Teaching biomedical engineering in a nonspecialized engineering department: an integrated approach

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Abstract

The engineering department at Harvey Mudd College offers unspecialized Bachelor’s and Master’s degrees in engineering. However, an engineering major may choose to emphasize a particular engineering specialty by an appropriate choice of three elective courses and two Engineering Clinic projects. Over the last few years, the department has witnessed a significant increase in numbers of both students interested in biomedical engineering (BME) as well as industry sponsored clinic projects in this field. “Introduction to Biomedical Engineering” is an elective course designed to introduce students to major areas of BME, to identify where their interest lies before deciding what they might pursue, either as professional engineers in industry or as graduate students. While the syllabus is intentionally broad, the breadth of topics covered in class is supplemented by a required class project in a specific area chosen by the student. Lectures cover areas of physiology, medical instrumentation, biomedical optics, biosystems analysis, biomechanics and biomaterials.

Introduction

The Harvey Mudd College (HMC) catalog states “Based on the premise that the primary function of engineering is design, the engineering program provides broad-based knowledge and experience in synthesis as well as analysis. It is designed to prepare students for professional practice as well as advanced study in various engineering specialties.” An interdisciplinary approach to problem solving is the underlying theme of the curriculum. Students graduate with an unspecialized Bachelor’s or Master’s degree.

A sequence of systems courses that unites all engineering fields under a common framework is at the core of the curriculum. This sequence integrates knowledge gained from a thorough background in engineering science and computer science while technical electives provide opportunity to study specialized areas in depth. In addition, professional experience that draws on this broad knowledge base is provided by challenging industry sponsored design problems in the engineering clinic. The clinic brings together teams of students to work on carefully selected projects under the monitoring and evaluation of professors. Thus the program is built around engineering science, systems, and design. It is believed that this broad engineering program is most likely to produce engineers capable of adapting to changing technology.

An engineering major may choose to emphasize a particular engineering specialty by appropriate choice of elective courses and engineering clinic projects. Specific programs tailored to individual needs are developed in consultation with an engineering advisor. Technical electives available to students in the engineering department until spring 1996 were in the areas of civil/structural engineering, chemical engineering, computer engineering, electrical engineering, materials engineering, and mechanical engineering. Over the last few years...
student interest in BME has increased tremendously. The number of clinic projects in BME has been rising steadily in the nineties, with 7 (out of 28) projects sponsored by industries in this sector during 1995-96. To accommodate this emerging area in the curriculum, a new course in BME was offered for the first time in spring 1996.

**Course Design**

To take advantage of rest of the engineering curriculum, and because this is a nonspecialized department, it was decided that the introductory BME course must a) Cover all major areas of BME, and b) Also provide a mechanism for pursuit of narrow topics of interest.

We believe that one of the messages that needs to be conveyed in an introductory BME course is that a clear understanding of the appropriate physiology is essential prior to design of engineering systems capable of interacting with living systems in a desired fashion. Any tendency to keep the physiology at arm’s length in this multidisciplinary field would be counterproductive. Therefore it was decided that basic physiology would be a component common to lectures in the areas of biomedical measurements, biomedical optics, physiological systems analysis, biomechanics, and biomaterials. A syllabus (see table 1 for details) comprising these topics was created such that the essence of each area could be conveyed in a short series of lectures. The syllabus also takes into consideration the fact that enrolled students would have already taken most if not all of the five required engineering science courses- chemical engineering principles, introduction to electrical engineering, materials engineering, introduction to computer engineering, and engineering mechanics.

Students were also asked to choose a specific topic for the class project. Since this course is a technical elective, they were told that their project goal should be to get credit for researching a topic they have been curious about for a long time. The project could be a well-researched and carefully put together “report”; it could also be a working model (to be accompanied by a written report). Students were encouraged to work in teams of up to three individuals. A 15 minute presentation during the last week of classes was required of all teams. Attending every project presentation was made compulsory.

Other logistics included weekly homework assignments, and three in class exams. The exams included both multiple choice questions and traditional problem sets to allow for effective testing of the breadth of material covered.

**Project Descriptions**

In this first offering of the course, projects ranged from literature surveys describing shortcomings and needs of current technology to more focused topics which involved finding answers in the literature to specific questions that were posed by student teams. If the questions were not answered adequately by literature and patent searches, the teams would write brief proposals describing how they might go about solving the problems. While this approach might be considered a trifle advanced for an undergraduate class, it seems appropriate in order to meet the overall goals of the course. Besides, the students at HMC possess the credentials to successfully undertake such a task.

