Integrating Research and Teaching Heightens Value to and of Undergraduates

Engaging students in activities outside the traditional curriculum in microbiology encourages them to become lifelong, critical thinkers

Alix Darden

When The Citadel hired me in 1995, I was asked to develop several courses, teach undergraduates about genetics, microbiology, molecular biology, and immunology, and set up a lab to involve some of those students in research projects. While I was preparing for my first semester, my expectations were straightforward. I envisioned my primary role was to impart information to students in the classroom and to familiarize them with the scientific process through their efforts in teaching laboratories and, in some cases, research laboratories.

Rather naively, I believed that the majority of my time at a school whose primary mission is educating undergraduates would be spent teaching. However, I learned quickly that the majority of my work did not directly involve time spent with students. Instead, I faced a variety of other faculty responsibilities, many of which kept me away from students (Table 1).

Of course, another unwritten duty for anyone teaching undergraduate science courses entails staying current in your field, a duty that takes on new dimensions because your field now includes a wide range of subjects covered in the courses you teach in addition to the field in which you are doing research. Moreover, microbiology, genetics, and the related fields that I teach about are not stagnant. New advances, both intellectual and technological, are constant and many, meaning new information needs to be incorporated steadily into classroom lectures and research projects.

Other duties revolve around research and teaching labs, both of which need to be supplied, organized, and have materials prepared. In many institutions these duties fall totally or at least partly to whoever is teaching the relevant courses. Hence, when I include particular lab exercises in my course syllabus, I need to consider the quality of the learning experience and the cost as well as the preparation time for each one of them. Startup funds to support research activities typically are limited, meaning that teachers may want to write grants to support research and possibly also some of the activities undertaken in teaching laboratories. Also, down the road, a faculty member will need to show promotion and tenure committees evidence of his or her scholarly achievements, which typically include presenting research findings at national meetings and then publishing reports based on that work.

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Several Years of Teaching Change One's Perspective

After several years in my faculty position, my perspective of student-faculty interactions began shifting. The student learning role seemed incredibly passive, and I often felt that I was

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Table 1. Examples of faculty responsibilities performed away from students

Teaching	Scholarship	Service
Design courses Prepare syllabuses Write and grade tests, papers, etc. Prepare laboratories for class Develop classroom activities to enhance learning Develop new laboratory exercises which reflect advances in the field Stay abreast of current literature in all the fields you teach Learn the class management computer program of your institution	Stay abreast of current literature in your research field Stay abreast of technical advances in your field Write abstracts, papers, grants, etc. Organize and run research lab	Institutional committees Community Professional organizations

spending far more time on the course than the students were. Meanwhile, I learned of a shift among educators at the national level, who began promoting active student learning as part of movement to reform higher education.

During the past decade, faculty members and other experts across the country repeatedly called for fundamental challenges in postsecondary science education. One important proposal for reforming the system recommends creating learner-centered environments in which students actively learn science by doing research. For example, their academic progress in the sciences is enhanced when they collaborate with peers and instructors, engage in research projects, explore fewer classroom topics but in greater depth, relate scientific understanding to relevant social issues, and develop oral and written communication skills. By participating in these varied activities, science students learn how to learn and become lifelong learners.

During this same period, both local and national assessments of what students are learning became, and continue to be, a legislative issue tied to the financial support of many state institutions. Faculty are required to show that their students can think critically about relevant issues and apply the information in novel ways. Another higher education reform was introduced in 1990 with the publication of *Scholarship Reconsidered: Priorities of the Professoriate,* by Ernest Boyer. It redefines scholarship and what constitutes scholarly work, incorporating not only the scholarship of discovery, but also the scholarship of teaching and learning. In a sense, this new definition gives faculty members at colleges and universities formal permission to look at what and how our students are learning.

When faculty members serve as mentors to students doing research, this collaboration benefits both parties. I now regard student learning as an area of my research and watch for all areas in which I can collaborate with my students. This type of relationship, in turn, provides faculty members with support and assistance on the job where once there was little, if any. The benefits to the student include a chance to do the science that they are learning about in classes, insights into career paths that they might follow, and one-on-one interactions with individual faculty members.

