JOURNAL OF MICROBIOLOGY & BIOLOGY EDUCATION, December 2012, p. 191-192
 DOI: http://dx.doi.org/10.1128/jmbe.v13i2.456

Enhancing Engineering Students' Learning in an Environmental Microbiology Course

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INTRODUCTION

Environmental Microbiology is one of the key courses for junior students in an environmental engineering program. The course covers the fundamental knowledge of microbial processes in environmental engineering processes. A laboratory section is included in the course to help students gain hands-on experience in environmental microbiology. While these engineering students have gained some knowledge of biogeochemical cycles and sewage treatment, most of them haven't learned microbiology previously and usually have difficulty in learning environmental microbiology because microbiology deals with invisible living microorganisms instead of visible built environment. Many teaching techniques can be used to enhance students' learning in microbiology courses, such as lectures, animations, videos, small-group discussions, and active learning techniques. All of these techniques have been applied in the engineering class, but the results indicate that these techniques are often inadequate for students. Learning difficulties have to be identified to enhance students' learning.

PROCEDURE

Feedback from students and colleagues has been collected and analyzed. Several learning difficulties have been identified and teaching approaches have been developed to address these difficulties.

The first difficulty is to adapt to students' different learning patterns. Environmental microbiology is difficult for many engineering students because the amount of information presented in the textbook is large and most of the concepts are not directly linked to each other. Unlike physics and chemistry, in which a few principles can be applied throughout the courses, there are many descriptive concepts in microbiology and the connections between these concepts are not obvious. Nevertheless, some students have to see the big picture before they can better understand the individual processes, and these students often suffer from conventional lectures as they will only get the big picture at the end of a semester, which is often too late. To help students see the big picture at the beginning of the course, I have developed a mind map (Fig. 1) to show the links between the concepts in microbiology and distribute it in the first lecture. The concepts are classified into three tracks: information exchange, mass exchange, and energy exchange. Such a mind map makes it much easier for students to gain a better understanding of many dispersed concepts that will be covered later in the class and how these concepts are interconnected.

The second difficulty is to motivate students to study microbiology, or as my colleague Dr. Alex Ip put it, "to identify what the students need, but not what they want." Because the complex concepts and processes in microbiology are difficult to convey in texts, course instructors are inclined to use animations and videos to visualize these concepts and processes. While animations and videos are usually preferred by students and are indeed much more effective than texts in helping students learn the knowledge, relevant animations and videos are often not available, and more important, simply working on the effective delivery of concepts and processes focuses on the wrong problem. Surely visual aids help students learn, and surely students love to see videos, but as a way of delivering concepts and procedures in both natural and engineering systems, their use does not necessarily guarantee student learning. Students have to understand that learning the concepts and processes in environmental microbiology, although it is difficult at times, will help them better understand environmental engineering processes, and failing to do so will probably affect their ability to learn engineering processes. Course instructors should not lower the bar to make things easier for students; instead, they should emphasize the importance of microbiology to properly motivate students to learn the complex concepts, which is critical for their future success as environmental engineers.

The third difficulty is to understand how environmental microbiology can be applied to environmental engineering. To address this difficulty, practical examples on the application of microbiology in engineering can be provided to help students understand that microbiology is intertwined with engineering. Before taking the introductory course Environmental Microbiology, many students may have learned that microorganisms can be used to treat wastewater, but most

