Making the Right Moves

A Practical Guide to Scientific Management for Postdocs and New Faculty

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Chapter 13

TEACHING AND COURSE DESIGN

As a new junior faculty member, you might have mixed feelings about taking your place in front of a class. You stare at a sea of faces and think: "What am I doing here? I'm a scientist, not a teacher." Very likely, you feel uncomfortable with teaching because you have never learned how to do it. In this chapter, you will learn how to become a more effective teacher by using a variety of strategies, including "active learning." By experimenting with different teaching methods, continually assessing their effectiveness, and modifying them based upon assessment results, you can become a "scientific teacher" who is as rigorous in teaching as in research. Although the chapter focuses on teaching undergraduates at large research universities and students at medical schools, the methods described can easily be adapted to teaching undergraduates at smaller liberal arts colleges and to teaching graduate students.

This chapter suggests ways to improve your current teaching style by assessing your strengths and weaknesses and learning from colleagues and other professionals. It also offers advice for revising and designing courses, helping your graduate students and postdocs learn to teach, creating a teaching portfolio, and balancing your teaching and research responsibilities.

WHY TEACH WELL

Beyond your contractual obligations, there are important reasons to teach well. Gaining the varied skills required to become a good teacher will benefit you professionally by strengthening your résumé, enhancing your communication skills, and bringing new energy to your lab investigations. You will also contribute to the greater good of society by educating the next generation of students (those who become scientists, as well as those who go into other fields), and you should gain great personal satisfaction by giving a diverse set of students the knowledge, insights, and enthusiasm they need to succeed in science careers. These reasons are explored in greater depth below.

Reasons to Teach

A strong teaching record can help your tenure case. If you are knowledgeable about teaching and can cite evidence that your teaching is effective, the people who are evaluating you will care—or you can make them care. Your ability to prosper in an academic environment will depend in part on your teaching record.

Get to know potential students for your lab. Teaching a class well will likely give you access to top undergraduate or graduate students who may want to join your lab.

Increase science literacy. Increasingly, scientists will be called upon to communicate effectively with the public about complex societal issues, such as genetic engineering or stem cell research, that directly involve advances in science and technology. Teaching will improve your communication skills. In addition, by effectively teaching students who will not be scientists but policy makers, business leaders, and others, you will increase science literacy.

Science needs to retain the best and brightest students. Colleges and universities are losing students from science classrooms at dramatic rates. About 60 percent of students who declare biology as a major do not graduate with that major. The statistics are worse for women and minorities. Often, the students dropping out of science are the ones with very good grades who have gotten the message that science is boring, that teachers already know all the answers, and that there is nothing left to be discovered. By changing your teaching style to one that engages students in the discovery process, you will help change the current trend.

Science needs to draw diverse participants. Heterogeneous groups of people are more effective at problem solving and defending their decisions. To continue to make science a thriving enterprise, we need to attract and retain a diverse community of students and to recognize, appreciate, and satisfy their diverse styles of learning.

Intellectual growth. Ongoing interactions with new students will provide you with new skills and improve on existing ones. For example, teaching will help you improve your communication skills, which are invaluable to research.

Increase job satisfaction. Your science experiments are not always going to go according to plan, and at times you may become frustrated with the pace of research in your lab. Teaching a class may provide you with a much needed distraction and sense of accomplishment.

BECOMING AN EFFECTIVE TEACHER

Teaching the lecture component of a basic science curriculum for medical school students or a year-long microbiology course for undergraduates can be daunting. You want to be well-prepared for this new responsibility. So, how do you learn to become a capable and effective teacher? There are several steps you should take before you even set foot in the classroom.

Assess Your Strengths and Weaknesses

Research has shown that the best teachers are not only knowledgeable about their subject matter, but they also show a concern for students and know how to stimulate interest, encourage discussion, explain topics clearly, and show enthusiasm. Think back to your teaching assistant (TA) days or other teaching experiences you may have had. They might give you some insights into what teaching skills you could improve.

The type of course assigned might not mesh with your scientific preferences, but you should take the time to assess your strengths and weaknesses and take those into account when planning your classes. For example, if you are an extrovert, sharing your enthusiasm for science with students should be easy for you, but you might need to avoid overwhelming students with a rash of complex ideas and, instead, give them more time to pose questions and reflect upon solutions. If you are an introvert, you might find teaching in a large lecture to be so intimidating that you retreat behind your lecture notes and have difficulty interacting with students. If you are given a choice, you can build your confidence by starting with a topic you know well and feel passionately about. After you have established some rapport with students, encouraging give-and-take might be easier for you. Working with small groups is a strategy that should suit your personality. Since good teaching is part art, part technique, and part personality, you will need to find techniques that both fit your personality and address your students' varied learning styles.

Take Advantage of Professional Help

To help you become a better teacher, take advantage of whatever professional assistance your college, university, or medical school offers. Although formal programs aimed at improving learning are still rare, their numbers are rapidly increasing, and many informal programs exist. Some universities offer career development programs for junior faculty; these programs give opportunities for new faculty to build and expand their teaching and other professional skills. Many universities have teaching and learning centers that will give you tips and pointers, offer individual consultations, and videotape your performance as a teacher and suggest ways to improve it. Often, these centers have substantial online resources on curriculum development, teaching techniques, and other issues related to becoming an effective teacher. If your college or university does not have such a center, you can explore the Web to see what's available on other campuses. (A comprehensive list of teaching and learning centers can be found at *http://www.hofstra.edu/faculty/ CTSE/cte_links.cfm*.)

