

## A New BME Curriculum for the 21<sup>st</sup> Century

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### Abstract

This paper describes the design and content of a new undergraduate degree program in biomedical engineering at the University of Tennessee, Knoxville. Program enhancement with the use of advanced teaching tools and the Internet is discussed.

### I. Introduction

The field of biomedical engineering (BME), defined as a new engineering discipline in the mid-twentieth century has been the focus for the development of new degree programs at many universities for over forty years. At present most major universities and colleges offer BME degree programs at either or both undergraduate and graduate levels. The growth in the number of BME programs has been a response to several factors including:

- the steady development of new technologies impacting health care
- a high level of government funding of BME research
- a high level of interest in the BME field among university students

For institutions with BME degree programs, there has been a need for regular curriculum updating and improvement to maximize the educational benefit to students. A major such updating has occurred recently in the BME program of The University of Tennessee, Knoxville campus (UTK) as detailed below.

Since the early 1970's The University of Tennessee, Knoxville had offered an undergraduate Engineering Science (ES) Program BME option. This option program was built around a curriculum concentrated in mathematics and the engineering sciences (mechanics of solids and fluids, thermal and material sciences) and featured 18 hours of technical electives. To accommodate students having interest in the field of biomedical engineering, several BME faculty were hired and five undergraduate and two graduate BME elective courses were developed and were offered regularly over a period of more than twenty-five years. During the recent past, it was noted that 80% or more of the 80-100 students enrolled in the undergraduate ES degree program selected the BME option. For this reason and the decreased interest of students in other engineering science sub-disciplines, it was decided by the faculty of the parent department (Mechanical and Aerospace Engineering and Engineering Science) that a new undergraduate program in BME should be developed to replace the undergraduate ES program. Subsequently, during the 1999-2000 academic year, a new curriculum was developed, and was initially offered to students in the fall 2000 semester.

## II. Program design criteria

In designing our new undergraduate BME degree program our faculty had the advantage of a “fresh start” and in fact none of the original ES BME option program elective courses were retained in the new curriculum. The set of guidelines adopted for the content of the new BME degree program included the following:

- ABET criteria for BME degree program accreditation are required to be met; a particular need is to effectively integrate the life sciences with engineering subjects in curriculum coursework.
- The curriculum is packaged as a four-year program in order to compete effectively with other regional schools offering four-year BME programs.
- The curriculum is to have a strong foundation in basic engineering sciences (physics, fluid and solid mechanics and the thermal sciences).
- It was desired to include a sufficient number of course electives so that from time-to-time new courses could be developed and offered as electives to provide an introduction to emerging BME technologies. In addition, with a substantial number of electives, the curriculum could serve as a basis for medical school application.

## III. Curriculum structure

Our new undergraduate BME curriculum is presented in detail in Table 1 below. As can be noted, the curriculum totals 135 semester hours with scheduled semester course loads varying from 16 to 18 hours. The curriculum overall is built on the foundation of a balance of engineering sciences, mathematics, BME core and other courses as follows:

Engineering sciences:	30 hours
Basic sciences: (chemistry, biology, physics, material science)	22
Mathematics	16
BME core courses:	24
BME elective courses:	6
Technical elective courses:	6
Other required courses:	31

The structure of the curriculum incorporates a three-year-old modification to a common first year which includes two six-hour fundamentals of engineering courses. The content of these courses (which have been described in detail elsewhere<sup>1</sup>) includes statics and dynamics, MATLAB computer methods and numerous analysis and design exercises. While the second year of the program gives attention to building competence in basic engineering sciences, a two-course sequence in basic biology is included to provide the background for the integration of biological