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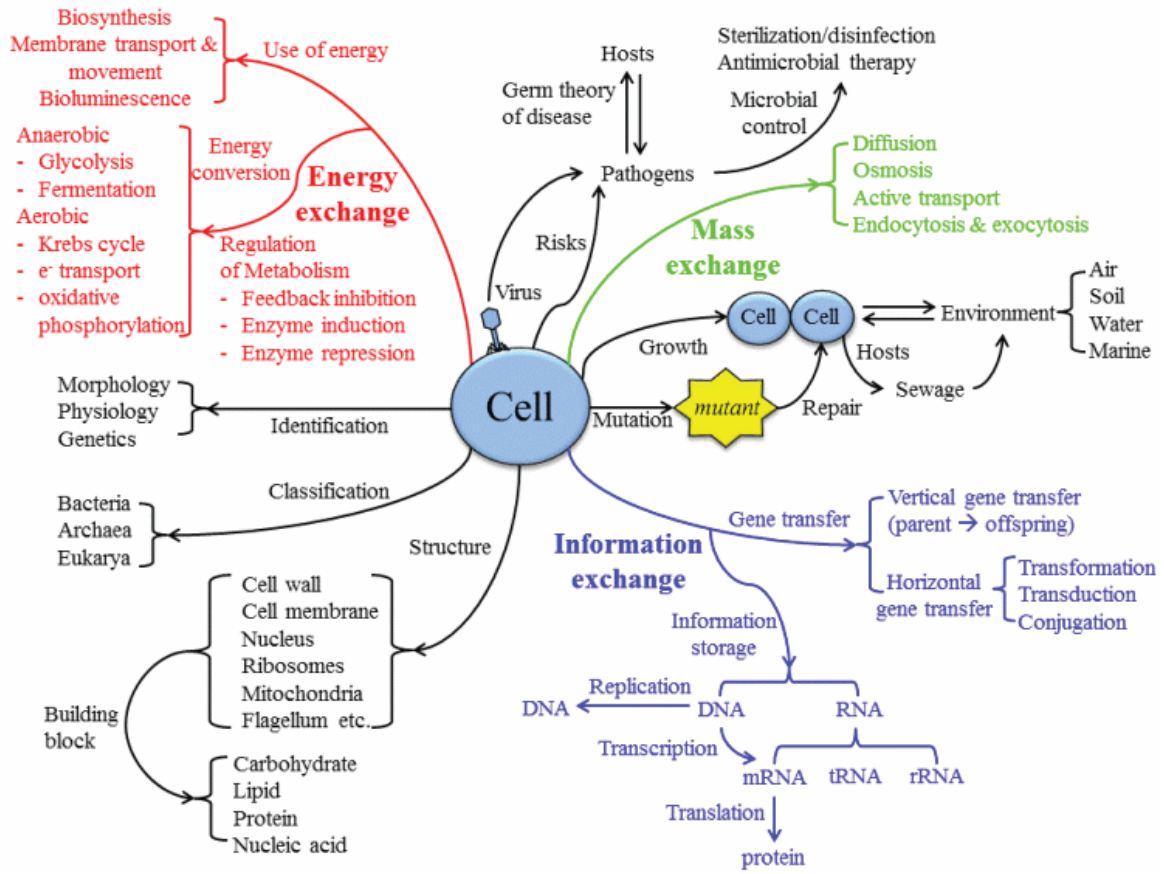

FIGURE 1. Mind map of environmental microbiology.

students haven't realized that more than 99% of existing secondary wastewater treatment systems in the world are biological wastewater treatment systems, and microbiology is the key for the optimization these engineering systems. Efforts to use only physical/chemical treatment techniques to treat wastewater have proved unsuccessful. Furthermore, students should learn that biological wastewater treatment systems are still the most cost-effective systems to clean wastewater, while recently developed techniques, such as reverse osmosis, are efficient but costly. Another example is the application of anaerobic digestion to treat wastewater in the spacecraft to Mars, which may seem counter-intuitive to the lay public as oxygen is available only in limited amounts in this environment. Microbiologists, in contrast, understand that microorganisms don't require oxygen—they just need electron donors and carbon sources to survive and reproduce. Additionally, the discovery of antibiotic-resistant bacteria in a four-million-year-old cave in Carlsbad Caverns National Park in New Mexico in the absence of selective pressure imposed by antibiotic use may confuse wastewater treatment plant operators who work on removing antibiotics in wastewater with the hope of reducing the development of antibiotic-resistant pathogens. With these practical examples, engineering students will better understand the necessity of learning environmental microbiology and how they could apply microbiology to engineering.

CONCLUSION

Identifying engineering students' difficulties in learning microbiology is a critical step in improving students' learning experience in an environmental microbiology course. In this article, three difficulties have been identified and approaches have been developed. Overall, the feedback from students is positive, which is reflected in both the teaching evaluation reports and in conversations with students. The students get a chance to think about why they need to learn microbiology in an engineering program, and how microbiology can help them understand those engineering systems. Identifying the difficulties also helps lecturers to tweak their teaching techniques to adapt to the students' needs to enhance students' learning in an environmental microbiology course.

ACKNOWLEDGMENTS

The content of this article requires no sponsorship of study. The author thanks Drs. Alex Ip, Richard Liew, Lakshminarayanan Samavedham, and Mr. Alan Soong for their valuable input, as well as the support from the National University of Singapore Center for Development of Teaching and Learning.

The author declares that there are no conflicts of interest.