AC 2007-217: A HYBRID CLASS CONTAINING MICROBIOLOGY AND ENVIRONMENTAL ENGINEERING AT TEXAS TECH UNIVERSITY

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Abstract

Due to the ever-changing demands in the field of environmental engineering, students today must have a diverse background in science as well as in engineering design principles. As indicated in the ABET general criteria for advanced programs, graduates of environmental engineering programs should have proficiency in biology, including microbiology and aquatic biology. Graduates of the 5-year Freshman to Master's Environmental Engineering and the Master of Science in Civil Engineering degree programs at Texas Tech University are exposed to microbiology and aquatic biology concepts through a new hybrid course. The purpose of CE 5385/ENVE 4385 Microbial Applications in Environmental Engineering is to educate students in microbial biology, which will further their understanding of microbial processes in environmental engineering applications. Additionally, the contribution of the course to the professional component of the curriculum is to provide civil and environmental engineering students a minimum understanding of microbial biology to further their understanding of biological treatment processes. The course has been offered four times and is in continuous revision. Subsequently, the book selected for the course has changed several times in order to maximize the resources available to students regarding topics covered while minimizing the number of books purchased. The course benefits the students by preparing them for both the F.E. and P.E. exams. The course has benefited the curriculum by ensuring all students receive basic information on microbiology, allowing for more in-depth coverage of other topics in advanced courses such as CE 5383 Bioremediation of Wastes in Soil Systems and ENVE 5399 Biological Municipal Wastewater Treatment. Overall, the course benefits the environmental engineering community by improving graduate preparedness for their future profession by providing the necessary knowledge to develop and apply new hybrid ideas to solve engineering problems.

Introduction

At Texas Tech University, students may obtain an environmental engineering degree in one of two tracks. One program, the 5-year Freshman to Master's Degree Program in Environmental Engineering, allows incoming freshman to obtain a Bachelor in Environmental (non-accredited) while also receiving a Master in Environmental Engineering (MEnvE) (accredited).[1] The degree program includes a variety of civil and environmental engineering courses, environmental science courses,[2] physics, and general education requirements as specified by the Texas State Board of Higher Education. Additionally, students may pursue an environmental engineering degree following the more traditional route of obtaining a Masters of Science in Civil Engineering (MSCE) with an emphasis on environmental engineering. Students enrolled in the MSCE program take graduate level classes in civil and environmental engineering and electives from a variety of areas including in civil engineering, environmental toxicology, geology, and geography. For a detailed description of the degree program, please see the Department of Civil and Environmental Engineering website.[3]

In both degree programs, students take courses in air pollution control, solid waste treatment, and hazardous waste while receiving in depth coverage of water and wastewater treatment techniques and design including physical, chemical and biological of water, wastewater and sludge treatment. The core curriculum for both programs includes five water and wastewater courses, and the MEnvE students take an additional required course (i.e., CE 5393 Unit Processes Laboratory) in mathematical modeling as it related to environmental engineering, specifically wastewater and water treatment systems.

A unique course included in the wastewater/water treatment content track is a hybrid microbiology-environmental engineering course called ENVE 4385/CE 5385 Microbial Applications in Environmental Engineering. The purpose of the course is to educate students in microbial biology, which will further their understanding of microbial processes in environmental engineering applications. The faculty, responsible for the environmental engineering discipline classes, decided to develop this course to ensure the MEnvE curriculum meets ABET Criterion 8 for Environmental Engineering by including environmental microbiology and aquatic biology, while relating these topics to sub-disciplines of environmental engineering such as wastewater treatment, water treatment, and bioremediation.[1] Additionally, the contribution of the course to the professional component of the curriculum is to provide civil and environmental engineering students a minimum understanding of microbiology to further their understanding of biological treatment processes.

The course, Microbial Applications in Environmental Engineering, was developed in the Spring, 2004, and has been taught each subsequent fall for incoming MSCE students and the MEnvE students. The purpose of this paper is to provide the current content, address the fluidity of the course content, highlight student benefits and the benefits to the curriculum due to the inclusion of such a hybrid course, and inform others of a possible solution that may solve curriculum issues.

Course Content

As previously indicated, the purpose of this course is to teach students microbiology concepts to further their understanding of microbial processes used in environmental engineering. Over the years, the course has morphed such that the topics covered fall into four general topic areas: Cell Structure, Metabolism and Biochemical Cycles; Information Flow; Environmental Microbiology; and Analytical Identification Methods. The content in each of the areas are presented in detail below.

<u>Cell Structure, Metabolism and Biochemical Cycles</u>. The purpose of this material is to provide background information on microbiology so that microbiological concepts may be related to specific topics pertaining to environmental engineering design. To help the students understand the relationship of this course to other courses in their curriculum, the first lesson introduces environmental microbiology issues and relates them to topics in environmental engineering including bioremediation, water treatment, wastewater treatment, and so forth.

