

Helping Educational Reforms To Succeed in a Microbiology Department

Several factors prove crucial when adapting inquiry-guided reforms to an undergraduate microbiology curriculum

Virginia S. Lee and Michael Hyman

During the past decade, a rising chorus has called for major reforms in how we teach science, technology, engineering, and mathematics. Part of the impetus for those reforms comes from concerns over growing numbers of students leaving the sciences, the eroding stature of the United States in the sciences compared with countries such as China and India, and also losses of personnel to fields such as biotechnology.

In response to such pressures, one path to reform is the development of educational practices that explicitly engage students while enhancing how they learn science. These practices,

including inquiry-based laboratory exercises and peer instruction, find empirical support from studies that help to explain the underlying psychological processes that are integral to learning science or other technical subjects. The monograph *How People Learn*, issued in 2000 by the National Academy of Sciences, further supports approaches in which students are actively engaged in the learning process. Meanwhile, the National Science Foundation and various nongovernment foundations support curricular innovation in the sciences.

When it comes to reforming a science curriculum, however, innovation is not enough.

Thus, despite spotty reform efforts, U.S. colleges and universities are generally proving slow to change their educational practices. Departments need to be ready for change and then need to develop and implement a vision if those reforms are to take hold. Instead of doing so, too many instructors, particularly those teaching introductory science courses, continue to stupefy their students with rote information. Further, undergraduate curricula in the sciences typically remain an afterthought to research agendas. Thus, we need to understand what makes some reform efforts successful to improve the chances of disseminating these successes to other institutions.

Case Study: Microbiology Teaching at North Carolina State University

In 2000, one of us (V.L.) began working with faculty members from 10 academic departments at North Carolina State University (NC State), including the Depart-

Summary

- Microbiology and other science departments are reforming how they teach, in part by better engaging students through inquiry-based laboratory exercises and peer instruction.
- In 2000, 10 academic departments at North Carolina State University including the Department of Microbiology, began bringing inquiry-guided learning (IGL) practices into broader use.
- The project team from the department focused on revising four required core courses for undergraduate students who major in microbiology but eventually added IGL components to nearly all the microbiology courses.
- While externally funded innovation is helpful, several internal factors are critical to the success of reform measures, including departmental vision, a need for a change, collegiality, support for the teaching mission, and access to outside resources.

Virginia S. Lee is principal and senior consultant at Virginia S. Lee & Associates, LLC, Durham, N.C., and Michael Hyman is Associate Professor in the Department of Microbiology, North Carolina State University, Raleigh.



Table 1. Department of Microbiology Learning Outcomes with Selected Objectives

1. Demonstrate a sound working knowledge of the field of microbiology.
2. Demonstrate a command of the skills necessary to perform effectively and safely in a microbiology laboratory and to show that they
 - (a) have mastered the techniques essential to sound laboratory practice;
 - (b) can ask pertinent questions about microbiology, formulate hypotheses based on those questions, and design experiments to test those hypotheses;
 - (c) can apply deliberate and thorough observational skills to conduct experiments and collect data;
 - (d) can organize and summarize data and present them in a way that is accurate and comprehensible in both verbal and graphical modes; and
 - (e) can interpret data and draw conclusions that allow the students to support or refute hypotheses and make a case for alternative hypotheses.
3. Understand, manage, and apply information about microbiology from both scholarly and popular sources and to communicate their understanding clearly and coherently for different audiences.

ment of Microbiology. That project was aimed at introducing inquiry-guided learning (IGL) practices into broader use at NC State, particularly in science departments. Such practices encourage students to learn subjects by actively investigating complex issues and asking tough questions. The overall project encompassed courses being taught in several science and engineering majors, and involved four campus-wide initiatives, all geared to improving student learning.

During and after the project period, members of the microbiology team made particularly good progress introducing IGL approaches into their undergraduate curriculum. We asked ourselves what was it about the microbiology department that enabled it to make substantial progress so quickly.

The undergraduate major offered by the microbiology department, one of 21 departments in the College of Agriculture and Life Sciences at NC State, was approved in 1992. Since then the numbers of microbiology majors grew from 58 that first year to about 200 in 1998, when enrollments stabilized. In 2000, a specialized facilitator worked with the department to institute curricular-level outcome criteria that undergraduate students who were majoring in microbiology were required to meet (Table 1).

In developing those outcome criteria, the microbiology faculty began to think more extensively about their approach to teaching undergraduate students and soon realized that additional teaching reforms were warranted. Thus, the department came to participate in the Hewlett Campus Challenge Project, which em-

phasized IGL as an efficient approach to teaching students enrolled in research-based scientific disciplines. Moreover, members of the department saw that IGL directly addressed many of the shortcomings that they had identified in their courses.

The Hewlett project focused on four outcomes for students—critical thinking, independent inquiry, taking personal responsibility for learning, and intellectual growth and maturity. The Hewlett project outcomes were consistent with those that the department had identified. Further, the project provided a framework for improving courses and broadening access to other experts at NC State who could help faculty in the microbiology department better understand issues such as the diversity of student learning styles and the variety of ways students develop critical thinking skills.

