2006-1595: ENVIRONMENTAL BIOTECHNOLOGY COURSE

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Environmental Biotechnology Course

Abstract

Environmental biotechnology, the application of living organisms to environmental problems, is an increasingly important topic. One notable example is bioremediation, i.e., the use of microorganisms to clean up contaminated environments, including contaminated soils and sediments. Environmental biotechnology is at the interface of biology and engineering, which presents both significant opportunities and limitations. Effective application of environmental biotechnology requires professionals who have a background in both areas. The undergraduate engineering curriculum has traditionally not emphasized training in biological sciences, although many environmental engineering curricula have incorporated some engineering microbiology in concert with, or as a prerequisite for, wastewater treatment courses. In general, however, whereas environmental engineers have considerable engineering skills required for the design of processes *per se*, have only a rudimentary knowledge of general biology and microbiology in particular. Growth in biology-related courses in the engineering curriculum is becoming more widespread, as chemical engineering departments begin to emphasize life science related research, and as biomedical engineering departments grow and diversify. Thus, the development of an Environmental Biotechnology course satisfies an urgent need in terms of professional preparation, and is timely as biology becomes more integrated into the engineering curriculum.

The proposed environmental biotechnology course will develop in environmental engineers an awareness of the most relevant, often diverse, aspects of the subject. The course will begin with general microbiology including structure, metabolism, growth kinetics, genetics, ecology, and diversity of microorganisms. This will prepare students for more in-depth treatment of such topics in other courses, and for important and emerging engineering applications of environmental biotechnology dicussed in the second half of the proposed course. These include state-of-the-art advances in wastewater treatment (including removal of carbon, nitrogen, and phosphorus; transformation of anthropogenic chemicals; and water re-use); bioremediation, including bioaugmentation and natural attenuation; production and mechanism of biofertilizers and biopesticides; fundamental and practical aspects of biosensor mechanism, design and implementation; development of microbial fuel cells; generation of valuable products from wastes; applications and ecology of biolfilms; quorum sensing (microbial cell-cell communication), and environmental genomic

I. Introduction

A senior-level undergraduate course, entitled "Environmental Biotechnology," has been developed at Rensselaer Polytechnic Institute (RPI). The developed course is available as a technical elective. Environmental biotechnology, the application of living organisms to environmental problems, is an increasingly important topic. One notable example is bioremediation, i.e., the use of microorganisms to clean up the contaminated environments, including contaminate soils and sediments. Environmental biotechnology is at the interface of biology and engineering, which presents both significant opportunities and limitations. Effective application of environmental biotechnology requires professionals who have a background in both areas. The undergraduate engineering curriculum has traditionally not emphasized training in biological sciences, although many environmental engineering curricula have incorporated some engineering microbiology in concert with, or as a prerequisite for, wastewater treatment course. In general, however, whereas environmental engineers have considerable engineering skills required for the design of processes per se, have only a rudimental knowledge of general biology and microbiology in particular. Growth in biology-related courses in the engineering curriculum is becoming more widespread, as chemical engineering departments begin to emphasize life science related research, and as biomedical engineering departments grow and diversify. Thus, the development of an Environmental Biotechnology satisfies an urgent need in terms of professional preparation, and is timely as biology becomes more integrated into the engineering curriculum. The proposed environmental biotechnology course will develop in environmental engineers an awareness of the most relevant, often diverse, aspects of the subject, together with communication skills and teamwork. RPI's current emphasis on biotechnology makes the present integrated and interdisciplinary curriculum possible.

II. The Curriculum

A. Details of Course Coverage

The proposed course combines elements of several courses offered in a typical Biological Sciences curriculum. It will combine elements of Introduction to Biology; Introduction to Cell and Molecular Biology (cellular biochemistry, metabolism and energy flow; genetics); and Microbiology (physical and chemical activities of bacteria). The emphasis will be completely different from biotechnology courses taught in many biology departments, which tend to emphasize the production of commercial products, not public health, waste treatment, or pollutant transformation. The course covers a broad range of material; therefore, it was critical to carefully choose topics and present new topics at a pace that facilitates student assimilation of material and stimulates their interest. The proposed course will provide a strong background for Biological Process Engineering courses that emphasize the design of biological processes using reactor concepts, substrate utilization and cell growth kinetics, and material and energy balances. Table 1 includes the suggested topics and the time that will be spent

Basic Microbiology

Fundamental microbiology such as cell biology, metabolism, kinetics, and molecular biology, will first be taught. Uniqueness of this part is that a significant amount of engineering aspects will be incorporated, in particular in the area of metabolism and kinetics, which the science counterpart does not traditionally emphasize. This allows engineering students to have a clue on how much and how fast substrate including pollutants will be transformed. A goal of this part of the course is that students become familiar with basic microbial concepts and terminologies.