During the first 9 class periods of the course, students learn the differences between prokaryotes and eukaryotes, and general characteristics of microbes including bacteria, fungi, protozoa, algae, and viruses. Two lectures present the components of the cell (i.e., cell structure) and their functions. For instance, students learn the difference between pili (sex structure) and fimbriae (cell attachment), which is then readdressed in a later portion of the course (i.e., microbial attachment and microbial transport). Additionally, the students learn the structural differences between Gram Positive and Gram Negative bacteria. Next, the processes of metabolism (i.e., all chemical reactions in the cell) are presented. Specifically, the course focuses on catabolic processes such as Glycolysis, Enter-Dourdoroff pathway, Pentose-Phosphate pathway, and the Citric Acid Cycle. The course limitedly addresses anabolic pathways such as the formation of storage granules and the cell wall. Although an interesting topic, anabolic pathways are slightly beyond the needs of the course. For those who desire more information, students are encouraged to take biochemistry courses that address these issues. Lastly, this section of the course material concludes with the biochemical cycles of carbon, nitrogen, phosphorous, and sulfur with specific emphasis on the movement of these materials between environmental compartments, the potential biochemical reactions, and the microorganisms driving these systems.

<u>Information Flow</u>. The next 5 class periods in the course present the processes of information flow within the cell, which specifically focuses on microbial genetics. The basics of DNA replication, transcription, and translation are presented. The purpose of this section is to educate the students on the genetic material in cells so that they understand nucleic acid techniques used to identify microorganisms. The students learn about the structure of DNA and RNA, and the enzymes and proteins necessary to perform the operations of DNA replication, transcription, and translation. Additionally, amino acid and protein structure are presented, which relate to cell structure and biochemical pathways. Lastly, processes resulting in DNA mutations and recombination are presented. Specifically, the lesson focuses on transduction, conjugation, and transformation as potential techniques to share genetic information between bacteria as these processes are appropriate topics in bioremediation because genetic potential affects microbes' ability to change or alter environmental conditions.

<u>Environmental Microbiology</u>. Over the next 8 class periods, which coincide with one-third of the class, the students learn about environmental microbiology topics. The general topics covered include terrestrial environments, aquatic and extreme environments, microbial transport, indicator organisms, microorganisms and organic pollutants, wastewater treatment, water treatment, disinfection, and water distribution systems. The environmental microbiology portion of the class integrates cell structure, metabolism, biochemical cycles, and microbial genetics information with environmental engineering topics. The students learn how the terrestrial environment impacts microbe concentration, activity, and location. The students learn about soil and microbe/virus properties that inhibit or encourage microbe transport in the subsurface. Techniques used to model and describe transport in soil systems such as column studies and lysimeters are presented. Both of these topics relate to the efficiency and effectiveness of bioremediation.

Although the students have other courses on water treatment, wastewater treatment, wastewater composition, and solid waste composition, the information presented in the course highlights the source and fate of indicator organisms in such processes, discusses inactivation mechanisms of indicator organisms and addresses appropriate applications for using indicator organisms. In the lesson covering microorganisms and organic pollutants, factors affecting biodegradability (i.e., genetic potential, bioavailability, contaminant structure, and toxicity) are addressed, which relate to topics covered previously in the class. Most importantly, the students learn how to address these factors in engineering designs.

Analytical Identification Methods. Now that the students have an understanding of microbe physiology as well as their role in environmental engineering systems, methods for detecting, identifying, and enumerating microbes are presented. During the last 4 lessons of the class, the students learn about microscopic methods, cultural methods, and physiological and nucleic acid methods for identifying microbes and assessing activity. The microscopic method lesson addresses microscopy and the various techniques such as bright-field microscopy, dark-field microscopy, differential phase microscopy, fluorescent microscopy, scanning electron microscopy, and transmission electron microscopy. Upon completion of the lesson, the students can match the application to the most suitable microscopy technique.

The culturable methods lesson presents information regarding dilution and plating methods as well as the most probable number technique. Physiological methods to measure microbe activity include carbon dioxide and biomass concentrations and are presented to the students. Lastly, the students learn about nucleic acid methods, such as gene probing, Southern and Northern Blots, and polymerase chain reaction (i.e., PCR). Other topics covered include restriction fragment length polymorphism and gel electrophoresis. Students learn the target of each technique (i.e., DNA, RNA or protein), applications of each technique, and their appropriateness for identifying microbes or their activity in environmental and pure cultures.

