A Biological Engineering Curriculum That Works

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Abstract

The Biological Resources Engineering program at the University of Maryland today attracts ten times as many students as it did ten years ago. This phenomenal growth can be attributed to a faculty who committed completely to a Biological Engineering curriculum to serve the needs of industry and student interests. This curriculum has been modified nearly constantly to improve the education students receive, in order to give a broad and fundamental basis for their future careers. Nearly all course materials have changed, as well. Exit interviews with seniors have shown that students are very satisfied with the education they receive at the University of Maryland.

The curriculum integrates many objectives, including:

1. education based on fundamental principles
2. broad range of applications included
3. group work emphasized
4. practical working knowledge imparted
5. communications skills exercised
6. biology truly integrated with engineering
7. biomedical engineering embraced
8. close identification with engineering ongoing

This has led to a curriculum including some truly unique courses: Biology for Engineers, Cycles in Biology, Systems Approach to Transport Processes, and Capstone Design with Prototype Fabrication and Testing. This combination of courses, along with requirements for biology, engineering sciences, and liberal studies has been shown to be attractive to matriculating freshmen. Current directions point to a total undergraduate enrollment that could again double in the next few years.

Introduction

When Young (2004) presented his enrollment reports to NABEC and ASAE, one educational program stood out from the rest (Table 1). That program is the one at the University of Maryland. Starting with a total undergraduate enrollment of 15 in 1993, when the program changed officially from Agricultural Engineering to Biological Resources Engineering, total undergraduate enrollment is now 140 and climbing. This phenomenal growth can be attributed to a faculty who committed early and completely to a Biological Engineering curriculum to serve the needs of potential students and industry. There was no turning back to the former Agricultural Engineering program, because several key courses had already been evolving into something new with a broader and more fundamental scope.

Although independently designed, the University of Maryland curriculum closely resembled the Biological Engineering curriculum at Mississippi State University. However, the University of Maryland curriculum has been modified nearly constantly to improve the educational experiences students receive, and to prepare them better for their future careers. Nearly all course materials have been changed to reflect current trends in the two worlds of engineering and biology. Of the two, knowledge in biology is changing more and more rapidly. Keeping course content current is one of the biggest challenges for a successful Biological Engineering curriculum. The success of this program is reflected at both ends of the student experience. The Clark School of Engineering surveyed high school students who were accepted as freshmen into the University of Maryland. Of the 543 students who responded, 19 were Biological Resources Engineering majors. Primary reasons for attending this program are given in

Table 2. Program, faculty, reputation, and quality account for 84% of the reasons why students decided to enroll in this program.

Primary reasons are also given for those students who elected not to enroll in the program (Table 3). In this case, program, faculty, reputation, and quality were not major considerations for not attending. This seems to indicate that the Biological Resources Engineering program at Maryland has been recognized as a program that can meet the educational needs of potential students.

Exit interviews are held with students when they complete their Capstone Design II course either the semester they graduate or one semester prior to graduation, depending on scheduling. The results are shown in Table 4. The objectives shown in the Table are taken from objectives developed as part of the ABET accreditation process, and reflect broad goals of the program. Results in Table 4 indicate that seniors are generally in agreement that the program meets the stated objectives, and, generally, seniors are very satisfied with the educations they have received. That is not to say, however, that all seniors are satisfied about the entire curriculum. The relatively large standard deviations for some of the responses, and differences from one year to the next indicate that some students are not entirely satisfied with everything in the program. There is a continuing tension, for instance, between those students who thrive in groups and those who prefer to work individually. However, overall, seniors' responses have been gratifying.

The Curriculum

The Biological Resources Engineering (BRE) curriculum is included at the end. The curriculum is highly prescribed, but does include five technical electives that allow some specialization at the undergraduate level. There are 50 credits of engineering sciences and design, 42 credits of basic sciences and mathematics excluding biology, 18 credits of biology taught by life scientists, 19 credits of liberal studies, and 22 credits of courses integrating engineering with biology. Because a significant proportion of our students use their undergraduate education to step into professional careers in the health sciences, advice is given for choice of courses to follow certain career paths.