**Table 1: UTK Biomedical Engineering Curriculum**

<b>FALL</b>		<b>SPRING</b>	
<b><u>Freshman</u></b>			
English 101	3	English 102	3
Chem 120 Chem I(w/lab)	4	Chemistry 130 Chem II(w/lab)	4
Math 141 Calc I	4	Math 142 Calc II	4
EF 101 Engr. Fund. I	<u>6</u>	EF 102 Engr. Fund. II	<u>6</u>
	17		17
<b><u>Sophomore</u></b>			
Phys 231 Elect & Mag	3	Physics 232 Waves & Modern	4
Math 241 Cal III	4	Math 231 Diff Eqs	3
ES 231 Dynamics	3	Math 200 Matrix Comp.	1
BME 271 Intro to BME	3	ES 321 Mechanics of Materials	3
Biol 130 Gen Biol	<u>4</u>	Biol 140 Cell Biology	4
	17	MSE 201 Intro to Mat. Sci	<u>3</u>
			18
<b><u>Junior:</u></b>			
Tech Elective	3	Technical Elective	3
EE 301 Circuits	3	BME 346 Design of Experiments	3
ES 341 Fluid Mechanics	3	BME 310 Biomechanics	3
BME 300 Eng. Physiology	3	ME 331 Thermodynamics	3
MSE 474 Biomaterials	3	BME 301 Jr. Seminar	1
Economics 201	<u>3</u>	Philosophy 345 (Medical Ethics)	<u>3</u>
	18		16
<b><u>Senior:</u></b>			
BME 455 BME Design	2	BME 469 BME Design II	4
BME 430 BME Laboratory	3	BME Elective	3
Engineering Electives	6	General Ed Elective	<u>9</u>
General Ed Elective	3		16
ME 402 Review Eng. Fund.	1		
BME 431 Sr. Seminar	<u>2</u>		
	16		
		Total = 135 Semester Hours	

sciences with engineering in the BME specialty courses to follow. The field of biomedical engineering is introduced to students in a three-hour introductory course in the first semester of the sophomore year. The inclusion of this course early in the curriculum serves to build and maintain student interest in the BME field since all but one of the BME specialty courses are placed in the last three semesters of the program. In the first semester of the third year a BME course on engineering physiology is included. This is the first course designed to integrate the presentation of physiological principles with engineering methods mainly through coverage of

applications such as the measurement of selected physiological variables. Also in this semester, on a just-in-time basis following courses in chemistry and the mechanics of materials, a course in biomaterials is presented. In response to industrial advisor input related to clinical device evaluation, and to satisfy the need for coverage of basic statistics, a BME course on the design of experiments is included in the second semester of the third year. A first course in biomechanics is also placed at this point in the curriculum. One additional core course in the first semester of the senior year is a BME laboratory course that includes a cross-section of exercises involving “hands-on” experience. As is common in undergraduate engineering programs, the senior year includes a two-semester sequence in engineering design. To assure that our BME students are exposed to a broad range of available design tools, they will be trained along with our large body of mechanical engineering students in the use of modern mechanical design methods. Following this basic training, BME student teams engage in a one semester-long exercise focused on the design of a specific clinical device.

The curriculum includes two BME seminar courses, one in the junior year and one in the senior year. The first includes coverage of subjects important to the BME field but not included in other core courses such as clinical device testing and governmental regulation. The second seminar course is targeted on career issues including PE registration, opportunities for graduate study and techniques for job placement in the BME field.

In the design of any undergraduate engineering curriculum, it is always challenging to provide an optimal balance between the coverage of important core subjects and elective courses. It was deemed important to allow for a sufficient number of electives so that the basic curriculum could suitably accommodate introductory coverage of emerging BME practice areas such as tissue engineering and nanoinstrumentation. In addition, we have historically had substantial numbers of BME students desiring to enter medical school. For these reasons our new curriculum includes a total of 15 hours of engineering and technical electives. The six hours of open technical electives allow students intending medical school to meet at least two of any required prerequisite courses beyond the required year of basic biology.

#### IV. BME Core courses

The content of the 24 semester hours of BME core courses is as follows:

BME 271 Introduction to Biomedical Engineering; placed early in the curriculum to generate and maintain student interest in the BME field; introduction of clinical vocabulary; building of teaming, communication and independent literature search and communication skills.

