed.

DEFINITION OF BIOLOGICAL ENGINEERING

Biological Engineering is a science-based engineering discipline integrating conventional engineering topics, engineering design, and applied biological sciences within a single curriculum. Biological Engineering applies basic, applied, and engineering sciences to the solution of problems involving biological organisms and their environments. Biological engineering involves:

- the characterization, measurement, and representation of systemic processes within an organism or patterns of relationships between organisms and their environments;
- engineering design to develop processes and systems that influence, control, or utilize biological materials and organisms for the benefit of society.

SCOPE AND AIM OF THE BIOLOGICAL ENGINEERING CURRICULUM

Biological Engineering embraces an undergraduate education:

- based on a knowledge of the basic sciences of mathematics, physics, chemistry, and biology;
- augmented with an understanding of the applied biological sciences, namely organic chemistry, biochemistry, and microbiology;
- integrated with training in the engineering sciences of statics, dynamics, strength of materials, fluid mechanics, and thermodynamics, as well as engineering economics and basic electrical principles;
- uniquely applied to developing engineering solutions to problems that affect plants, animals, and the natural environment.

* Accepted 14 August 2006.

The undergraduate curriculum in Biological Engineering meets ABET accreditation requirements and all University general education requirements. Basic and applied science courses were chosen from existing courses within the University. Additionally, engineering science topics were selected from offerings within the College of Engineering.

Significant biological content was integrated into core departmental courses in such a way as to assist students in the application of principles from basic science, applied biology, and engineering in the solution of problems in biological and natural resource-based industries. Examples relating to biological science that incorporate engineering analysis were included in the content of core curriculum courses.

SKILL COMPETENCIES OF BIOLOGICAL ENGINEERING GRADUATES

A science-based education in Biological Engineering is oriented towards developing inductive and deductive skills of reasoning. In addition, students require training in skills that relate the intuition and engineering art required of the engineering practitioner. Intuitive skills relating to magnitude, implementation, practicality, and appropriateness of engineering designs and design calculations are part of the undergraduate experience. Such an applications background stems from well-designed laboratory exercises, student-work experience opportunities, and industry internship positions. Eight of the core biological engineering courses have a 3-hour lab. Furthermore, a capstone design experience is part of the undergraduate experience.

STRATEGIES FOR PROGRAM IMPLEMENTATION

A new series of core Biological Engineering courses were developed or revised from existing courses to achieve congruence with the stated scope and goal of the program. Additionally, required facilities development and equipment purchase for implementation of meaningful laboratory experiences was pursued.

CURRICULUM

Table 1 shows the Louisiana State University's Biological Engineering curriculum [1]. This curriculum contains 131 semester hours. It is an unitary program without any specialties. All students take a core curriculum of the same courses except for electives. Table 2 shows the curriculum components. The students complete 30 hours of biological engineering, 15 hours of biology, 11 hours of chemistry, 9 hours of English, 18 hours of

Table 1. Curriculum in Biological Engineering (total semester hours = 131)

