AC 2011-578: BIOLOGY FOR FIRST-YEAR ENGINEERS, A NEW COURSE AT LOYOLA MARYMOUNT UNIVERSITY

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Biology for First-Year Engineers, a New Course at Loyola Marymount University

A new course "Biology for Engineers" was developed for first year engineering students at Loyola Marymount University (LMU). The course is part of the science sequence for all first-year engineering students at LMU. The fundamental concept of this course was to provide first-year engineering students with a basic background in focused areas of biology as it applies to engineering applications. The course was first taught in 2009 and again in 2010. It will again be taught in 2011. Topics for this course have included, cell biology, biochemistry and genetics as it applies to genetic engineering, studies of the nervous system and the brain as applied to bionic prosthetic devices that take advantage of the nervous system and parasitology as it applies to the worldwide need for clean drinking and irrigation water. These topics were linked, in some form, to the National Academy of Engineers "Grand Challenges for Engineering" for the 21st century. Course material was addressed in lecture and with a research assignment that asked the students to prepare a paper on a topic that linked biology and an engineering application. Although the course focused on the biology needed to understand the associated processes in the engineering applications, the course could easily be adapted to address a plethora of other areas that link science and engineering. The course content at this level served to broaden engineering students' understanding of the science of biology as it relates to engineering, stimulate interest in technical careers, address an ABET science requirement and to address at least one common engineering program outcome related to life-long learning. ABET related assessment was conducted with respect to the research assignment from the class.

Introduction

The interrelationship between the fields of Biology and Engineering presents a growing opportunity for engineers and that biology should be a core science course for engineers according to the NSF, NIH and others [1, 2]. Knowledge of biology specific to the complex communities of organisms was a necessity in order to develop biological technologies for the secondary treatment of sewage. Knowledge of the function of the nervous system was needed in order to develop appropriate designs of active prosthetics such as the agonist-antagonist active knee prosthesis [3]. An understanding of surgical techniques and tissues were needed to develop laser surgical techniques to replace scalpels. Some exposure to the science of biology may benefit engineering students and contribute to the development of technologies in the future.

Beginning in the spring semester 2009, a new class "Biology for Engineers" was required of all first-year engineering students at Loyola Marymount University (LMU) as a three-credit offering. It was taught again in 2010 and 2011. It added another field of science to add to the existing chemistry and physics requirements. It also helped to address the Accreditation Board for Engineering and Technology (ABET) standards for science and mathematics breadth for engineering programs. In most cases, engineering students never take a biology class but some may use the science. If they do take one, it is often a pure general biology class isolated from the fields of engineering. In a few cases, a focused biology class may have been taught in support of an aspect of specific programs. For example, a graduate level "Biological Processes" course that focuses on Biological technologies used in Environmental Engineering is taught in support of the LMU Master's Degree in Engineering in Civil Engineering program. The "Biology for Engineers" course for first-year engineers is designed to broaden the students' perspectives in the fields of engineering and improve their preparation to successfully study and practice in the various fields of engineering. It is different from a typical biology class in that it presents the science from the perspective of engineering applications and utilizes the National Academy of Engineers Grand Challenges for the 21st Century [(4)] as a basis to develop the topics.

In 2004 and again in 2005, a pilot course "Biology and Chemistry Applications for Engineers" was offered to first-year engineers who entered the university having successfully completed an Advanced Placement chemistry class [(1, 2)]. This course integrated aspects of the sciences of biology and chemistry with engineering. These two articles include reviews of some of the motivating literature for the concept of the class. Textbooks now exist. "Biology for Engineers" [(5)] is a broad-spectrum text that was published in 2011 and addresses the field of biology from an engineering standpoint. The author clearly highlights the difference between the perspectives of scientists and engineers. Scientists are most interested in the discovery of facts that may unify into a general theory. The engineer is interested in the application of theories and facts generated by the sciences. "New Biology for Engineers and Computer Scientists" focuses on biology as applied to biomedical engineering and was published in 2003 [(6)]. "Environmental Biology for Engineers and Scientists" [(7)] and "Applied Cell and Microbiology for Engineers" [(8)] are also examples of more focused texts. The National Academy of Engineering in 2008 presented its fourteen Grand Challenges for Engineering [(4)]. All of these Grand Challenges utilize the linkage between the sciences and engineering. A significant number of these require a link between the science of biology and the fields of engineering.