At this time, the students do not have the opportunity to experiment with these techniques, but the hope is to add a lab to the class or a class to the curriculum to provide an opportunity for hands on instruction. Due to the intense nature of the course, one class period during the analytical identification methods allows the students to have a "play day." Students are given swabs and plates and are encouraged to collect environmental samples from their surrounding environment and to perform a heterotrophic plate count. The lesson does teach students about the aseptic technique as well as how to make streak plates. However, the goals of the lesson are to help the students realize the ubiquitous of microbes around them and to have fun.

Modifications to the Course. The previous discussion indicates how the course is currently taught. However, the course has morphed since its conception. Initially, the course focused on wastewater microbiology; however, it seemed to parallel topics covered in the students other wastewater courses. Therefore, a decision was made to holistically cover environmental topics, which allows us to address topics in Criterion 8 such as aquatic microbiology and microbiology. Over the semesters the course was taught, the information regarding bacterial metabolisms has been expanded, reduced, and expanded again, which has reduced the amount of information presented on bacterial cell structures and their formation.

Source Materials for the Course

Required Textbooks. The first textbook used in the course was Wastewater Microbiology.[4] As the course morphed, the book did not address all the topics to be covered; therefore, the next book adopted for the course was Environmental Microbiology.[5] The basic environmental microbiology and analytical identification information presented in this course comes from this textbook. Chapters 1 through 2 provide an introduction to environmental microbiology and microorganisms in the environment including information on structure, shape, size of bacteria, viruses, algae, fungi, and protozoa. However, the cell structure and metabolism lessons needs to be presented in greater detail; therefore, outside resources are included in this portion of the course.

Additional Texts. To add to the information regarding bacterial structure, metabolism and information flow that is presented in the hybrid course, general microbiology information is obtained from two microbiology texts: Brock Biology of Microorganisms[6] and Microbiology.[7] Selected readings and figures are incorporated into the lesson and provided on the course webCT site. The additional text provides background students are assumed to know from previous science and environmental engineering classes. Because this class is an elective for students pursuing the BSCE and the graduate students may not have had biology during their undergraduate education, the review material allows the students to learn the material on their own so that they may succeed in the course. As indicated, the Microbial Applications in Environmental Engineering course is an elective for students obtaining a Bachelor of Science in Civil Engineering. As biology is not required in their degree program,[8] these students may need the reference materials to accompany the lessons to improve their understanding of the information presented.

Additional Sources. In addition to other textbooks, articles from peer reviewed journals, magazines, and newspapers are incorporated into the lessons to demonstrate the fields of environmental engineering and microbiology are constantly changing. An excellent source of supplemental articles for the students is *Microbe, the News Magazine of the American Society for Microbiology*.[9] *Microbe* is written for a general audience so that the reader does not have to be an expert in the field to comprehend the information presented, which is a benefit to the students. Additionally, the magazine has contained feature articles covering topics such as the history of microbiology, microscopy techniques, and peptidoglycan. These articles are made available to the students through the webCT course site. The bonus questions on the exams typically cover the outside reading assignments.

Students conduct article reviews of peer reviewed journals as a component of the graduate students' grade and for extra credit for the undergraduate students enrolled in the course. The purpose of the assignment is to encourage critical thinking of the students, challenge their understanding of microbiology concepts while teaching them life-long learning skills. Additionally, the students are provided with an opportunity to learn more about specific topics and current trends in environmental microbiology.

Benefits of the Course to the Environmental Engineering Curriculum

The MSCE and the MEnvE degree programs have benefited by incorporating this hybrid course in the curriculum. A few topics that were covered in CE 5383 Bioremediation of Wastes in Soils or CE 5399 Biological Wastewater Treatment were moved to the Microbial Applications in Environmental Engineering course. The change has allowed for more in depth coverage of bioremediation strategies and design of wastewater treatment systems in the other two courses.

Additionally, Bioremediation of Wastes in Soils is an elective course; thus, moving the material to the required Microbial Applications in Environmental Engineering course ensures all students learn the important information covered. The course, Microbial Applications in Environmental Engineering, allows the MEnvE degree program to cover topics listed ABET Criterion 8 for Environmental Engineering.[1]

At least three courses would be necessary to cover the topics addressed by this course through traditional microbiology and environmental engineering courses. For example, the students would have to take a general microbiology course to cover microbial structure and metabolism topics. Then the students would take a microbial genetics course to cover the information flow component of the course. Lastly, the environmental microbiology topics would be covered in a separate course. Therefore, this hybrid courses saves six hours in the MEnvE curriculum, which is crucial during times when the Texas State Legislature is trying to reduce the number of hours in degree programs. Also, typical MSCE students are unlikely to take two microbiology courses so the incorporation of this course improves their overall environmental engineering education.