Table 1. Topics included in the interdisciplinary curriculum on environmental biotechnology.

Subjects	No. Lecture
Introduction	1
Basic Microbiology	
Cell Biology/Taxonomy	1
Metabolism and Bioenergetics	3
Microbial Growth	2
Microbial Molecular Biology	2
Principles	
Genetic Engineering	
Microbial Diversity	
Microbial Groups	2
Metabolic Diversity	3
Microbial Ecology	2
Microbial Interaction	1
Special Topics	
Wastewater Treatment	1
Water Treatment	1
Bioremediation	1
Biosensor	1
Environmental genomics	1
Biofilm	1
Microbial fuel cell	1
Biocontrol (biological pesticides)	1
Generation of valuable products from waste	1
Tests and Project Presentations	3

Microbial Diversity

It is essential for students to know how diverse microbial species and their activities in environments are, and understand how they function. Thus in the second part of the proposed course, a variety of microbial species, in particular environmentally relevant species (e.g., pollutant-degraders and waterborne pathogens) and their important characteristics will be introduced. Traditional and modern microbial methods to characterize microbes will also be taught. At this point, we anticipate that a significant portion of students start to lose their interest and hence may have difficulty in focusing on the subjects. Since one excellent way to help students stay awake is to use visualization tools, we will try to use as many pictures and movies of microbes as possible. Microorganisms play vital roles in the natural chemical cycles of elements such as carbon, oxygen, nitrogen, and sulfur and also in the transformation of anthropogenic pollutants. Microbes are also actively involved in geological processes such as weathering, soil formation, and mineralization. Therefore, microbial metabolic diversity, which is the detailed version of basic microbial metabolism taught earlier, should be a core of environmental biotechnology and thus be taught for details. Since we believe that each individual microbial metabolic activity should be interpreted in the context as global phenomenon, we will try to link it to microbial ecology. After this part of the course, we expect that students are at least not intimidated when reading microbiology-related journal articles such as Applied and Environmental Microbiology.

Special Topics
Microorganisms exist over a broad range of environmental conditions, and this ubiquitous nature may provide microbes with versatile functional abilities and unique ecological roles. They have conducted their unique activities through most of Earth's history, even under very inhospitable conditions, and their long-perfected abilities are adaptable to perform functions useful to mankind. The rest of the course will therefore focus on engineering aspects of environmental biotechnology (i.e., environmental applications), in which recent research advances on environmental biotechnology will be introduced and explained relatively deeply. Examples include traditional and novel water and wastewater treatment, bioremediation, biosensor, environmental genomics, biofilm, microbial fuel cell, biocontrol (biological pesticides), and generation of valuable products from waste (Table 1). The aim of this part of the course is to provide students with an in-depth understanding on each topic and realization of the relationship between microbiology as a scientific object and environmental engineering as its potential application area.

B. Strategy for effective learning
Bug of the Day
One of the most serious challenges that engineering students faces when taking biology classes is that memorization is required for much of the course contents, which is not common in engineering courses. It is particularly true when it comes to microbial diversity (e.g., the names and functions of many microbes). Thus, over the entire semester, a variety of microbial species, which would be either environmentally relevant or have interesting characteristics, will be introduced to students in the beginning of each class in the name of "Bug of the Day." PowerPoint presentation for approximately 5 minutes will be offered. Slides will be mostly comprised of pictures with limited words, which tend to more effectively help students stay alert and also attract their attention. Students are to participate in this activity as a part of homework, as "learning by teaching" is considered being the most efficient learning strategy. Each student will be assigned total two microbes over the entire semester, which should be studied and described, exactly as the instructor would do. Each presentation will be assessed by other students as well as the instructor, thereby leading to the improvement of their presentation skills. Thus we expect to observe that most students are able to make effective oral presentations, particularly, for their final reports.

Project
Students enrolling in the present course will be divided into teams with each team working on a different project. Even though two or three students will be encouraged as a team, students, in particular graduate students and/or undergraduates with research experiences, can also do individual projects. Teams will be provided with a list of possible project topics. Since hands-on experiences encourage development of curiosity, analytical proficiency, and manual dexterity, which are three desirable characteristics of an engineer, students are encouraged to take apart and explore each of the experimental projects as deeply as desired, keeping in mind any safety considerations appropriate for these activities (i.e., safety glasses worn at all times). However, for those who are not interested in conducting experiments, reviewing literature is an option, in which case evaluation criteria would be different.
To develop communication skills, all students must submit bi-weekly progress and end-of-semester final reports, and make one hour oral presentations on their final project results. After reading the biweekly progress reports, the instructor will provide concrete, practical suggestions that help the students write more correctly and clearly. The instructor often helps polish their writing skills. The progress reports are read not only by the instructors but also by all of the students involved in our classes and projects. We expect that the final reports look like professional journal articles or technical proposals, in terms of formats, writing style, and contents. We also expect to observe that most students are able to make effective oral presentations. The final reports will also be evaluated by both the instructor and students.