This curriculum integrates many objectives, including:

1. education based on fundamental principles.

   Development of engineering skills involves a small set of fundamental principles that can be applied to a broad range of applications. Learning and retention of the principles is reinforced with each application, so the most effective engineering curriculum is one that emphasizes fundamentals.

2. broad range of applications included.

   One of the biggest challenges for a Biological Engineering curriculum is for all courses to have meaning for all student interests. One of the biggest challenges for Biological Engineering faculty is to become familiar with applications on technical topics different from their primary technical interests. If it involves engineering related to biology, then the application is included one place or another in the BRE curriculum.

3. group work emphasized.

There are many benefits to students working in groups. Much of engineering in industry involves concurrent engineering design through teams of employees representing different specialties. Students working in groups, especially on challenging or protracted projects, develop a mutual trust and morale that is good for a program. Faculty have smaller numbers of assignments to grade. The ability to assess individual contributions to group work has been successfully implemented at Maryland, and thus group work is incorporated in nearly all our required BRE courses.

4. practical working knowledge imparted.

Students enter the BRE program with little practical experience in mechanical, electrical, and chemical systems. Yet, the faculty has decided that students need to be given some sense of reality if they are to be prepared for engineering practice. This is done in many ways: 1) practical design projects are assigned and only workable solutions are accepted, 2) practical applications are explained in class, 3) prototypes are required to be designed, built, and tested in several courses, and 4) engineering judgment is actively pursued. Students are penalized for impractical solutions, and concepts that require “magic” rather than “logic” are unacceptable. There is a trend for students who have been coddled in high school to expect the same treatment in BRE courses. Sometimes it is difficult to break these habits, but every attempt is made to do so.

5. communications skills exercised.

   Written and verbal reporting is important to engineering, and these skills are exercised and enhanced in the BRE curriculum. Presentations are graded and these grades count more or less (up to 40%) of the final score in departmental courses. Professional looking as well as sounding reports are expected.

6. biology truly integrated with engineering.

   Engineering sciences and life sciences are not treated separately. BRE courses at all levels integrate both. Although students take courses in many different departments, the better to appreciate different points of view, they are assisted with recognizing how biology and engineering overlap in Biological Engineering. The challenge to the faculty is to remain conversant with biological knowledge and methods as the field continually evolves. The newest information about biology at all levels must be appreciated, at least to the extent that this information can be translated into a form meaningful for engineering application. New information in the field of biology must be able to be fit into the context of a few fundamental biological principles.

7. biomedical engineering embraced.

Table 5 shows that our students in 1998 had vastly different interests than they do today. For the last few years, our students have been predominantly interested in biomedical engineering and biotechnology. We do not look upon these students as aliens. Rather, we believe that the most productive route to biomedical engineering is the general Biological Engineering curriculum. All students, no matter what their eventual goals, are exposed to medical, environmental, agricultural, biotechnical, psychological, and sociological issues and applications. The faculty are convinced that this will mold superior biomedical engineers, as well as others, who can have a better appreciation for the many integrated aspects of the biological world in which we live. Student interests have stretched the technical horizons of the BRE faculty, but this has been accepted as a small price to pay for a dynamic undergraduate student body. Some faculty even feel this to be an advantage.

8. close ongoing identification with engineering

Once the decision had been made to metamorphose from Agricultural Engineering into Biological Engineering, the justification for the undergraduate program to be administered in the College of Agriculture weakened considerably. After the interests of the students became predominantly biomedical engineering, the faculty realized that survival of the BRE program depended upon being identified as the only program offering biomedical engineering at Maryland. When the College of Engineering moved toward the establishment of a graduate Bioengineering program and then a Department of Bioengineering, the course of action needed for survival was clear. On November 1, 2004, a petition signed by ten of thirteen BRE faculty was delivered to the Provost requesting that the Department and its engineering programs be moved administratively to the College of Engineering. Administrative and financial issues are now being discussed by the University administration, and the outcome could well be a strong Biological Engineering program totally identified with the College of Engineering and enthusiastically supported by the Dean of Engineering.