Project Revises Four Core Courses in Undergraduate Microbiology Curriculum

The project team focused on revising four core courses that NC State undergraduate students who major in microbiology are required to take in sequence (Table 2). Some of this planning took place during a retreat that included other members of the undergraduate teaching faculty as well as several senior members of the department. The main focus of the retreat was to discuss the courses and to explore how IGL tied in with the undergraduate curriculum learning outcomes and program assessment.

During that retreat, participants mapped out how specific courses serve to meet curricular outcomes. Faculty members agreed that the IGL courses provided their students with valuable learning experiences. The faculty then attempted to determine how well their core courses prepare students for the next phase of their careers in microbiology. This discussion highlighted how fully the faculty embraced the curriculum and how much they value those courses as being part of the larger learning experience of their students. Thus, none of the core courses is kept as the singular domain for any particular individual in the department.

The faculty members attending the retreat also considered how well the then-current curriculum addressed the needs of undergraduate students majoring in microbiology in terms of

academic rigor. For example, when they reviewed the grade point averages (GPA) of undergraduates and other factors, the faculty members realized that the more gifted and motivated students could benefit from having available more intensive courses and other enrichment opportunities. To respond to this need, the faculty expanded the number of positions available in the honors general microbiology lecture and laboratory courses and also began developing a research-intensive honors curriculum that included general education courses as well as a four-semester research program.

The department introduced further changes into the undergraduate curriculum, eventually adding IGL components to every course taken by students majoring in microbiology (Fig. 1).

Teaching Expands, New Instructor and Graduate Program Added

When the faculty grew comfortable with the demands of IGL-based courses, they began to consider new directions to take, realizing that IGL approaches to teaching place greater demands on resources than do conventional lectures. One step was to hire a temporary instructor, who enabled the department to expand enrollments in the honors lecture and laboratory courses and also to make the laboratory course a requirement rather than an option for undergraduates majoring in microbiology.

In recognizing the value of the IGL approach for teaching undergraduate students, several members of the faculty also took steps to introduce IGL-based principles into courses for graduate-level students in microbiology. Two faculty members, including Michael Hyman, who served as Hewlett project team leader, later received support from the Sloan Foundation to establish a professional master's degree program in microbial biotechnology (<http://microbiology.ncsu.edu/graduate/mmb/index.htm>). This multidisciplinary program prepares graduate students for jobs in biotechnology companies, including those located in nearby Research Triangle Park, N.C. The 72-credit-hour program centers on a 12-credit-hour (3 credits/semester) case studies course in which students solve problems posed

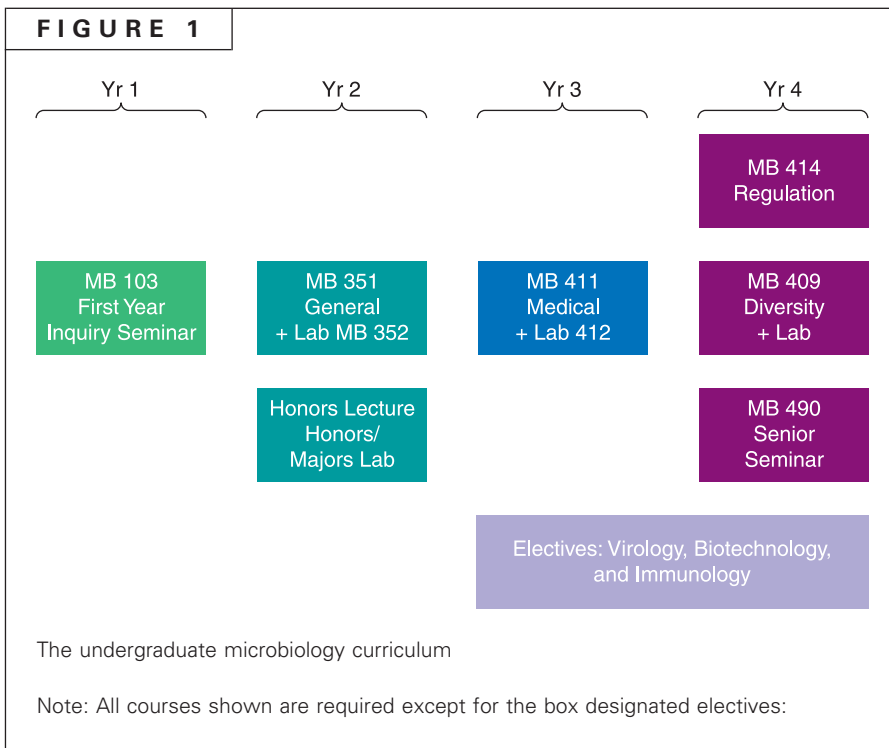
Table 2. Attributes of Microbiology Required Courses Before and After IGL