The "Biology for Engineers" class provides students with skills preparation to link the science of biology and fields of engineering. It adds a core science track to the LMU engineering curricula. It differs from a typical biology class in that it treats the science of biology from the perspective of related engineering applications and due to its link to the NAE Grand Challenges for the 21st Century.

Course Goals

In addition to offering the biology course from the standpoint of the engineer, the course was designed to provide students with:

1. An opportunity to demonstrate knowledge of biology and engineering;
2. An opportunity to demonstrate effective written communication skills;
3. The opportunity to explore the impact of engineering solutions in a global, economic, environmental or societal context;
4. An opportunity to demonstrate skills needed to engage in life-long learning;
5. An opportunity to explore a contemporary issue with respect to the fields of biology and engineering;

These goals are subordinate but consistent with the LMU Engineering Program Outcomes as the course is offered to first-year students. Program outcomes, shown below, are directed to the level of proficiency expected of graduating seniors. These are Program Outcomes defined by ABET for engineering programs [9]. Graduating students will have:

1. An ability to apply knowledge of mathematics, science and engineering (a)
2. An ability to communicate effectively (g)
3. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context (h)
4. A recognition of the need for and an ability to engage in life-long learning (i)
5. A knowledge of contemporary issues (j)

Course Content

BIOL 114, "Biology for Engineers" was offered to first-year engineering students. It was and is a 3-credit class offered in three one-hour sessions per week. Due to the size of the class, in excess of 80 students, is and was a standard lecture/exam class. Lectures utilized a significant internet-based content in order to keep the content from being too dry and to take advantage of recently published materials.

"Biology for Engineers" presented students with fundamentals in targeted areas of biology in the context of engineering applications as well as a fundamental approach for research in biology. Skills and perspectives developed in the class are appropriate for exploring engineering implications of aspects of biology. Content was varied by semester.

Spring 2009. The content of the course in this semester focused on topics in biology and biochemistry in support of genetic engineering and the study of the human nervous system in support of myoelectric prosthetics. The former is related to the NAE Grand Challenge "Engineer Better Medicines" and "Engineer the Tools of Scientific Discovery" while the latter relates to the Grand Challenge "Reverse Engineer the Brain." In the first segment, the course included the following general topics.

1. Biochemistry—A study of biological molecule classes including carbohydrates, fats, proteins and nucleic acids
2. Cell Biology—A study of the basic anatomy and functions of a cell
3. Genetics—A study of the basic principles of genetics
4. Biotechnology—A study of DNA cloning, technologies to study a genome
5. Genetic Engineering—Methodologies and products

The second segment of the course included the following general topics

1. Muscular System—A study of the anatomy, physiology and neural stimulation of muscle tissue
2. Nervous System—A study of the structure, function and transmission of neural potentials

3. The Brain—Structure and function of regions of the brain
4. Myoelectric Prosthetics—Touch Bionics i-LIMB hand and some other technologies

Spring 2010. The content of this course focused on topics in biology in support of study of clean water and the study of the human nervous system in support of the artificial retina. The former is related to the NAE Grand Challenge of "Provide Access to Clean Water." The latter relates to the Grand Challenge "Reverse Engineer the Brain." The first segment of the course included the following topics.

1. Water Treatment and Consequences—A study of the California water system, desalination, greywater and water treatment technologies.
2. Viruses—A study of viruses with emphasis on water-borne viral diseases
3. Bacteria—A study of bacteria with emphasis on water-borne bacterial diseases
4. Protozoa—A study of protozoa with emphasis on water-borne protozoan diseases
5. Helminthes—A study of helminthes with an emphasis on water-borne helminthes diseases

The second segment of the course focused on the following topics.