1st Semester Freshman Year	Sem. Hours
BE 1250 Introduction to Engineering Methods	2
BIOL 1201 Biology for Science Majors I	3
BIOL 1208 Biology Lab for Science Majors I	1
CHEM 1201 Basic Chemistry	3
ENGL 1001 English Composition	3
MATH 1550 Analytical Geometry and Calculus I	5
	17
2nd Semester Freshman Year	**Sem. Hours**
BE 1252 Biology in Engineering	2
CHEM 1202 Basic Chemistry	3
CHEM 1212 Basic Chemistry Laboratory	2
ENGL 1002 English Composition	3
MATH 1552 Analytical Geometry and Calculus-II	4
PHYS 2101 General Physics for Tech Students	3
	17
1st Semester Sophomore Year	**Sem. Hours**
BE 2352 Quantitative Biology in Engineering	3
BIOL 1202 Biology for Science Majors II	3
BIOL 1209 Biology Lab for Science Majors II	1
CE 2450 Statics	3
MATH 2065 Elementary Differential Equations	3
PHYS 2102 General Physics for Tech Students	3
	16
2nd Semester Sophomore Year	**Sem. Hours**
BE 2350 Experimental Methods for Engineers	3
BIOL 2051 General Microbiology	4
CE 3400 Mechanics of Materials	3
CHEM 2261 Organic Chemistry	3
EE 2950 Comprehensive Electrical Engineering	3
	16
1st Semester Junior Year	**Sem. Hours**
BE 4303 Engr Properties of Biol Materials	3
BIOL 2083 The Elements of Biochemistry	3
CE 2200 Fluid Mechanics	3
ENGL 3002 Tech & Professional Writing or ROTC	3
Engineering Design Elective	3
	15
2nd Semester Junior Year	**Sem. Hours**
BE 3340 Process Design for Biological Engr	3
BE 4352 Transport Phenomena in Biological Engr	3
CE 2460 or ME 3133 Dynamics	3
ME 3333 Thermodynamics	3
Engineering Design Elective	3
	15
1st Semester Senior Year	**Sem. Hours**
BE 3320 Mechanical Design for Biological Engr	3
BE 3190 Professionalism for Biological Engr	1
BE 4290 Senior Engineering Design	2
BE 4341 Biological Reactor System Design	3
General Ed., Social Science Elective	3
General Ed., Humanity Electives	6
	18
2nd Semester Senior Year	**Sem. Hours**
BE 4292 Senior Engineering Design Laboratory	2
Engineering Design Elective	3
Elective or ROTC	3
General Ed., Arts Elective	3
General Ed., Humanity Elective	3
General Ed., Social Science Elective	3
	17

Table 2. Biological Engineering curriculum components

Item	Sem. Hours
Biological Engineering	30
Biology	15
Chemistry	11
Design Electives	9
Elective	3
English	9
Engineering Science	18
Humanities	18
Mathematics	12
Physics	6

Table 3. Engineering Design electives

BE 3381 Nonpoint Source Pollution Engineering
BE 4323 Biomechanics for Engineers
BE 4332 Molecular Methods in BE
BE 4340 Food and Bioprocess Engineering
BE 4342 Sugar Process Engineering
BE 4347 Sugar Factory Design
BE 4360 Mobile Fluid Power Control
BE 4380 Aquacultural Engineering
BE 4383 Natural Resource Engineering
EVEG 3110 Water and Wastewater Treatment
IE 4461 Human Factors Engineering
IE 4462 Safety Engineering
ME 4133 Machine Design I

engineering science, 12 hours of mathematics and 6 hours of physics. The curriculum also includes 9 hours of design electives, 18 hours of humanities electives and 3 hours of free elective. The design electives are where the student may specialize and take courses to assist in getting a job or graduate school entrance requirements. The design electives are shown in Table 3.

At the start, all new students are enrolled in BE 1250 Introduction to Engineering Methods. This course teaches computer aided drafting. During the last half of the course, the students are introduced to engineering design. They design, build, and demonstrate an engineering device. The students also are informed about biological engineering and are aided in the transformation from high school to college student. There is a biological engineering course every semester. This allows the department to stay in touch with and assist students. All of the faculty advise students and students must be advised before they can register for courses. The courses build on each other and students are encouraged to stay on track. A student starting in the first calculus course and staying on track will graduate in 4 years. The seniors take a two semester senior design sequence. The seniors are formed into teams and design, build and test an object or process. Ideas are given to us from industry and other university faculty. The curriculum is a 'Communicating Across the Curriculum' program. Students take a communicating intensive course each semester. The students in the senior design sequence complete written and oral presentations.