Course	Pre-IGL	Post-IGL
MB103: First year introductory course 1 credit, 1 hour/week	College-wide 150 students/section Presentations by different disciplines, presentations and assignments on computer and library use	Department's own course 25 students/section Mostly guided discussion Assigned reading/writing assignments to assess and develop critical thinking
MB351: General microbiology (Over 250/semester)	Large lecture—all lecture Graded work: multiple choice exams	Large lecture – mostly lecture, minute papers, in-class challenge questions Graded work: four homework assignments (total equal to one exam), four exams: combination multiple choice and essay
MB411: Medical microbiology (80 students/year in 1 semester)	Mostly lecture, occasional case studies Graded work: exams combination of multiple choice, short answer and essay	2/3: mostly lectures, in-class challenge questions and discussions 1/3 (one day/week) group work on discussion questions: total group work grade equal to one exam
MB352: General microbiology lab (25 students/section)	Techniques described and then practiced by students	Same for nonmajors New labs for majors and honors students: learning basic techniques and scientific reasoning through two experimentation modules
MB412: Medical microbiology lab (25 students/section)	Techniques described and then practiced by students	New laboratory modules: virology and bacteriology experiments designed by students within limited parameters
MB490: Senior seminar	25 students/section Discussion and student presentations Several writing assignments	Not changed

to them by local industry executives and other experts.

Five Critical Factors for Reforming Undergraduate Teaching Programs

Several factors contributed to the success of efforts by NC State microbiologists to improve their approach to teaching both undergraduate and graduate students. Externally funded innovations are not sufficient to bring about long-lasting or sustainable change. While such re-



sources can help to galvanize change, other conditions must be in place for those changes to catch hold, including a departmental vision, the need for a change, collegiality, support for the teaching mission, and access to outside resources. Recognizing those factors and taking steps to put them in place can help to create the state of readiness that is vital for such reform efforts to succeed.

Faculty members in the NC State Department of Microbiology already had developed detailed curricular-level student learning outcomes before they began their concerted teaching reform campaign. Thus, they identified and agreed to a set of expectations for undergraduate learning. In articulating these goals, faculty members also spent considerable time thinking more explicitly about the discipline of microbiology. In doing so, they went beyond the content of individual courses to identify those overarching skills and competencies that students of microbiology need to develop.

After developing curricular-level outcomes for students to meet, the microbiology faculty recognized a discrepancy between their approach to teaching most lecture or conventional lab courses and the methods that would be required to meet those newly identified outcomes. However, they did not immediately

know what those new teaching methods should be. This gap created pressure for change, which the Hewlett project helped to address. This process of “identifying and uncovering a disorienting dilemma” stimulates change, according to education specialist Jon Wergin of Antioch University in Yellow Springs, Ohio.

When implementing teaching reforms, collegiality proves important. Indeed, other academic values, including autonomy, academic freedom, and specialization, can help to undermine undergraduate curriculum reform efforts either because they deflect interest away from teaching to research or because they make cooperation difficult. In the NC State Department of Microbiology, however, there was a high degree of collegiality, particularly among the four faculty members who were directly responsible for teaching undergraduate courses. Further, hiring procedures insured that new faculty would

recognize the importance of teaching and thus share that philosophical orientation.

Another feature that promotes collegiality is to have junior faculty members all teach the same courses and therefore face comparable challenges. Having a rotation system that has successive junior faculty members teaching courses that all undergraduate students are required to take forces the junior faculty to organize, sharing their successes and failures while disseminating useful information to all members of the group. The fact that few of them had teaching experience further enhanced their sense of collegiality as they faced these teaching assignments together. Of course, without tenure, they were strongly motivated to do well. Yet the entire process was so new that they retained flexibility and enthusiasm as they swapped ideas and notes and suggested approaches. This bonding built a strong subculture that senior members of the department fostered.

Despite their strong focus on research, the members of the microbiology department also strongly value undergraduate teaching. In 1974 the department had hired a faculty member, Gerry Luginbuhl, whose primary focus was undergraduate teaching, and part of her mission was to develop the undergraduate curriculum.

As a senior member of the faculty, her involvement and commitment to undergraduate teaching further conveyed to junior faculty members the importance of the undergraduate teaching mission to the department. Further, the college administration supports the teaching mission, providing resources to improve the infrastructure of the teaching laboratories.

The department and the university administration through its regional accrediting body supported the Hewlett project from the outset. Thus, the regional accrediting body, the Southern Association of Colleges and Schools, endorsed student learning outcomes and outcomes-based assessments as a requirement for academic program review.

Microbiologists in the department were further encouraged to improve their undergraduate teaching programs through contact with

ASM, which broadly supports undergraduate teaching, in part through an annual conference on this subject prior to the General Meeting. The Hewlett project enabled several NC State faculty members to participate in that meeting. The department subsequently provided support for at least one attendee each year. Based on honors laboratory projects, students in the department began posting teaching aids on the ASM website (www.microbelibrary.org/asmonly/details.asp?id=2020 and <http://nsdl.org/resource/2200/20080618222528647T>). Additionally, the department is taking advantage of other recommendations that ASM compiles regarding the training of well-rounded microbiologists. These recommendations offer useful benchmarks, particularly as the department continues to refine its learning outcomes-based curriculum.

ACKNOWLEDGMENTS

We are grateful to the William and Flora Hewlett Foundation for its support of a project to review and reform educational practices in 10 academic departments at North Carolina State University, including the Department of Microbiology.

SUGGESTED READING

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