Unique Courses

With a blueprint provided by the foundational paper by Johnson and Phillips (1995) and the report by Garrett et al. (1992), the faculty has developed several courses unique to the University of Maryland. Course development is continuing, with the goal of providing the best possible Biological Engineering program consistent with previously-stated goals. Therefore, it is expected that additional changes will be made in course titles, course contents, and teaching methods. When the program becomes fully administered in the College of Engineering, it is expected that faculty presently in other engineering departments will join the Biological Engineering Department and offer an even wider range of general and specialty courses. Thus, the program will continue to evolve and become better adapted to student and employer needs.

Some of the unique courses are described briefly:

1. Biology for Engineers

    This course covers the full range of biology from genetics to ecology, and including some psychology, sociology, allometry, and the basic sciences of physics, chemistry, mathematics, and engineering sciences. The approach taken is the utilization of biology in an integrated fashion. Topics covered include artificial organs, neural engineering, imaging, molecular sieves, control of prostheses, biosensors, human factors, reliability theory, biomarkers, endocrine disruption, RNA interference, cellular receptors, and many other important topics in Biological Engineering and biological utilization. This is an overview course meant to develop perspective, and so may be taken by freshmen together with seniors and graduate students. Material for this course is available on the web at www.bre.umd.edu/johnson.htm.

2. Systems Approach to Transport Processes.

    This course is intended to give students an appreciation for the fundamental nature of transport processes and to show how these concepts can be generalized to apply to a range of applications much wider than traditionally given. Systems concepts of effort and flow variables are developed and detailed with fluid flow, heat transfer, mass transfer, and some electrical applications. Similarities are explored, and design problems are given in the three major transport processes with application in medicine, biotechnology, and environment. Written communications skills are emphasized, and group skills are developed. This course is one of the harder courses in the curriculum in the amount of student and faculty effort required.

3. Biocycles:

A biological engineer needs to understand the interaction between living organisms, their food webs, and conditions in which each organism may be capable of living and functioning. Different systems, including Biosphere, Hydrosphere, Lithosphere, and Atmosphere are covered to give the students a sense of interconnectivity as different cycles from different systems interact to sustain life as we know it. Students are first introduced to the "Gaia" theory proposed by James Lovelock.

With the Gaia theory as a base, students then learn about different cycles and ecosystems dynamics. The course describes energy flow and chemical cycling through the ecosystem. Using appropriate flowchart diagrams, energy flow originating from the sun and flowing through different components of the ecosystem is described. It concludes that energy flows through the ecosystem rather than being recycled, thus necessitating an external source of energy like the sun. Chemical elements (e.g., carbon, nitrogen, phosphorus) recycle between abiotic and biotic components of the ecosystem.

Describing different biocycles makes students appreciate equations that may be used to determine population dynamics of living species with respect to the availability of each element required for survival.

4. Capstone Design Courses

The capstone course has several practical objectives. The lecture in the first semester (1 credit hour) covers design from project conception to commercial production; ethics; the engineer as a driver of change in society; one lecture on practical material such as types of threads, bolts, materials, etc.; aesthetics and human factors engineering; interviewing; and job hunting. The project forces students to bring together all the mathematics, engineering, biology, human needs, and other courses they have had and apply the concepts and knowledge to a single design. The fact that students have to dig into patents, library references, suppliers catalogues, design manuals and other sources teaches life long learning and how to find the information a designer needs. Students find that there are many practical things they need to know that they will not learn from books, such as that aluminum cannot be welded to stainless steel, pipe threads are tapered for a reason, etc. Most importantly the project prepares students for the work world and gives them the confidence they need to successfully carry out designs in their first job.

During the second semester (2 credit hours) the student groups meet only with their faculty mentor, typically for an hour per week. The group then builds the design, with appropriate machine and electronics help, and tests the design against their original design specifications that were developed during the first semester. They present their design and test results to the faculty and provide a report on the project to their mentor at the end of the semester. The manufacture and testing of the device forces students to select materials, purchase parts, estimate labor and costs, find suppliers for parts and materials, understand the importance of how design specifications are selected so they can be tested, and all of the other small but important activities needed to build and test a device. The capstone gives students an insight into engineering practice.

