Teaching Emerging Diseases: A Strategy for Succeeding with Nonmajors

MARION FIELD FASS*

Department of Biology, Beloit College, Beloit, Wisconsin 53511

A nonmajors course on emerging diseases served to introduce students to basic concepts in microbiology and to improve scientific literacy. The course used a range of learner-centered approaches to encourage students to take responsibility for their own learning. Evaluations demonstrated both student satisfaction and an increased understanding of important issues in microbiology.

Infectious diseases have caught the public's attention. Preston terrified us with his presentation of Ebola in *The Hot Zone* (20), and themes of vulnerability to disease pepper the writings of popular authors from Robin Cook (8) to Tony Hillerman (16). The threat of infectious disease epidemics has replaced fear of a nuclear holocaust for many Americans.

The emergence of infectious disease in the public agenda provides microbiology educators with an important opportunity to engage nonmajors in a learning adventure that introduces them to concepts of genetics, microbiology, ecology, and epidemiology. Social issues surrounding the spread of and efforts at the control of disease provide clear examples of the importance of scientific literacy for decision-makers, community leaders, and educated consumers of medical care. A problem-focused course on emerging diseases at Beloit College has served to reach nonmajors, particularly science-phobic students, with content and activities that have increased their understanding of science and have provided them with some of the skills to increase their ability to be scientifically literate citizens.

GOALS AND OBJECTIVES

Biological Issues: Emerging Diseases has been taught at Beloit College since 1996. The goal of this course was to increase nonmajors' understanding of central biological principles and the interrelationships between changes in biological systems and social and political forces. This course was designed to promote scientific literacy by increasing the ability of nonscientists to read and understand science in the news and on the Internet and to make responsible decisions as citizens. Our nonmajors will be the politicians and voters of the future, and rational science policies depend on their abilities.

An additional goal of Biological Issues: Emerging Diseases was to introduce students to experiences in the microbiology laboratory in a manner that would be useful for them. Beloit College requires that each student take two science and math courses, at least one of which is a laboratory science. Students learned how to behave safely in the laboratory and then worked on activities to enhance their under-

standing of concepts introduced in class readings and discussions. Although these students were nonmajors, they did many of the laboratory activities from Introductory Microbiology and were expected to prepare laboratory reports and discuss their findings.

BIOLOGICAL ISSUES: EMERGING DISEASES IN THE BELOIT COLLEGE CURRICULUM

The course grew out of an earlier Biological Issues course on the biological, social, and political aspects of the AIDS epidemic. Biological Issues could be used to satisfy the general education requirement for science for students who are not majoring in science and was not open to biology majors. The course was taught in a workshop format that met three times a week for 2 hours each session. Lecture, discussion, and lab were freely mixed, and students did not distinguish lecture and lab sessions. Lectures, when they existed, were limited to 20 minutes. Enrollment in this class, as in all Beloit College biology courses, was capped at 24 students.

The workshop format used in Biological Issues was adapted from the format for Workshop Human Biology at Beloit College and from the Workshop Physics class designed by Priscilla Laws at Dickinson College (18). The workshop format moved students away from the passive learning mode and was structured to encourage them to be responsible for their own learning. Frequent quizzes and discussion of content required that students keep up with assigned reading. The class size allowed both full-class discussions and small-group problem solving.

Innovations such as workshop science classes and problem-based courses are well accepted at Beloit College. Beloit's faculty have been involved in the BioQUEST Curriculum Consortium and the ChemLINKS project, which have explored new strategies to introduce undergraduates to research-based science. Biological Issues: Emerging Diseases built upon these innovations.

CONTENT

The course emphasized the themes from the ASM Undergraduate Microbiology Curriculum Recommendations (2) (Table 1). A course in emerging diseases must teach concepts of bacterial evolution. Within the context of disease threats, students were introduced to the basics of microbial genetics and how genetic factors determine changes in dis-

*Phone: (608) 363-2784. Fax: (608) 363-2052. E-mail: fassm@beloit.edu.