Assessment of Students' Performance
It is typical that instructors are solely responsible for the assessment of student performance, which is unavoidable in most of courses. However, it would be beneficial, if students have a chance to be involved in the assessment process. It is anticipated that students can learn more effectively, as they will pay more attention to peer's works and also can more readily catch what is more desirable things to do to improve their own works. Therefore, we will attempt to have students take part in assessment of performance of both oral presentations and written reports. A guideline will be provided for a consistent and meaningful assessment (Table 2). Students need to write down a score on each questionnaire, which will then be collected and given to students with a final grade and written performance summary.

IV. Course Evaluation
An integral part of the present courseware is the feedback/evaluation mechanisms. Enrollment in Spring 2006 is 12 students and 1 sit-in, including graduate students, which is the normal enrollment for a typical senior undergraduate or graduate elective in the environmental engineering program at RPI. Majority of students (11 out of 13) is taking our class major in environmental engineering. The teaching evaluation program conducted by the RPI Resistra's Office at the end of each semester is used to improve future offerings of the courses. The results will be compared with the average

Table 2. A guideline for students to evaluate others

Use the following scales: 5: Excellent 4: Above Average 3: Average 2: Below Average 1: Poor
Oral Presentation Clarity: _____ Logics _____ Words _____ Pronunciation _____ Behavior (eyes, hands, repeated gesture etc.) _____ Answers to student questions _____ Ability to maintain students' interests _____ Usefulness of presentation _____ Relatedness to lectures _____ (Improvement) *Written Report* Clarity: _____ Logics _____ Words _____ Sentences _____ Format _____ Neatness _____ Usefulness of report *Comments*

performance of the Department, the College, and the University and are not available to the instructors until the students have received their grades. However, such quantitative data for the present course is not available due to insufficient number of samples collected for a meaningful statistical analysis. On the other hand, an additional evaluation questionnaire including comments (Table 3) will be implemented. Using this additional evaluation sheet, the course will be evaluated twice a semester, both in the middle and at the end of the semester. The questionnaire can be completed anonymously. Instructors and students thus interact with each other in an effective and timely manner.

V. Challenging Issue

The most challenging issue we face in the stage of course development is the number of enrollment. As offered as a technical elective, it is difficult to meet the minimum required number of students to be admitted by the school (approximately 6 per class). This problem arises from the small size of the environmental engineering program, whose average enrollment is 10 per year in recent years. Even from this small pool, only a

Table 3. Questions in course evaluation

Use the following scales: 5: Excellent 4: Above Average 3: Average 2: Below Average 1: Poor
Lecture ____ Clarity of instructor's presentation ____ Answers to student questions ____ Instructor's ability to stimulate students to learn ____ Instructor's concern for the students ____ Willingness of instructor receive student feedbacks ____ Availability of instructor for help outside of class ____ Usefulness of "Bug of the Day" ____ Depth of the lecture ____ Usefulness of the course *Homework, Quiz, Test, and Project* ____ Reasonableness of homework ____ Reasonableness of quiz ____ Reasonableness of test ____ Reasonableness of project ____ Fairness in homework and quiz grading ____ Fairness in test and project grading *Comments*

portion (4 out of 12) is signed up for the proposed course in this year, mainly due to students' unawareness of the importance of this course, which should be effectively addressed. Another reason is the conflict of class schedules with other courses offered in different departments. Some students are just uninterested in microbiology at all. Unlike undergraduate students, most of graduate students, particularly in the junior level (6 out of total 13) are enrolled, probably due to the fact that they better understand the importance of this subject. Because of the low number of enrollment, an experienced fulltime graduate TA, who can instruct experiments, is not available, which limits the ability to pursue more challenging project topics. We make every effort to incorporate this course as a requirement, so that every student can take this great opportunity to be equipped with knowledge and confidence on environmental biotechnology that is becoming increasingly important.

V. Conclusion

Our students have the unique opportunity of receiving science and engineering aspects training on environmental biotechnology. Moreover, the students are exposed to state-of-the-art facilities at RPI, along with the integration of important research advances on broad aspects of EB. In addition, engineering students, who are future engineers in industry or faculty members in academia, will be well-prepared for the competitive world market of the environmental application of biotechnologies and will be enabled to make significant contributions to industry and the nation.