Dynamic Pressures

The University of Maryland is presently experiencing pressures to a degree that has not happened before. First among these is the pressure of national rankings. It has been the goal at the University of Maryland to improve its *U.S. News and World Report* ranking, and programs within the University are also feeling the same pressure. The second cause of pressure is the tendency for faculty tenure decisions to rest unevenly on research productivity and external funding. Because of this, many younger faculty are paying less attention to teaching effort, which leads to uninspired courses and grade inflation. In addition, there is now cost reduction pressure coming from the Board of Regents. University of Maryland faculty are now expected to teach 10% more courses and it is proposed to penalize students who either take more than 5 years to complete their degrees or take more than 120 credit hours without finishing their degrees.

The students are different these days. They appear to be less patient, less likely to think creatively, and expect more individual attention. The society is changing, as it always has, and students reflect many societal influences. In this dynamic, it is easy for program quality to be lost.

Effect of Globalization

Changes are occurring that will have profound effects on engineering and engineering education. There are three interesting articles in the Fall 2004 issue of *The Bent of Tau Beta Pi* that point to these changes. The first article is a short announcement of a Forrester Research report that projects a 40 percent increase in outsourced service jobs, including engineering and architecture, by the end of 2005 (Bent, 2004). The second is an editorial referring to the July 9, 2004 issue of *The Chronicle of Higher Education* in which eight pages were devoted to the question of supply of engineers and scientists. Although it is not yet generally conceded, the author of this editorial concluded that an oversupply of engineers is likely to become reality in the near future (Froula, 2004). IEEE, the editorial states, has already become alarmed by a seven percent unemployment rate of electrical engineers. And, our colleges and universities are educating new engineers at a near record level of over 75,000 per year. Asian universities are producing over 400,000 engineers per year, and these engineers, working at much lower salaries than their U.S. counterparts, are already competing with U.S. engineers on a global level.

The third *Bent* article is written about techonomics, or the means by which technology affects the cost of goods and services (Martin, 2004). A short passage from this article makes an important point:

> With the availability of nearly perfect information made possible by the global information network, many of the traditional transaction costs of outsourcing are significantly diminished. Specifically, location of multiple sources is now made easily, which causes switching costs to decrease and availability issues to diminish. External competition for traditionally internal transactions is both facilitated and accelerated. The pendulum shifts to the "buy" decision and away from the internal "make" decision as the quality and quantity of information expand for decision-makers.
>
> The Law of the Innovation Economy anticipates a diminishing number of employees in an optimally sized corporation as all but the most essential functions are outsourced. The reduction in organizational size will be accompanied by an increasing number of efficient organizations—the age of the small business is upon us in the free market economy. Job growth statistics in the last decade bear this out.

It should be clear that the future holds many changes for engineering education, including the education of medical and biological engineers. Indeed, the major question to be asked is "what are the essential skills to be possessed by biological engineers so that they won't be the ones displaced in the future?" This is a much broader question than one of simply listing the technical areas to be covered in the education process. Indeed, the program at the University of Maryland is headed in the direction to improve:

1. fundamental skills
2. thorough, but general knowledge of biology and engineering interrelationships
3. ability to make technical decisions and engineering judgments
4. communications skills
5. ability to accept new information and place it into a previously-arranged, general context.

The result is to produce a versatile engineer who can perform at many different levels and in many different scenarios. As has been stated before, the biological engineer [who has a solid future] must be a "specialist in technical diversity" (Johnson, 2005).

Under this scenario the technical specialist has a very limited future outlook. Those who can run Computational Fluid Dynamics (CFD) computer programs, or who can clone organisms will find employment in specialty-job shops and compete against other similar organizations all over the world.