A large number of students use this program to qualify for medical school. All of the requirements for medical school except the second organic chemistry course and the organic chemistry lab are included in the curriculum. Another large

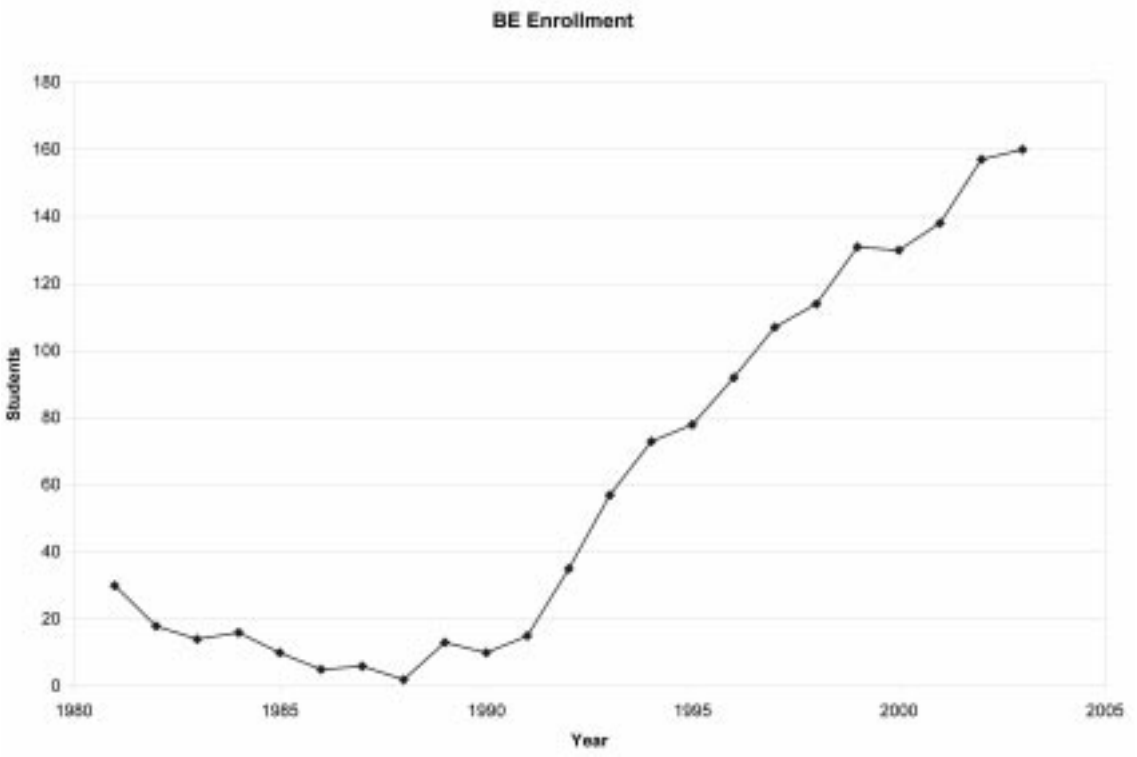

Fig. 1. Biological Engineering enrollment.