Benefits of the Course to the Students

In addition to benefiting the degree program, the hybrid course provides value-added to the students. The course provides basic information students should know to perform laboratory research. For example, students learn about microcosm studies, column studies, bacterial sample collection and handling, which are all factors that can improve the success of laboratory projects. By tailoring the microbiology topics to environmental engineering, the hybrid class ultimately adds to the students' knowledge and provides skills that will enhance research productivity. Graduating ENVE students' response to ABET 2000 Criterion 8 Outcomes, specifically the understanding and proficiency in science and math are presented in Table 1. The inclusion of the data is to assess the students' perceived impact of the hybrid class on their science training. Two sources of data are presented: exit interviews and the department chair survey. In evaluating the students' response to proficiency in earth science as well as biology and chemistry, the response value increased after the Microbial Applications in Environmental Engineering class was taught (S04 and F05). The italicized values represent the responses after inclusion of the hybrid class in the curriculum. Unfortunately, responses are not available for all semesters and not all students complete the questionnaire. However, we believe the class benefits the students by marrying science concepts with engineering practicality.

Table 1. Graduating ENVE Students Response to ABET 2000 Criterion 8 Outcomes

Topic	Average Response by Semester									Average Score*
	F00	S01	F01	S02	F02	S03	F03	*S04*	*F05*	
MEnvE Exit Interview Results for Criterion 8 Outcomes (no respondents S00, F04, S05, S06, F06)										
Proficiency in math, physics, general chemistry & earth science	4.5	3.5	4.1	4.3	4.3	4.0	5.0	4.5	5.0	4.2 *4.7*
CE Department Survey of MEnvE Graduates on Criterion 8 Outcomes										
Biology & chemistry	4.2	4.0	3.5	4.5	5.0	-	4.2	-	5.0	4.2 *5.0*
Total Responses	2	2	7	8	3	3	1	4	2	32

Note: S=Spring graduates and F=Fall graduates
*Indicates a weighted average

In addition to preparing the students for an immediate future in research, the course prepares them for future success on the F.E. and P.E. exam.[10,11] However, FE exam results are difficult to use as assessment tool as100 percent of the ENVE students pass the exam. Many of the topics are covered in the environmental engineering P.E. exam and the afternoon session in environmental engineering. Biology and microbiology topics are covered under water resources, fate and transport is covered under environmental assessments, and sampling and measurement methods are covered under remediation.

Most importantly, the hybrid microbiology-environmental engineering course allows students to learn about microbiology issues while demonstrating how science improves engineering analysis and design. Typically, students learn these topics (i.e., biology and chemistry topics) in science courses and then many semesters later the students are asked to recall the information and apply the science to engineering design. A good example is the topic of softening covered in traditional water treatment courses. Many semesters may have elapsed since taking chemistry so the students have to refresh their chemistry background to improve their understanding of the softening chemical reactions. However, the hybrid class exposes the students to the science, which is immediately related to environmental engineering design. For example, nutrient cycles can be related to wastewater treatment and nitrogen and phosphorous removal. Cell components such as glycolax and fimbriae affect cell attachment and those cell components can be related to biofilm development, which can be related to water distribution fouling problems. The interconnectedness between the science and engineering topics is believed to improve the students understanding of the science presented in the class, as well as ways to manipulate the science to improve environmental engineering design.

Comparison to other Hybrid Environmental Engineering-Microbiology Courses

Due to the ABET requirement to include microbiology and biology in environmental engineering coursework, universities having an environmental engineering degree have also developed hybrid courses. Other universities had addressed this issue by including microbiology or biology courses, typically taught through biological sciences, in the course curriculum.[12, 13, 14] Other undergraduate and graduate programs have developed a hybrid course to teach microbiology through the engineering department.[15, 16, 17, 18, 19, 20] At some institutions, the courses appear to be more focused on general microbiology concepts such as microbial ecology, classifications and microbial diseases, [17] while others focus more on microbial metabolism, growth kinetics, biogeochemical cycling.[16,18, 19] At Iowa State University,[15] C E 421 Environmental Biotechnology, which is dual-listed with 521, focuses more on microbes in engineered systems, while having less emphasis on general microbiology concepts such as cell structure. Some courses are similar to ENVE 4385/CE5385 Microbial Applications in Environmental Engineering by covering topics of basic cell structure, metabolism, ecology and impacts on engineered systems.[20] Therefore, it is apparent that hybrid courses are diverse, yet have common microbiology threads; however, few courses are the same.

Conclusions

Overall, the hybrid microbiology-environmental engineering course, ENVE 4385/CE5385 Microbial Applications in Environmental Engineering, is believed to benefit the environmental engineering curriculum at Texas Tech University. The students are better prepared for future coursework, research, and professional practice. In fact, more courses would benefit from the enhanced integration of science topics and engineering issues.

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