Because student learning is now an area of my research, I need to generate hypotheses to test. These observations led me to develop the following hypothesis. Many time-consuming, supposedly routine faculty activities can be recast as valuable learning moments for undergraduate students.

Engaging Students in Nontraditional Learning Activities

I now routinely engage students in activities that ordinarily are not considered part of the traditional college curriculum in biology and microbiology (Table 2). I also reward these students for participating in those varied learning activities in a variety of ways, including with grades, food, fun, and opportunities to formulate and express their opinions. However students are rewarded, it is important that the faculty member recognize the time they spend doing something as valuable. Examples of activities in which my students are often engaged include laboratory prep work of several sorts, generating exam questions and other classroom-related tasks, and reviewing research lab findings and observations as part of the newest curriculum developments.

Preparation of teaching labs puts enormous demands on me, and I am not provided with any assistants to help in this work. It is not unusual for me to prepare each week for two different upper-level laboratories. Now my students regularly participate in these activities.

For the microbiology teaching labs, my students are responsible for making the growth media that are used. Each week media requirements are listed, including how much to make and what type of vessel to use. Student groups check off what media they will make, divide the labor, and start mixing media soon after they enter the lab.

Each student also is required to participate in one 30-minute lab clean-up session per semester during which they dispose of old cultures, put away equipment, and refill reagent containers. On the last day of a class, all students participate in a major lab clean-up, each given their own chore. By the time they leave, all dirty glassware is cleaned and put away, all old cultures autoclaved and disposed of appropriately, workboxes cleaned out and reorganized, sinks washed down, and bench tops cleaned, leaving the lab ready for the next semester.

Our genetics teaching laboratory is not so labor intensive as the microbiology lab course. However, many students majoring in biology education are interested in gaining such lab preparation experience, and I gladly teach them how to prepare for our genetics lab course—helping with several tasks such as labeling reagents for molecular biology exercises, breeding flies, pouring agar plates, making agarose gels, and setting up workstations.

I also engage students in several unusual activities to enhance their involvement in the classroom side of their course work. For instance, I give students credit for generating test questions and providing answers for those questions. This activity requires a good working knowledge of the material being presented in lectures, meaning that students who come up with good exam questions are demonstrating an ability to apply the information.

Because I use modeling activities to help students understand abstract concepts and because identifying such models can be very time consuming, I also give students credit for finding and presenting their own examples of such modeling to the class. They are expected to provide a handout that will facilitate anyone else in the class using that activity.

Meanwhile, to teach them how to find and evaluate current scientific information, students are required to do literature searches, to find related references on particular topics, and to outline a paper that they might write using these references. This exercise not only teaches them lifelong learning skills but also provides me with useful information on topics that I sometimes later incorporate into my lectures.

When introducing new laboratory exercises or learning activities into classes, I often do so as part of smaller, upper-level courses in which highly motivated students are enrolled. This approach allows me to refine the newer exercises, figuring that, if these motivated students cannot make it work, then it probably is not going to work for first- and second-year students.

Every time I return from attending an ASM undergraduate education conference or national meeting, I bring new ideas for engaging students. However, I realize that not everything will be effective. Therefore, students are asked to give feedback on what works and what does not, sometimes asking them to respond to surveys that are several pages long. To encourage them to complete these surveys and to provide reliable information, I give them credit and/or provide food as rewards.

Table 2. Students as Worker Bees

Teaching	Scholarship	Service
Generate test questions	Proofreading abstracts, manuscripts, and grants	Judge science fairs
Help prepare and clean up labs	Perform literature searches	
Generate teaching activities	Compare laboratory techniques	
Field test lab exercises	Present timely scientific findings	
Field test teaching activities		
Curriculum development		

Full-Time Teaching Changes One's Perspective on Scholarship Activities

When juggling a full teaching schedule, room for thinking about other matters seems to be one of the first luxuries to disappear, while time for scholarship often goes by the wayside. Hence, when I can incorporate material relevant to my research into a course, I do so because it means that more of my brain space can be devoted to scholarly work than it otherwise would be.