BME 300 Engineering Physiology; human physiology principles taught in an interdisciplinary context; builds on general and cellular biology; emphasis on engineering modeling in the application of quantitative biology.

BME 301 Seminar; current topics in BME field; discussion of BME careers.

BME 310 Biomechanics; applications of statics, dynamics, strength of materials, fluid mechanics, and material science to biological systems; engineering applications on a range of scale from cellular to whole body levels.

BME 346 Design of Experiments; introductory statistics; applications to the design of experiments on living systems and medical device evaluation.

BME 430 BME Laboratory; set of laboratory exercises in selected areas of BME application: bio-fluid and bio-solids property measurement; BME instrumentation; simulations.

BME 431 Seminar: invited speakers; professional opportunities for BME professionals; job search techniques.

BME 455 BME Design: Basic non-technical factors in design: economic, legal, FDA regulation; design tools and methods.

BME 469 Design Project: BME team design projects; projects originating with BME industry, local medical community, UT School of Veterinary Medicine; presentation of project results to customers.

#### V. Incorporation of modern teaching methods

In the design of all new engineering degree programs it is imperative to include coverage of basic tools subjects (e.g. mathematics, engineering sciences) and state-of-the-art topics needed by graduates to be optimally prepared for the marketplace. In the BME field however, there are several characteristics of typical employment settings that need to be considered in deciding on the manner in which curriculum courses are packaged and delivered. In particular, BME professionals must be proficient in working in interdisciplinary teams and in communicating with health care professionals and they must be proficient in acquiring data from a variety of diverse sources. For these reasons we sought to identify and utilize in our BME core courses one or more instructional innovations beyond the traditional lecture delivery format. Based on a survey of currently available systems, we have chosen to utilize the method of “process education” in several of our courses. This teaching approach based on student self-motivation and goal-setting emphasizes teaming and role-playing within student teams. The use of this method in our introductory BME course is described in detail in a companion paper<sup>2</sup>. In addition to the use of a “process education” format in course instruction, it is planned to utilize several other methods to enhance student learning experiences including the following:

- Student teaming in all BME courses to complete major project assignments
- Frequent student in-class presentations of assigned work
- Regular in-class group discussions of case studies to illustrate course principles
- Use of internet-based course reference materials

## VI. Internet-based distance education

With the sequential development of the BME core courses in an internet-ready format, it will be possible to offer UTK BME courses to other universities. For institutions with an established BME degree program it will be advantageous to reciprocally offer specialized course modules and entire courses to partner institutions not having faculty expertise in all BME subject areas. In this regard, we have begun exploring possibilities for reciprocal Internet course offerings between UT and other universities in Tennessee.

## VII. Summary

The establishment of a totally new undergraduate BME program at the University of Tennessee has offered a unique opportunity to achieve excellence in contemporary BME education. By constructing a program based on traditional basic engineering coursework, a block of optimally-sequenced BME core courses and a sizable block of course electives, our new BME curriculum prepares students for both advanced study and work in BME industry. Finally, with the use of proven advanced teaching methods and Internet-based education, we are striving to broaden and optimize the impact of our new program to maximize the ultimate professional achievement of our graduates and the mutual success of our partnering institutions.

### Bibliography

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### RICHARD JENDRUCKO

Richard Jendrucko is currently Associate Department Head and Professor in the Department of Mechanical and Aerospace Engineering and Engineering Science. He has served as the Program Coordinator for the department's Biomedical Engineering Program and has been active in teaching biomedical engineering for over twenty-five years. Professor Jendrucko has also served as ASEE Biomedical Engineering Division Chair.

### JACK WASSERMAN

Jack Wasserman is a professor in the Department of Mechanical and Aerospace Engineering and Engineering Science where he has taught in the biomedical engineering program for over twenty-five years. He serves currently as Coordinator for the Biomedical Engineering Degree Program. Professor Wasserman is the recipient of seven teaching awards and he holds the position of Fellow in the Center for Undergraduate Excellence and the Interactive Technology Center at the University of Tennessee, Knoxville.