TABLE 1. ASM undergraduate microbiology curriculum recommendations

Core Theme	Concepts
1. Microbial cell biology	<ul style="list-style-type: none"> • Information flow within a cell • Regulation of cellular activities • Cellular structure and function • Growth and division • Cell energy metabolism
2. Microbial genetics	<ul style="list-style-type: none"> • Inheritance of genetic information • Causes, consequences and uses of mutations • Exchange and acquisition of genetic information
3. Interactions and impact of microorganisms and humans	<ul style="list-style-type: none"> • Host defense mechanisms • Microbial pathogenicity mechanisms • Disease transmission • Antibiotics and chemotherapy • Genetic engineering • Biotechnology
4. Interactions and impact of microorganisms in the environment	<ul style="list-style-type: none"> • Adaptation and natural selection • Symbiosis • Microbial recycling of resources • Microbes transforming environment
5. Integrating themes	<ul style="list-style-type: none"> • Microbial evolution • Microbial diversity

ease virulence and pathogen survival. With a basic understanding of cell biology and genetics, students could appreciate the influence of selective pressures on microbes. Laboratory experiences in bacterial transformation complemented these concepts.

In order to understand disease concepts, students also studied the immune system and how it functions to protect humans from most pathogens. AIDS provided an example for students to amplify their own basic knowledge and to appreciate the advances of recent research and the challenges of the future. All students graduating from U.S. high schools have had some AIDS education, and although they knew that AIDS destroys the immune system, they had little appreciation of what that meant physiologically or how it affected subsequent infections. The topic of AIDS also provided the opportunity to introduce concepts of epidemiology and of factors affecting the spread of infectious diseases.

The concepts of microbial diversity, ubiquity, and adaptation were also important as students developed an understanding of emerging infectious diseases. Changes in the environment were related to the reemergence of new pathogens, and this demonstrated the adaptational advantages that bacteria and viruses have over humans.

This course aimed to help students identify their previous understandings of disease and then to modify them according to scientific principles. Students “knew” about disease, and they had learned about issues in environmentalism. This course helped them explore their understandings and identify their misunderstandings (7) and gave them the opportunity to apply new information in analyzing complex problems.

THE COURSE

Biological Issues: Emerging Diseases built upon a

problem-based approach to content. Laurie Garrett’s popular book *The Coming Plague* (14) was the main textbook. Garrett, a journalist with training in immunology, has woven the science and politics of emerging diseases around episodes of disease outbreaks. These examples became the cases for exploration and the starting points for discussion and lab activities.

Garrett’s starting chapter outlined an outbreak of hemorrhagic fever in Machupo, Bolivia, and provided an introduction to methods of epidemiological investigation, notions of contagion, and the concept of the role of a vector in the spread of a viral disease. More importantly, as Garrett described the case, the emergence of the outbreak could be linked to social and political events. The interrelationship of disease and power politics provided an introduction to interdisciplinary exploration of disease causation and brought students with diverse interests into the discussion. Garrett’s review of how Centers for Disease Control and Prevention (CDC) scientists established disease causation led directly to the presentation of Koch’s postulates, and students then participated in an elegant but simple lab on Koch’s postulates and yogurt (6).

Table 2 illustrates selected topics from chapters in *The Coming Plague* (14), the biological concepts they were used to demonstrate, and the laboratory activities that enhanced learning. Garrett’s book has no charts, drawings, or photos and is weak as a science text. This was easily supplemented, however, with access to microbiology textbooks and with support texts such as *The Microbiology Coloring Book* (1) or with outside readings and the wealth of microbiology re-

TABLE 2. Samples of topics in Laurie Garrett’s book *The Coming Plague* used to provide case-based illustrations for difficult biological concepts

Sample topic	Biological concepts discussed
	<ul style="list-style-type: none"> • Laboratory activities
Bolivian hemorrhagic fever	Consequences of ecological change and human intervention, disease causation <ul style="list-style-type: none"> • Koch’s postulates and yogurt lab
The age of antibiotics	Bacterial evolution <ul style="list-style-type: none"> • Bacterial conjugation lab
Swine flu and Legionnaires’ disease	Antigens and antibodies, DNA, RNA <ul style="list-style-type: none"> • Flu vaccine effectiveness study
Urban centers and disease	Epidemiology of infectious disease <ul style="list-style-type: none"> • BioQUEST epidemiology simulation
Toxic shock syndrome	Evolution of virulence
“Thirdworldization”	Environmental factors and vulnerability to disease <ul style="list-style-type: none"> • Environmental microbiology lab—genetic diversity in soil samples

sources on the Internet (13).