When appropriate, I incorporate examples from my research into both lecture material and laboratory exercises. If, as part of a course requirement, students are reading and discussing journal articles, I routinely assign them articles from my research to-read list. Thus, as I read and analyze the article for that class, I double-up on reading and analyzing it for my research. Additionally, the students often bring up very interesting points during the discussion that I sometimes overlook. Similarly, students can learn how to use electronic resources such as Medline by researching a topic relevant to research in my lab. When I review and give them grades for their literature searches, I often also find references of potential interest, thus achieving additional goals with this activity.

Laboratory exercises can involve using kits or techniques that I also want to use in my research. One semester, for example, I obtained yeast DNA microarray chips from the Genome Consortium for Active Learning (GCAT, http://www.bio.davidson.edu/Biology/GCAT/GCAT.html), a program for bringing functional genomic methods into the undergraduate curriculum, primarily through student research. Students in my molecular genetics class spent the semester designing and implementing a research experiment using these microarrays. At the time, I had no direct experience with microarray experiments, so my students and I became a team with different roles to play. We often worked out experimental difficulties as a group. I was not tempted to provide them with ready answers to questions that arose because I could not! Students were exposed to the experience of working on a real research project, while I learned enough about microarrays to determine the appropriateness of the technique for my research.

Undergraduates are also an excellent resource for reviewing grants. They have helped me by editing grants and reading proposals for clarity. An upper-level undergraduate student majoring in biology should be able to comment on the flow and readability of the grant proposal. Students were honored that I respected their opinions. When students read and edited a particular grant proposal two hours before it was mailed, their comments led me to correct significant errors that I had overlooked. The grant was funded.

Results—Does this Approach Really Work?

As with every experiment that I do, assessment is critical. Anything my students do, I evaluate for its effectiveness—grading their work while asking their opinions. I also evaluate how I spend my own time, if for no other reason than my yearly evaluation requires me to do so. Based on student feedback, I know whether and how much repetition of certain activities is effective and at what point it merely becomes tedious. Using this approach, I have successfully moved activities from upper-level to introductory courses, in effect, field-testing these materials in upper-level classes. Correspondence with past students indicates that they continue to use many of the skills that they learned in these classes.

Feedback from students motivates me to continue to be innovative in the classroom. I believe that because of the current ways in which I interact with students, I have become a better teacher and my students are better learners.

Many of these activities have been presented and published because I document these activities, making much of the work that I initially viewed as a required task become part of my scholarly work. Essentially two goals that I am evaluated on, teaching effectiveness and scholarship, can be achieved with one activity.

What Do Students Learn? What Have I Learned?

No job in science is done the way science has traditionally been taught in college. Science requires individuals to apply information, work in teams, and integrate new information into their ongoing activities. In effect, I am now exposing my students to near-immediate, real-world applications of what they are learning in classrooms and laboratories, allowing them to demonstrate their skills in authentic assessments while they undertake tasks much like those that they will be performing as they pursue various careers.

I believe that learning needs to be an active process at all times. The faculty's role is to facilitate, guide, and motivate the learning process—training students to be lifelong learners and critical thinkers. Because information in the sciences is constantly changing, they need to learn how to evaluate, integrate, and apply information, not simply memorize accepted facts and theories.

The faculty-student relationship is very much one of the powerful over the weak. We faculty members give students grades and, to some extent, control what they will do in the future. As students become our collaborators rather than mere recipients of our knowledge, they come to realize that their opinions are respected and valuable to the faculty. When that happens, students take ownership of the learning process and become more involved in learning, realizing that they have a critical stake in that process and control over it. I have been energized by seeing what my students are capable of achieving. Thus, my students have proved an integral part of my success as a junior faculty member.

SUGGESTED READING

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