This year, project proposals on the following topics were submitted by students in the third week of classes: shortcomings of current artificial heart designs, models of prosthetic knee replacements, feedback and control in artificial limbs, the future of functional electrical stimulation, veterinary applications of electrostimulation, optical pulse based oximetry, DNA diagnostics software, optimization in understanding
myelin models, applications of shape memory metals, bone regeneration using piezoelectric bone properties, techniques of biomaterials sterilization.

Enrollment

28 junior and senior students were enrolled in the class. Considering the size of HMC (60-70 engineering graduates each year) this is a fairly large number. While most of the students were engineering majors, there was representation from biology, chemistry, and physics majors as well. In a survey taken at the beginning of the course, students’ plans after graduating included graduate school in BME, medical school, industry, entrepreneurial ventures, and consulting setups. Areas of interest included the entire gamut of research and development in the field ranging from medical instruments, and physiological systems analysis, to biomechanics, and biomaterials.

Table 1

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<th>Syllabus</th>
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<td><strong>Basic Physiology and Biomedical Measurements.</strong> Appropriate anatomy, physiology, and neurophysiology of various subsystems of the human body are presented along with biomedical measurement methods and usage of various biomedical instruments available for patients care (diagnosis, monitoring treatment etc.). Introduction to circuits for biomedical applications using operational amplifiers, data acquisition, patient safety.</td>
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<td><strong>Biomedical Optics.</strong> Therapeutic applications of lasers. Various types of lasers, laser-tissue interactions, concept of selective photothermolysis, and methods of temperature measurements are presented. Clinical uses of lasers in dermatology for treatment of various vascular and pigmented lesions, and recent developments in urology for treatment of benign prostatic hypertrophy and prostate cancer are also discussed.</td>
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<td><strong>Biosystems.</strong> Applications of systems analysis and control theory in the study of biological systems. This includes development of computer simulation techniques to study the dynamic response of physiological systems, identification and simulation techniques utilizing linear and some nonlinear models. Selected aspects of eye-movements, pupillary response, cardiovascular systems are used as examples and problems.</td>
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<td><strong>Biomechanics.</strong> Static strength, stiffness, fatigue strength and materials used in the design of biomedical engineering systems are presented along with case studies covering different aspects of biomedical engineering systems. Spinal biomechanics and cardiovascular fluid mechanics are emphasized.</td>
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<td><strong>Biomaterials.</strong> Introduction to the use of artificial and natural materials in the human body. Properties, compatibility characteristics and performance requirements of materials for implants, and facial and dermal prostheses. The concept of biocompatibility is developed, along with mechanical, immunological, and toxicological aspects of compatibility between materials and the body.</td>
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Discussion
While the lectures clearly take a shotgun approach to teaching BME, this seems to have specific advantages with respect to what we are trying to achieve at HMC. Students here have only three technical elective courses left to their choice. By providing a glimpse into almost every major area of BME in a single course, and by exposing the class to several specific applications via class project presentations, it is hoped that the students will pass the course having been exposed to both fundamentals and cutting edge knowledge. In the survey taken at the beginning of the semester, a majority of the students indicated that they were very interested in applying technology to living systems directly but were not aware of how various modalities of bioengineering accomplished this. Thus the goals set for the course matched very well with student expectations as well.

Perhaps a course of this type will be appropriate in a specialized biomedical engineering department also. Even though students pursing an undergraduate degree in BME many specialized courses, it might be quite useful to offer an overview of the field in a semester long course. The function would be to serve as a birds eye-view of BME, thus allowing aspiring bioengineers to gage the field in its entirety, before selecting advanced classes. To draw a parallel in the graduate setting, it is not at all unusual to offer a laboratory course with experiments in several areas of research, frequently as a core requirement.

We expect to incorporate a laboratory component as well to future offerings of this course. Equipment for experiments in biomedical instrumentation and biomedical optics are in place. Another option being explored is to design a new BME experiment for use in an existing required engineering core course called “Experimental Engineering” which currently consists of 12 experiments in various traditional engineering disciplines. A suitable BME experiment could be a useful addition or perhaps a substitution for an already existing experiment with which it overlaps significantly. Besides the technical issues, today’s biomedical engineers are faced with ethical considerations on an unprecedented scale. While discussing this important topic is beyond the scope of the course described in this paper, the freshman design course provides an appropriate means of communicating the significance of ethical and product liability issues effectively in a project oriented environment. Interestingly this year, two out of three projects in the freshman design course are in the area of rehabilitation engineering.

References


ARVIND RAMANATHAN is currently an Assistant Professor of Engineering at Harvey Mudd College. He received a B.E. in electronics and instrumentation engineering from Annamalai University, India, and the M.S. and Ph.D. degrees in biomedical engineering from the University of Iowa. His interests include neural control of the heart as it pertains to sudden death and assistive technology applications for the disabled.