The pedagogy in Biological Issues: Emerging Diseases was varied (Table 3). Two-hour blocks allowed for discussion, simulations, modeling, projects, and the use of labs tied closely to readings. Reading worksheets were used in class with small groups to help them structure discussions about the material they had read. Table 4 illustrates questions for a discussion of Paul Ewald's article on the evolution of virulence that appeared in *Scientific American* (9). Students were given these questions in class and were asked to work in small groups during class time to develop answers. This strategy encouraged students to use scientific terms and concepts and forced them to confront issues they did not understand. During these discussions, the professor circulated among groups, asking questions, keeping them on task, and directing them to new ways of looking at their questions.

TABLE 3. Pedagogical strategies in Biological Issues: Emerging Diseases

Pedagogical Strategies
<ul style="list-style-type: none"> • Lecture • Laboratory exercises, including staining, plating, conjugation, and transformation • Discussion • Critical analysis of Web pages from scientific, public interest, and commercial sources • Computer-based simulations, including BioQUEST MicroGCK and Epidemiology • Case studies and role-play simulations, including the ecological impact of AIDS in an African village and a staging of a conference on foodborne diseases • Design and execution of a community study of the effectiveness of the influenza vaccine • Guided small group discussions of readings • In-depth report, presentation, and development of Web page on country's diseases • Computer graphing of international health and social statistics

Whereas Garrett's book provided an excellent and varied set of case studies, Biological Issues: Emerging Diseases employed other case study scenarios as well. Barnett and Blaikie's 1992 book *AIDS in Africa* (3) provided short biographies of individuals and families from the shores of Lake Victoria in Kenya, from a community where AIDS had an early and devastating impact on village life. Barnett and Blaikie have described the effects of illness on family structure, farming, fishing, and daily nutrition. These anthropological cases provided a basis for students to develop role-plays about the effect of the epidemic on individuals, families, and the ecosystem. Other case studies came from readings and local issues, such as the debate over the establishment of a needle exchange clinic to halt the spread of human immunodeficiency virus (HIV) or discussion of the ethics of AIDS treatment trials in developing countries.

TABLE 4. Structured questions about reading providing the basis for student interaction about content^a

Reading questions
<ol style="list-style-type: none"> 1. Use examples to explain how a pathogen's virulence is related to its mode of transmission. 2. What is a "cultural vector"? How may cultural vectors affect disease virulence? 3. How does evolutionary understanding of virulence help explain why people with sexually transmitted HIV live longer in the 1990s than they did in the early 1980s? 4. What kind of virus is favored in a host population with frequent sexual partner changes? Explain why. 5. Define the following terms: <ul style="list-style-type: none"> -virulence -vector -rhinovirus -neonate -envelope protein

^aQuestions for discussion of Paul Ewald's article on the evolution of virulence (9).

Another format used in Biological Issues: Emerging Diseases was the "professional symposium." This was a modified role-play in which pairs of students were each assigned a short article from the 1997 National Conference on Emerging Foodborne Pathogens published in *Emerging Infectious Diseases* (5). Their assignment was to present the article as if they were the authors. On symposium day, each pair made a brief presentation of "their" findings and recommendations and the whole group later discussed what they had learned about the challenge of controlling foodborne pathogens. Students in this assignment took on the roles of professionals, and read and understood professional communications and were able to communicate them to their peers. They were introduced to the scientific, structural, and consumer issues that complicate the science of infectious disease control.

Keeping up with the emergence of new diseases required students to develop skills in using the Internet for research. The nature of the scientific issues and the need for communication about emerging infectious diseases have led to a tremendous database and continually updated material that students could easily access. Course Web pages (13) provided guidance to relevant sites such as the CDC, the journal *Emerging Infectious Diseases*, and the ProMed Surveillance sites. Students used these sites for their in-depth research projects on a disease or on the diseases prevalent in a particular country. Many of the students in Biological Issues: Emerging Diseases had studied abroad or planned on a semester away. Among 24 students, the travel experiences included China, South Africa, Ecuador, Senegal, Scotland, Russia, Ireland, Morocco, Hungary, and Botswana.

Another course objective was to ensure that the students use Internet resources critically. While students accessed many quality sites, they also found sites that dealt with opinion and were designed to persuade the reader about an alternative view. The class discussed this issue explicitly in an

exercise to evaluate bias in Web pages (12). Students contrasted information about immunization found when searching for “immunization” versus “vaccination.” Immunization is the term commonly used by pediatricians and public health professionals, whereas vaccination is used by parents’ groups, especially those opposed to mandatory immunization.

