Integration of undergraduate research in the BIOE curriculum at Rice University

Ka-Yiu San

Department of Bioengineering, Rice University
Houston, Texas 77005

Abstract

One of the special features of the Bioengineering Undergraduate program at Rice University is the ample opportunity for undergraduate students to participate in independent research projects under the supervision of faculty members. Various mechanisms have been developed to maximize such opportunities. Most students take advantage of these opportunities by enrolling in BIOE400 (Undergraduate Research) where they can earn one to three credit hours, depending on their involvement and efforts spent on the project. This course can be counted as one of the electives towards their degree requirements. Other students involved in research projects get paid for their efforts. At the same time, some students take advantages of the various scholarship programs that are available during the summer time. These programs include the NSF Cellular Engineering IGERT Undergraduate Research program, the matching fund program for the Brown Undergraduate Research Internships from the Dean of School of Engineering, and the NSF REU opportunities from individual faculty. In this presentation, an overview of various undergraduate research activities in the Bioengineering Department at Rice University will be presented.

Introduction

The Bioengineering undergraduate program at Rice University is designed to prepare students for careers in rapidly developing areas of biomedical engineering and bioprocessing. The undergraduate educational program in Bioengineering (BIOE) has the goal of producing a new type of biomedical engineer, fully conversant with modern biochemistry and cell and molecular biology. This type of biomedical engineer will translate bench-scale scientific advances in biological sciences into cost-effective new products and processes. New and innovative curricula are being developed to educate biomedical engineers who will not only create new tissues and cell-based therapies but also deliver them at a cost affordable to our health care system.

The educational program objectives of the B.S. degree in Bioengineering at Rice University are to:

- Provide students with a fundamental understanding of the life and medical sciences;

- Teach students to apply engineering principles in the life and medical sciences;
- Develop their critical problem solving skills in bioengineering;
- Develop their ability to communicate effectively and participate in interdisciplinary teams;
- Expose students to a broad education that prepares them for diverse careers.

Graduates will be prepared to pursue further education in graduate school or medical school or begin a career in the biotechnology industry.

Bioengineering students follow the typical engineering curriculum during their freshman year with two semesters of calculus, two semesters of general chemistry, an introductory programming course and two semesters of physics. The introduction of the students to the fundamentals of life sciences begins with organic chemistry and introductory biology in the sophomore year. Biochemistry and cell biology are critical for our program and are taken in the junior year. Because of the increasing importance of computational science and mathematical modeling in bioengineering, students take two more semesters of mathematics and one semester of engineering computational methods, which was especially designed to provide engineering majors with a rigorous introduction to analytical and numerical methods.

Students obtaining a B.S. degree in Bioengineering are required to take seven core courses in Bioengineering. To enhance knowledge in one area of Bioengineering, students select one of three emphasis areas or tracks: (a) Cellular and Molecular Engineering; (b) Bioinstrumentation, Imaging and Optics; and (c) Biomaterials and Biomechanics.

A unique future of the Rice BIOE undergraduate curriculum is the opportunities for our students to participate in undergraduate research. Some of the major benefits of undergraduate students involving in an independent research project are: 1) to experience the joy and excitement to conduct cutting edge research; 2) to provide opportunity to get involved in scientific discoveries; 3) to provide a better picture of graduate student life and help to clarify their career goals; 4) to provide more one-to-one interactions with the faculty advisor; 5) to acquire knowledge outside the classroom; and 6) to improve their communication skills.

Undergraduate Research Opportunities

Undergraduate students can participate in research projects offered by BIOE faculty either by enrolling in a research course (BIOE400) or by working on a project with a stipend. Most students take advantage of these opportunities by taking BIOE400 (Undergraduate Research) where they can earn one to three credit hours, depending on their involvement and efforts spent on the project. This course can be counted as one of the electives towards their degree requirements. Other students involved in research projects get paid for their efforts. In addition, there are plenty of opportunities for students to get involved in various research projects during the summer months. It is estimated that about half of our undergraduate students have taken these research opportunities. Most students begin participating in research projects during their junior year. However, some students start as early as their freshmen year by taking part in a university-wide Century Scholar Program.