In the 1970s and 1980s, biomedical engineers were graduating from educational institutions but were having a difficult time finding employment. The talk among industry representatives was that biomedical engineers weren't good engineers, that electrical, mechanical, or chemical engineers could be hired and taught biology, and that these "engineers first" could be much more valuable to industry than biomedical engineers. A look at typical biomedical engineering educational curricula of the time, however, reveals something a little different. Biomedical engineering students were often not taking many, if any, biology or physiology courses, and so were not well-versed in the life sciences. Hence, not only were they lacking in engineering specialty skills, but they didn't have expertise in their so-called area of biomedicine specialty.

There are those in industry who still talk about hiring engineers first and then teaching them biology afterward. The world of biology, however, has become much more complex. There truly is a need for engineers versed in biology, but their ability to make engineering judgments about the use of living things is key to whether or not they meet this need. It is not sufficient to give students examples in class; that is what biomedical engineers of the '70s and '80s were being given, and it wasn't sufficient.

You may see distinct differences appear in the educational programs from different biological engineering programs. Some, like Maryland, may aim to produce generalists grounded in practicality. Others may aim to produce more theoretical engineers capable of highly specialized problem-solving. Future techonomics projects that there will be more competition among educational institutions; the educational process itself will become subject to the same competitive and evolutionary pressures that govern change in the biological realm. If there develops an oversupply of medical and biological engineers then success of an educational program will be judged by the ability of its graduates to be placed into desirable employment. This is certainly a much different environment than has existed up until this point. Only those programs that remain flexible and changeable, able to meet the needs of the present and the future, will survive. To that extent, a rigid list of required competencies for medical and biological engineers could become obsolete within a fairly short time span. The need is for flexibility and giving the students the ability to continue learning.

More Immediately

In the near future, current trends in student enrollment are expected to continue. Total enrollment could very well double in the next few years, with the majority of students being female. Ethnic, cultural, and national origin diversity has increased greatly in the last few years, and this trend is also expected to continue (Table 6). Again, there is a challenge for instructional faculty to adjust teaching methods to be appropriate to the full range of student learning styles displayed in class, and to be able to give individual students adequate attention despite larger class sizes. Teaching methods must continue to adjust, and technical contents of courses must continue to be modified. The foundational Biological Engineering curriculum, however, has been successful thus far, and this is a good basis from which to make further changes when the need becomes apparent. To stop making such changes would be to risk becoming the educational equivalent of an extinct species.

Biological Resources Engineering

Required Courses and Sample Curriculum Outline

Freshman Year - Fall Semester

		Credits	
ENES	100	Intro. to Engr. Design	(3)
MATH*	140	Calculus I	(4)
CHEM*	135	General Chemistry I	(3)
BSCI	105	Principles of Biology I	(4)
ENBE	110	Intro. Biol. Res. Engr.	(1)
		Total	(15)

Freshman Year - Spring Semester

		Credits	
ENES	102	Statics	(3)
MATH*	141	Calculus II	(4)
CHEM*	136	General Chemistry Lab	(1)
PHYS*	161	General Physics	(3)
ENGL	101	Introduction to Writing	(3)
		Total	(14)

Sophomore Year - Fall Semester

		Credits	
CHEM	231	Organic Chemistry	(3)
BSCI	223	General Microbiology	(4)
ENES	220	Mechanics of Materials	(3)
PHYS	260	General Physics	(3)
PHYS	261	General Physics Lab	(1)
CHEM	232	Organic Chem. Lab	(1)
		Total	(15)

Sophomore Year - Spring Semester

		Credits	
MATH	246	Differential Equations for Scientists & Engineers	(3)
ENME	232	Thermodynamics	(3)
BSCI	230	Cell Biol. & Physiology	(4)
ENBE	241	Computer Use in Bio-resources Engineering	(3)
		[CORE course]*	(3)
		Total	(16)

Junior Year - Fall Semester

		Credits	
ENBE	453	Intro. Biol Matls.	(3)
ENME	331	Fluid Mechanics	(3)
or ENCE	305	Basic Fluid Mechanics	(3)
ENBE	455	Basic Electronic Design	(3)
MATH	241	Calculus III	(4)
		[CORE course]*	(3)
		Total	(16)