The Internet became an open-ended textbook for the exploration of issues related to emerging infectious diseases. Students in this nonmajors class and others (21) have developed Web pages of their own to contribute to the ongoing discussion of disease and epidemiology. Developing and publishing Web pages about diseases emphasized to students the need to be accurate, to attribute material to sources correctly, and to be responsible contributors to the scientific community (11). It also demonstrated to them how easy it was to put information on the Web and reinforced the need to evaluate the credibility of sources carefully.

FORMAL LABORATORY EXPERIENCES

Laboratory work in Biological Issues: Emerging Diseases was used to complement disease “stories.” Students in this course completed some of the same activities as in Introductory Microbiology. They were introduced to microscope work and to Gram stains and were able to identify the bacteria in the yogurt they cultured in the Koch’s postulates lab (6). They performed experiments to understand antibiotic resistance, worked with plasmids to transfer antibiotic resistance to competent bacteria, and explored microbial diversity by plating soil samples on varied media (15).

Students also participated in community health research. They used published data from UNICEF (4) to graph relationships between social and economic indicators, basic health indicators, and child and adult mortality. This exercise was designed to help nonscience students think quantitatively about health indicators and real rates of disease and death. Students also designed and executed a study of the effectiveness of the influenza vaccine in preventing upper respiratory infections on the Beloit College campus, modeled on a study by Nichol et al. in the *New England Journal of Medicine* (19). Students designed questionnaires, gathered and analyzed data, and wrote research reports. This effort introduced the students to the challenges of community research and helped them to understand the nature of results reported in the scientific literature.

In addition, the course also used BioQUEST (17) modules to simulate experiments and build models. These activities needed to be introduced with great specificity to nonmajors who struggled to see the connections between computer simulations and the bench laboratory experiments and population studies they represented. The students used the module MicroGCK to explore lab procedures in the identification of auxotrophs and to develop systematic testing skills. They also developed mathematical models of the spread of diseases using the module Epidemiology. This simulation introduced the Susceptible, Infected, and Recovered (SIR) model of disease spread. The students then needed

to develop hypotheses about disease spread in developing their own models. They generated graphs to illustrate the factors that differentiated patterns of disease spread.

EVALUATION

This course has been taught three times to a total of 72 students. During the first two years, the course was evaluated only by student grading and standard course evaluations. In 1998, the course was evaluated with an open-ended questionnaire distributed to all 24 students as well as by the grading of student progress.

The basic structure of the course has remained the same since 1996, but in 1997 class Web pages were developed to support the syllabus and make readings more accessible to students. In 1997 and 1998, students were assigned to develop Web pages for their final projects, and these were posted on the class website. The development of a website and assignment of Web page development formalized the use of the Internet in the course and provided students with guidance for Internet research related to emerging diseases. Students have reported that developing their own Web pages gave them a better appreciation of the ease of Web publishing and raised their index of suspicion about what they read on the Internet.

Changes in student knowledge and skills were measured in the process of grading the course. Grades were based on lab work (25%), midterm and final exams (40%), papers and presentations (25%), and attendance (10%). Of 72 students enrolled in 3 years, 3 students failed the course in the first year, but none failed or dropped in subsequent years. Successes were evident, as students who had dreaded science classes became competent in basic microbiological practices. In future years, a pretest-posttest evaluation of knowledge is planned.

Class participants in Biological Issues: Emerging Diseases were drawn from nonmajors across the disciplines. The 24 students in the 1998 class included students majoring in English, sociology, art, political science, economics, and psychology and included students in all years of their college experience.

The qualitative evaluation done in 1998 provided a more in-depth perspective of what Beloit College students completing this class felt they had learned. Beloit College students are accustomed to filling out questionnaires at the end of courses and realize that their input is valuable to professors and is used in tenure evaluations. Students do not hesitate to criticize professors and content and are equally forthcoming with praise. Student comfort with the format of evaluation increased the validity of the comments. Twenty-two of 24 students completed the evaluation questionnaires.

The open-ended questions in the evaluation were designed to assess how students perceived their skills after the course and to gain an understanding of how their views of microbial activity had changed. Students were asked how the course had affected their interest in biology. Eighty percent stated that their interest had increased, particularly in the

interconnectedness of biological and social factors in disease causation. One of the “science-phobic” students in the class reflected on her previous experiences in science classes as follows: “Before this class I had very little experience with biology. The experience that I had managed to turn me off to the subject. This class increased my interest in biology by about 100% and I found everything in the class very interesting.”