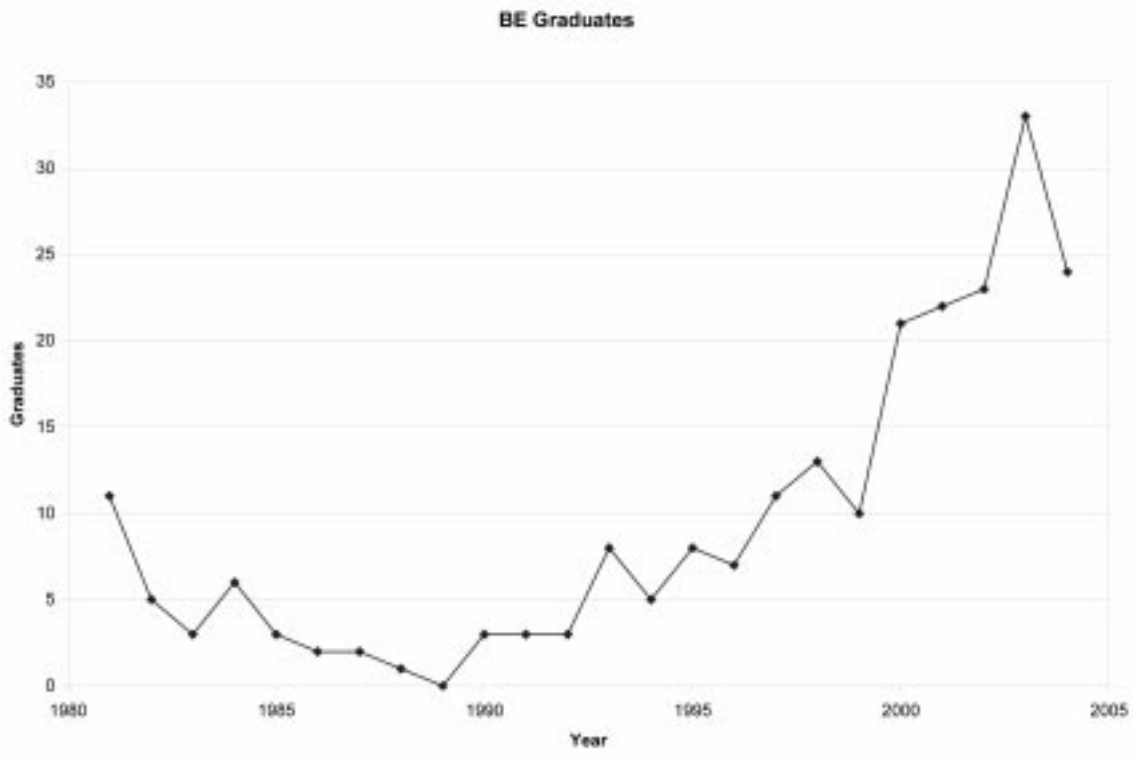

Fig. 2. Biological Engineering graduates.

group of students use this program to qualify for biomedical engineering graduate school.

ACCOMPLISHMENTS

This program was put in place in the spring of 1987. The enrollment has increased from 2 students in the fall of 1988 to 160 students in the fall of 2003 (Fig. 1). The annual number of BS graduates has increased from 0 in 1989 to 33 in 2003 (Fig. 2). A total of 188 students have graduated from this program as of 2004. Twenty-nine per cent of the students attended graduate school, 22% have went to work in environmental consulting, 12% in manufacturing, and 10% have gone to medical school (Table 4). Table 5 provides the course descriptions.

Table 4. Biological Engineering first employment of graduates starting 1992

Item	No.	%
Graduate School	56	29%
Environmental Consulting	41	22%
Manufacturing	23	12%
Medical School	18	10%
State Government	13	7%
Unknown	10	5%
Federal Government	7	4%
Technical Sales	6	3%
Bio-Medical Co.	5	3%
Bio-processing	4	2%
Foreign	3	2%
Military	2	1%
Total	188	100%

When the program was started in 1987, the title was Biological and Agricultural Engineering. By 1991 this name was not popular with the students or with the companies that hired our students. The urban students did not want anything to do with agriculture. The companies considered the name to long. They wanted a short distinct name. In 1992, the name of the program was changed to Biological Engineering. This change made everyone happy. Both students and companies liked the name.

SUMMARY

In the mid 1980s, undergraduates entering Louisiana State University from rural backgrounds seeking to enter agricultural-related industries were replaced by students from urban settings seeking careers in biological, environmental, and medical professions. In response to this, LSU developed an engineering curriculum explicitly integrating the biological sciences. This Biological Engineering curriculum is uniquely applied to develop engineering solutions to problems that affect plants, animals, and the natural environment. The enrollment increased from 2 students in 1988 to 160 in 2003. The annual number of graduates increased from 0 in 1989 to 33 in 2003 with 188 total graduates as of 2004. This program has been very successful and provides needed biological engineers for the Louisiana and regional economy.