Junior Year - Spring Semester

		Credits	
ENBE	454	Biol. Process Engineering	(4)
ECON	200or 201	Princ. of Econ. (or appv=d)**	(4)
		[BIOL SCI tech elect.]	(3)
		[ENGR SCI tech elect.]	(3)
		[CORE course]*	(3)
		Total	(17)

Senior Year - Fall Semester

		Credits	
ENBE	471	Biol Syst Control	(3)
ENBE	422	Water Res. Engr..	(3)
or ENBE	456	Biomedical Instrumentation	(3)
ENGL	393	Technical Writing	(3)
ENBE	485	Capstone Design I	(1)
		[BIOL SCI tech. elect.]	(3)
		[CORE course]*	(3)
		Total	(16)

Senior Year - Spring Semester

		Credits	
ENBE	482	Dyn. Biol Syst.	(1)
ENBE	484	Engineering in Biology	(3)
ENBE	486	Capstone Design II	(2)
		[ENGR SCI tech elect.]	(3)
		[ENGR SCI tech elect.]	(3)
		[CORE course]*	(3)
		Total	(15)

*Satisfies Campus-wide CORE General Education Requirements TOTAL Credits Required (124)
**ECON 200 or 201 satisfies CORE SB

Biological Sciences technical electives [BIOL SCI tech elect] may be chosen, depending on students' interests, from an approved list of courses in the following programs: Agronomy, Animal Sciences, Biology, Chemistry/Biochemistry, Entomology, Environmental Science and Policy, Nutrition & Food Science, Geography, Geology, Hearing and Speech, Health, Horticulture, Kinesiology, Meteorology, Microbiology, Natural Resources Management, Plant Biology, and Psychology.

Engineering Sciences technical electives [ENGR SCI tech elect] may be chosen, also depending on students' interests, from among the following programs: Aerospace Engineering, Biological Resources Engineering, Civil and Environmental Engineering, Chemical Engineering, Electrical Engineering, Fire Protection Engineering, Materials Engineering, Mechanical Engineering, and Nuclear Engineering.

A course can be used to satisfy biological science electives, and advanced studies for CORE, if approved by your advisor. Following are examples of these courses: GEOG 345 GEOG 446 GEOG 467 HLTH 471D PSYC 341 PSYC 356
GEOG 434 GEOG 462 HLTH 456 PSYC 310 PSYC 355 PSYC 357

Pre-medical students should select as biological science technical electives: CHEM 243 and BSCI 422. They should also take CHEM 103 and CHEM 113 instead of CHEM 135 and CHEM 136. In addition, most medical schools require 8 credits of physics including two labs. Contact premed advisor (301-405-2793) for more information

Pre-veterinary students should select as biological science technical electives: CHEM 243 and BCHM 261 or BCHM 461. Some veterinary schools may require additional chemistry. Check with your advisor.

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Table 1: Average percent annual enrollment change post name change (Young, 2004)

Curricula Name	# of Curricula	Average annual % change	Standard Error	95% Confidence Interval
Agr Engineering	5	0.6	4.53	(-8.2, 9.5)
Agr & Biological Engineering	4	4.0	5.08	(-6.0, 13.9)
Agr & Biosystems Engineering	2	-1.1	8.10	(-17.0, 14.8)
Agr & Bioresource Engineering	1	2.0	8.99	(-15.6, 19.7)
BioResources & Agr Engineering	1	-3.8	12.46	(-28.2, 20.6)
BioSystems & Agr Engineering	1	-1.0	10.00	(-20.6, 18.6)
Biological & Agr Engineering	1	3.0	9.46	(-15.5, 21.6)
Food, Agr & Biol. Engineering	1	13.5	11.45	(-9.0, 35.9)
Biological Engineering	8	18.1	3.87	(10.5, 25.7)
Biosystems Engineering	7	7.4	4.49	(-1.4, 16.2)
Biological Systems Engineering	5	9.9	4.97	(0.2, 19.7)
Biological Resources Engineering*	1	30.2	8.99	(12.5, 17.8)