Undergraduate Research Course (BIOE400)

Course Organization

Application of enrollment. Each student wishing to enroll in Undergraduate Research (BIOE400) is required to file a petition at the beginning of each semester (within the first two weeks of the semester). The students start the process first by identifying a potential project from list of available projects, which is posted on the Internet a week before the semester starts. They then contact the individual advisor to find out more details about the project. The student will file an application outlining the scope of the proposed research project and the number of credit hours to be taken. The application forms have to be signed by both the students and the project advisors. These applications will be reviewed and decisions will be announced before the end of the second week of classes. Penalty is imposed for late application to ensure the students have adequate time to participate in the proposed research project.

Reports and presentations. All students taking BIOE400 are required to turn in their final written reports at the end of the semester. Their project advisors will grade these reports and their recommended grades will serve as a basis of the final course grade. Two additional requirements are designed to provide more opportunities for students to improve their communication skills. In the Fall semester, the students are required to a make an oral presentation of their projects to their fellow classmates. Whereas in the Spring semester, the students are required to participate in the Rice Undergraduate Research Symposium (RURS) poster competition. The results from these presentations will be counted as a portion of their final course grade.

Further Improvements. Two additional modules are planned for future implementation. One module deals with **s**cientific research ethics. Topics in this module may include experimental techniques and the treatment of data, conflict of interest, publication and openness, fair use of sources. The second module is targeted to improve the students' scientific writing. This module will be offered with close collaboration with the Cain Project in Engineering and Professional Communication. The Cain Project was created through a generous gift from Gordon and Mary Cain; its mission is to prepare students to lead through excellence in communication.

Summer Research Opportunities

Numerous opportunities are available for students to participate in various research projects during the summer. These include the Undergraduate Summer Internships from the NSF Cellular Engineering IGERT program, the Brown Undergraduate Research Internship program from the School of Engineering, the Undergraduate Research Training Program (URTP) from the Keck Center and the NSF individual investigators' Research Experiences for Undergraduates (REU) programs.

Examples of Projects

The list of available projects spans a wide spectrum of research topics. The areas covered include tissue engineering, nano-biotechnology, metabolic engineering and biomechanics. A typical list of topics offered in the 2005 Spring semester is shown in the following table for illustrative purpose.

Project Advisor	Project Title
Dr. Anvari	1. Plasma membrane mechanics studies using the human embryonic kidney cell model
Dr. Athanasiou	1. Expression of Degenerative and Reparative Factors by Single Chondrocytes 2. Analysis of Effect of Impact on Cartilage Explants 3. Comparison of Growth Factor Effects on Engineered Cartilaginous Tissue
Dr. Grande-Allen	1. Automated Analysis of FACE Gel Data
Dr. Kavraki	1. Computer-assisted drug design 2. Functional annotation of protein structures
Dr. Liebschner	1. Engineering the Building Blocks for Tissue Replacement Scaffolds 2. Temporo mandibular Joint Disfunction, What is the Cause? 3. CAOS - Computer Assisted Orthopaedic Surgery 4. Relative Implant Motion May Cause Implant Failure 5. Do Bones Make Sound? Resonance Frequency Analysis of Vertebrae
Dr. Mikos	1. Bone Tissue Engineering 2. Cartilage Tissue Engineering 3. Drug Delivery
Dr. Raphael	1 Modulation of Membrane Mechanical Properties by Amphiphilic Comounds 2 Development of Polarization Microscopy for Measuring Molecular Orientation
Dr. San	1. Design, analysis and simulation of genetic and metabolic networks 2. Genetic and metabolic engineering to improve culture yield and productivity 3. Metabolic engineering of plant hairy root cultures for the production of pharmaceutically relevant compounds
Dr. West	1. Surface modification of bioactive hydrogels

Assessment

The performance of these research programs is excellent. For example, the students who have participated in these programs have earned numerous awards over the years. In addition, a number of these students are co-authors of peer-reviewed articles. A list of their achievements will be highlighted in my presentation to demonstrate the quality of these research programs.

Summary

We believe that our undergraduate research program at Rice University provides numerous opportunities for our students to participate in various research projects. This program also provides a unique environment to our students to gain invaluable out-of-the-classroom learning experiences.

Biographical Information

KA-YIU SAN

Dr. San is the E.D. Butcher Professor of Bioengineering at Rice University. Dr. San received his B.S. degree in chemical engineering from Rice University in 1978 and his M.S. and Ph.D. degrees in chemical engineering from the California Institute of Technology in 1981 and 1984, respectively. His research interests include systems biotechnology, genetic and metabolic engineering of microbial and plant cells, and mathematical modeling and optimization of bioreactors.