1. Nervous System—A study of the structure, function and transmission of neural potentials
2. The Brain—Structure and function of regions of the brain
3. Myoelectric Prosthetics—Touch Bionics i-LIMB hand and some other technologies
4. The Eye—Structure and function of the eye with emphasis on the retina
5. Artificial Retina—Technologies, effectiveness

Spring 2011. The course was just beginning at the time that the article was submitted. Resources included a large classroom, projection system, laptop and an Internet connection.

Course Goals Assessment

Using a scoring rubric consisting of proficiency scores from 1 to 4, the course goals were assessed using an assignment from the 2010 class with a score of 3 serving as the benchmark. Table 1 shows the scoring rubric and corresponding levels of proficiency.

Proficiency Score	Description
4	Clear on concept, few minor errors
3	Minor conceptual errors
2	Major conceptual errors, some understanding
1	No conceptual understanding

Table 1. Assessment Scoring Rubric Description

All students were assigned to prepare a 3-page paper addressing a topic that incorporated biology and engineering of their choice. In this assignment, students were asked to identify an appropriate topic, conduct library and/or internet-based research, write and submit the paper. A representative sample of 6 of these papers was subjected to detailed assessment with respect to the course goals. Table 2 shows the results of this assessment.

Course Goals	Average Score
1. Demonstrate knowledge of biology and engineering	3
2. Demonstrate effective written communication skills	2.83
3. Explore the impact of engineering solutions in a global, economic, environmental or societal context	3
4. Demonstrate skills needed to engage in life-long learning	3
5. Explore a contemporary issue with respect to the fields of biology and engineering	3

Table 2. Assessment of Proficiency with Respect to Course Goals

Referring to Table 2, the following discusses the assessment of the course goals.

1. Demonstrate knowledge of biology and engineering —It was accomplished at a sufficient level of proficiency of 3. The students did demonstrate that they understood the inter-relationship between biology and an engineering application. Each topic chosen by the students demonstrated knowledge of a topic that included both and could discuss it in a competent manner. The content of their work showed that they understood their topic from both perspectives. It was not expected that the students could apply this knowledge (yet) to the design of processes or systems, as they were only first-year students.

2. Demonstrate effective written communication skills —This was the most variable result with a composite score of 2.83. Four of the six showed a sufficient level of proficiency as they communicated their work reasonably. In the case of the two that were not up to par, having a proficiency score of 2, the students failed to edit their work, run the basic grammar and spell-checks. Four of the six did not cite references appropriately despite instructions. Two demonstrated excellent use of sources, excellent writing skills, and proper citations.

3. Explore the impact of engineering solutions in a global, economic, environmental or societal context —As demonstrated by the wide range of topics that the students selected, the quality of their written discussions and their assessed level of proficiency of 3, they certainly understood the effects of engineering solutions

with respect to at least one defined context. Topics included artificial heart valves (societal), artificial reefs (environmental), synthetic nanotechnology (societal), brain pacemaker (societal), a wound pump (societal) and genetic engineering of mosquitoes (societal, economic).

4. Demonstrate skills needed to engage in life-long learning —This was assessed at a proficiency level of 3. This was defined as an ability to learn about a topic not discussed in class using appropriate library and/or web resources. Students demonstrated that they were able to effectively do so and competently discuss the results of their research in written form.

5. Explore a contemporary issue with respect to the fields of biology and engineering —This was assessed at a level of 3. The topics chosen, as described in the discussion for Course Goal 3 represent current issues. The students' work demonstrated that they were able to competently address a contemporary issue with respect to both fields.

Conclusion

"Biology for Engineers" provided first-year engineering students with the opportunity to learn some principles of biology in the context of engineering applications. On a short-term basis, assessment of student work showed that the students, for the most part, successfully met the goals of the course. As a course in the engineering curricula at LMU, it provided one of the science components required for accreditation and offered the opportunity for program outcome assessment.

Literature Cited

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