*University of Maryland

Table 2: Primary Reasons for Attending Maryland
(Provided by 19 ENGR Respondents)

	BIOLOGICAL RESOURCES— ENGR "YES" RESPONDENTS **2004**
1. Program/Faculty	42.1%
1. Reputation/Quality	42.1%
2. Location/Distance	31.6%
2. Cost	31.6%
(Affordability/Scholarship)	(26.3%)(5.3%)
3. Academic Offerings	21%

Table 3: Primary Reasons for Not Attending Maryland
(Provided by ENGR Respondents)

	BIOLOGICAL RESOURCES— ENGR "NO" RESPONDENTS **2004**
1. Location/Distance	13.3%
1. Program/Faculty	13.3%
2. Cost	6.7%
(Affordability/Scholarship)	(0.0%/6.7%)
2. Academic Offerings	6.7%
2. Reputation/Quality	6.7%

Table 4: Ratings from Graduating Seniors on how well the Biological Resources Engineering curriculum has succeeded on a scale of 1 (not successful) to 5 (most successful).

Objective	Graduation Year			
	2002	2003	2004	All
The ability to design products and processes related to biological systems.	4.63 ± 0.50 (16)	3.94 ± 1.03 (17)	4.41 ± 0.59 (22)	4.32 ± 0.69 (55)
The ability to communicate well, especially with engineers and non-engineering biological specialists.	4.56 ± 0.63 (16)	4.18 ± 0.88 (17)	4.32 ± 0.48 (22)	4.35 ± 0.58 (55)
The ability to work successfully in teams	4.81 ± 0.66 (16)	4.35 ± 0.86 (17)	4.68 ± 0.72 (22)	4.62 ± 0.68 (55)
The ability to conceptually categorize information, especially biological information, in order to deal effectively with technical advances coming at a rapid pace.	4.63 ± 0.50 (16)	3.82 ± 1.13 (17)	4.15 ± 0.67 (20)	4.19 ± 0.81 (53)
An engineering education with a solid grounding in fundamentals that will have lifelong value.	4.69 ± 0.48 (16)	3.79 ± 1.08 (17)	4.10 ± 0.94 (21)	4.18 ± 0.88 (54)
An understanding of human behavior, societal needs, and forces, and the dynamics of human efforts and their effects on the environment	4.44 ± 0.63 (16)	3.47 ± 1.23 (17)	4.36 ± 1.14 (22)	4.11 ± 1.05 (55)

Values given are means ± standard deviations. The number of respondents is in parentheses.

Table 5: Interest areas for undergraduate students in Biological Resources Engineering.

Interest Area (May select more than one)	Percent with Interest* 1998	2004 Freshman
Agricultural Engineering	16	___
Animal Systems Engineering	6	___
Aquacultural Engineering	22	___
Biomedical Engineering/Biotechnology	77	77
Ecological Engineering	36	2
BioEnvironmental Engineering	47	8
Food Engineering	14	___
Pre-Vet	___	4
Water Resources Engineering	37	___
Undecided	___	8
Other	7	2

* Percentages add to more than 100% due to multiple area selection by students.

Table 6. Diversity Data for Biological Resources Engineering.

		Term			
Gender	**Race/Ethnicity**	**Fall 2001**	**Fall 2002**	**Fall 2003**	**Fall 2004**
Female	Asian:U.S.	13	15	20	22
	Black/African-American:U.S.	6	10	10	8
	Foreign	1	2	3	2
	Hispanic:U.S.	6	6	4	4
	Unknown:U.S.	2	3	3	4
	White:U.S	30	26	22	28
	Sub Total	58	62	62	68
Male	Asian:U.S.	11	16	19	19
	Black/African-American:U.S.	6	5	6	6
	Foreign	1	1	2	2
	Hispanic:U.S.	0	1	2	3
	Unknown:U.S.	1	0	7	9
	White:U.S.	38	38	33	29
	Sub Total	57	61	69	68
Total		115	123	131	136

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