Table 5. Biological Engineering curriculum course descriptions

1st Semester Freshman Year
BE 1250 Introduction to Engineering Methods (2) 6 hours lab. Fundamental of engineering design; presentations of an engineering design; graphical expression of engineering design using computer-aided drafting. BIOL 1201 Biology for Science Majors I (3) General concepts in cellular structure, cellular metabolism, cellular communication, and genetics. BIOL 1208 Biology Lab for Science Majors I (1) . Laboratory corresponding to BIOL 1201. CHEM 1201 Basic Chemistry (3) Modern chemical theories and principles; quantitative approach and problem solving; descriptive chemistry of selected elements and compounds. ENGL 1001 English Composition (3) Introduction to writing in forms of expressive and informative discourse. MATH 1550 Analytical Geometry and Calculus-I (5) Prereq: MATH 1022 Analytic geometry, limits, derivatives, integrals.
2nd Semester Freshman Year
BE 1252 Biology in Engineering (2) Prereq: BIOL 1201. Effect of variability and constraints of biological systems on engineering problem solving and design; engineering units; engineering report writing; oral report presentation; laboratory demonstration of BE analysis. CHEM 1202 Basic Chemistry (3) Prereq: CHEM 1201. Additional theory with emphasis on solution chemistry and a quantitative approach; descriptive chemistry of selected elements and compounds from the main groups and the first transition series. CHEM 1212 Basic Chemistry Laboratory (2) Prereq: Registration in CHEM 1202. Basic laboratory operations including selected experiments and introductory inorganic qualitative analysis. ENGL 1002 English Composition (3) Prereq: ENGL 1001. Introduction to writing, persuasive, evaluative, and other forms of argumentative discourse. MATH 1552 Analytical Geometry and Calculus-II (4) Prereq: MATH 1550. Techniques of integration, parameter equations, polar coordinates, infinite series, vectors in low dimensions; introduction to differential equations and partial derivatives. PHYS 2101 General Physics for Technical Students (3) Prererq: Registration in MATH 1552. Mechanics, wave motion, thermodynamics, and kinetic theory.
1st Semester Sophomore Year
BE 2352 Quantitative Biology in Engineering (3) Prereq: 1252. Characterization of biological phenomena in engineering design; relationships among parameters using linear and nonlinear statistical expressions; case studies of engineering solutions. BIOL 1202 Biology for Science Majors II (3) Prereq: BIOL 1201. General concepts in evolution, ecology, and the function of organisms. BIOL 1209 Biology for Science Majors II (1) Prereq: BIOL 1208. Laboratory corresponding to BIOL 1202. CE 2450 Statics (3) Prereq: PHYS 2101. Vectorial treatment of resultants and equilibrium of force systems, centroids and centers of gravity, fluid statics, friction. MATH 2065 Elementary Differential Equations (3) Prereq: MATH 1552. Ordinary differential equations, emphasis on solving linear differential equations. PHYS 2102 General Physics for Technical Students (3) Prereq: PHYS 2101. Electricity, magnetism, physical optics, and topics from modern physics.
2nd Semester Sophomore Year
BE 2350 Experimental Methods for Engineers (3) MATH 1552. Introduction to statistical analysis, experimental methods, technical report writing, and instrumentation for engineering applications; measurement of temperature, pressure, flow, strain, and vibration in biological and agricultural products; microprocessor data loggers and computer data acquisition systems. BIOL 2051 General Microbiology (4) Prereq: BIOL 1202 and CHEM 1202. Structure and function of microbial cells and their relationship to people and the environment. CE 3400 Mechanics of Materials (3) Prereq: CE 2450. Stress and strain, torsion, bending, deflections of beams, columns, statically indeterminate problems, combined stress. CHEM 2261 Organic Chemistry (3) Prereq: CHEM 1202. Representative classes of organic compounds; emphasis on varied professional goals of students, e.g., life sciences, physical sciences, engineering. EE 2950 Comprehensive Electrical Engineering (3) Prereq: MATH 1552. Elementary circuits, devices, and systems in electrical engineering.