Students were asked whether they were better prepared to read about and evaluate scientific issues in the news. Much of the class had focused on understanding science as it is reported in the newspapers and on TV, and how issues are represented on the Internet. Students also had participated in role-plays and discussions that had stressed their future roles as citizens and decision-makers. Their responses about their perceived ability to understand science in the public forum were positive. Eighteen of 21 responders commented that they were somewhat better or much better able to read and evaluate science in the news, and the remaining three reported that they were already strong in science evaluation skills before the class. Many students emphasized the value of learning about the language of science and discussed how the class had “demystified science” for them. One student spoke of this directly and commented that “scientists speak and write in their own language, which nonscientists have a fear of. This class helped me to realize that what science is telling us is not that hard to follow, if you take the time to really read it, and not just get lost in the language.” Another student related the “scariness” that science had held for her and noted that this class had helped her acknowledge the role of science in her everyday life.

Students were asked to identify what they had learned that was of most value to them. The twenty-two students contributed 41 responses. Their responses fell into three large categories: skills (46%), including laboratory skills, Internet skills, and scientific understanding; synthesis (33%), including critical thinking skills and understanding of the interconnectedness of science and social factors; and personal growth (20%), including greater awareness and empowerment. One student citing improved skills stated, “the most valuable thing I learned to do in this class was to conduct a lab. I had never conducted a lab before in my life and I thought at first I was not going to be able to do it, but I succeeded.” Another reported that “learning about microbial competition and genetic exchange and the rapidity at which all this occurs helped me to understand microbes and to become an obsessive hand and surface washer.”

The interrelation of science and social and political factors was cited by 9 of 22 students. One student said that “relating emerging diseases to ecology and all the other factors entailed [was most important to me]. I never realized that there was so much more to disease than the disease itself, like culture, economy, population movement.”

Students were asked to evaluate what parts of the course were most valuable, using a Likert-type scale, from 5 (“very valuable”) to 1 (“not at all valuable”). These data are displayed in Table 5. These results demonstrate a high level of

satisfaction with course components. The lowest-ranked component was *The Microbiology Coloring Book* which was used as a straightforward introduction to scientific concepts. In contrast to this, however, students were enthusiastic about the laboratory component of the course, even though they received no extra course credit for completing a laboratory course. A student reported that “lab work was a plus to this class. It helped illustrate many of the topics we discussed in the class, such as antibiotic-resistant strains of bacteria.” Another simply stated, “I enjoyed this class’s labs because I could see the larger picture.”

Most striking in this evaluation was the enthusiasm which nonscience students had for the material. As the course has evolved over the three years, it has included more sophisticated laboratory experiences, as students demonstrated that they valued the hands-on learning that came from growing their own microbes and watching them adapt. In a world where increasingly difficult issues about the role of antibiotics and about the uses of biotechnology are arising, it is valuable for nonscience majors to understand the ease of microbial change.

This course succeeded because it dealt with issues of great relevance to the students and used them as a hook to draw students into a greater understanding of the microbial world. Instead of starting with things unseen, the course started with things seen and experienced and focused on demystifying these experiences. It went from the concrete to the abstract and then back to the concrete again, as students were informed of their future roles as patients, community members, and voters. Scientific literacy became a responsibility, not a burden.

TABLE 5. Student evaluation of the value of selected course components

Component	No. of respondents giving indicated score ^a		
	"Very valuable" or "valuable" (5, 4)	"Moderate value" to "not at all valuable" (3, 2, 1)	Mean score
<i>The Coming Plague</i>	21	0	4.9
<i>The Microbiology Coloring Book</i>	5	16	2.7
Weekly reports on disease surveillance (MMWR) ^b	17	4	4.1
Foodborne disease symposium	9	12	3.4
Internet activities	12	9	3.5
Laboratory activities	16	5	4.0

^aOf a total of 21 respondents.

^bMMWR, *Morbidity and Mortality Weekly Report*.

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The ASM offers career materials including a 12-page pamphlet on careers in microbiology, "A Million and One," available in English and Spanish; a poster on heroes of microbiology depicting minority scientists who have contributed to the field; a poster on heroines of microbiology representing women who have contributed to the field; and a careers poster illustrating various facets of microbiology. Each poster includes a hands-on activity on the reverse side. To request any of these materials contact Fellowships-CareerInformation@asmusa.org or call 202-942-9283/202-942-9295.

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