1st Semester Junior Year
BE 4303 Engr Properties of Biol Materials (3) Prereq: CE 3400. Engineering properties, including rheology, friction, mechanical damage, texture, and thermal, optical, and electrical properties. BIOL 2083 The Elements of Biochemistry (3) Prereq: CHEM 2261. Nature and physiological uses of natural substances. CE 2200 Fluid Mechanics (3) Prereq: CE 2450. Statics and dynamics of continuous liquids and gases; control volume laws; conservation of mass, momentum, and energy; dimensional analysis and similitude; applications to pipe flows. ENGL 3002 Tech & Professional Writing (3) Prereq: ENGL 1002. Training in skills required of practicing scientist, engineers, and technical managers. Engineering Design Elective (3)
2nd Semester Junior Year
BE 3340 Process Design for Biological Engineering (3) Prereq: CE 2200, EE 2950, & ME 3333. Design applications in biological engineering using the engineering sciences of fluid mechanics and thermodynamics; electrical machines and controls. BE 4352 Transport Phenomena in Biological Engineering (3) Prereq: BE 2352; credit or registration in CE 2200 and ME 3333. Introduction to biological kinetics; time-temperature substrata-dependent growth and death of biological organisms; heat and mass transfer in engineering design and analysis; principles of material and energy balances in reactor design. CE 2460 Dynamics and Vibrations (3) Prereq: CE 2450 & MATH 2065. Treatment of kinematics and kinetics of particles and rigid bodies; force, movement, velocity, acceleration; impulse and momentum; work and energy; dynamics and vibration, concepts applied to structural and machine components. ME 3333 Thermodynamics (3) Prereq: PHYS 2101 & MATH 1552. Basic laws of thermodynamics, availability, perfect gases and pure substances, fluid flow, and basic heat transfer. Engineering Design Elective (3)
1st Semester Senior Year
BE 3190 Professionalism for Biological Engineers (1) Ethical standards, communication, professional societies, goal setting, safety, and time management. BE 3320 Mechanical Design for Biological Engineering (3) Prereq: CE 2460 & CE 3400. Philosophy of mechanical design for biological engineering; materials of construction; frame design; power transmission. BE 4290 Senior Engr Design and Professionalism (2) Capstone project selection and approval; project to be completed in BE 4292, completion of project feasibility study and outline of design project; ordering necessary parts; design philosophy, teamwork, and communication; economics, product liability and reliability; use of standards and codes; goal setting and time management. BE 4341 Biological Reactor Systems Design (3) S Prereq: BIOL 2051 and BE 4352. 2 hrs. Lecture 3 hrs. Lab. Microbial and biochemical principles used in design of biological reactors for biotransformation; metabolic output, and cellular production; design of batch and continuous flow reactors utilizing microbial kinetic models; attached and suspended growth systems and eucaryotic and procaryotic cells. General Ed., Social Science Elective (3) General Ed., Humanity Elective (6)
2nd Semester Senior Year
BE 4292 Senior Engineering Design Laboratory (2) Prereq: BE 4290. Engineering principles used to complete the project set forth in the outline submitted in BE 4290; design project completion. Engineering Design Elective (3) Elective or ROTC (3) General Ed., Arts Elective (3) General Ed., Humanity Electives (3) General Ed., Social Science Elective (3)

REFERENCE

1. Louisiana State University, *Undergraduate/General Catalog,* **96**(1), 2004–2005.

Dr. Richard L. Bengtson attended the University of Wyoming where he received a BS in Agriculture Engineering in 1966. He then completed a MS in Agricultural Engineering at the University of Illinois in 1967. After 11 years service with the US Army Field Artillery, he returned to school where he was awarded a Ph.D. in 1980 from Oklahoma State University. Dr. Bengtson is a Professor at Louisiana State University in the Biological and Agricultural Engineering Department. He teaches natural resources engineering and nonpoint source pollution engineering. Since 1992 he has been the Undergraduate Coordinator for the Biological Engineering Program.