Some professional societies also educate faculty. For example, the National Academies Summer Institutes on Undergraduate Education in Biology, the American Society for Microbiology Conference for Undergraduate Educators, and the American Association of Physics Teachers Workshops for New Physics and Astronomy Faculty are a few examples of available programs that you can investigate.

Observe and Be Observed

Just as you learn to improve your scientific work based on the critiques that editors give to your submitted manuscripts or comments that reviewers make about your grant applications, you can also learn about teaching from peers, senior colleagues, and others at your institution as well as from feedback provided by your students.

Ask a peer for feedback. You might want to consider a reciprocal arrangement with another junior professor in which you visit each other's classes. When you are being observed, ask your colleague to provide a frank assessment of your teaching skills. He or she can give you information and advice informally or by completing a written checklist that contains specific categories, such as structure and goals of the class, teaching behaviors, rapport with students, and subject matter and instruction.

Observe a senior colleague. Seek out senior colleagues who are reputed to be good teachers and ask them if you can attend their classes to see what they do that is effective. If you would like a faculty member to observe your teaching, and possibly serve as a "teaching mentor," choose someone who seems enthusiastic and knowledgeable about teaching at departmental meetings and who has developed a reputation for creative teaching. Experienced colleagues can offer suggestions for dealing with particular topics and give you additional ways to clarify and enliven the material.

Enlist an outside observer. An instructional consultant on your campus might be available to be an outside observer. Although the consultant might not be familiar with the content of your science courses, he or she usually has enough teaching expertise to comment on your techniques and give you suggestions.

Seek feedback through a formal peer review project. As you become a more experienced teacher, you might want to participate in more formal peer review of teaching projects, which aim to engage faculty in capturing the intellectual work of teaching by helping instructors document, assess, and reflect upon ways to improve student learning and performance. (A list of peer review projects and ideas can be found at *http://cte.umdnj.edu/career_development/career_peer_review.cfm*.)

Ask your students for feedback. Student evaluations of teaching effectiveness, now required at the vast majority of college campuses, can offer valuable clues as to what you are—and are not—doing well. However, many standard assessments, which contain quantitative questions designed to be analyzed by computer (e.g., "Overall, how would you rate the quality of the instructor's teaching?"), might not provide enough specific information. You might want to create an informal survey, with plenty of room for comments. The students' critiques can help you make any necessary course corrections. Bear in mind, though, that student ratings for your first course might be low but should quickly improve as you gain experience and confidence as a teacher.

PLANNING TO TEACH A COURSE

The following sections of this chapter will describe the concept of active learning, how to design a science course, and how to involve TAs in the process. But before you can even start writing your course outline or think about how many active-learning exercises you want to include in your lessons, you should ask yourself, What will the course accomplish? Below is a possible answer.

The goals of this course are

◆ *to teach the following three components(x, y, and z) in a deep and meaningful way;*

◆ *to sustain the interest of students who are planning to major in science;*

◆ *to provide an understanding of the method and principles of the scientific process for those not continuing with the subject; and*

◆ *to provide a strong preparation for the next course in the series.*

Once you have clearly defined the goals for the course, the next question you need to ask is, "How will I know I have accomplished these goals?" Methods for assessment are discussed in the section "Assessing Student Learning," on page 223. But keep in mind that assessment is something you need to think about from the start of the planning process. It is an important component of designing a course rather than something that is tacked on at the end.

THE PRINCIPLES OF ACTIVE LEARNING

Whether you teach at a large research university a medical school, or a smaller, liberal arts college, you can aim to create a classroom that reflects the process of science and captures the rigor, iterative nature, and spirit of discovery of science at its best. (See the box "Active Learning in Small and Large Settings" on page 216.) Active-learning strategies are at the core of this approach.

> *People learn best when they can apply knowledge to a practical situation immediately.*
>
> —Jo Handelsman, University of Wisconsin– Madison

What Is Active Learning?

Active learning uses a variety of problem-solving techniques to help students become active participants in the learning process, giving them the chance to clarify, question, apply, and consolidate new knowledge. The concept was originated by John Dewey, a philosopher of education who contended that learning must be built upon the experience of the learner, who actively integrates new knowledge into an existing conceptual framework. Today, broad support exists for the core elements of active learning, and a growing body of research has made it clear that supplementing or replacing lectures with active-learning techniques and engaging students in discovery and scientific process improve their abilities to understand concepts, think critically, and retain knowledge.

In the classroom, the principal tools of active learning are

◆ *Cooperative learning:* Students work in groups and the teacher is the facilitator. Cooperative learning builds a sense of community in the classroom that enables students to work together in noncompetitive ways.

◆ *Inquiry-based learning:* Students ask and answer questions and engage in the process of science.

◆ *Assessment:* The instructor continually assesses what students are learning and uses the feedback to make revisions as the course progresses.

Active Learning in Small and Large Settings

Active learning presents different opportunities and challenges, depending on the size of the institution at which you teach, and the format of the class you are teaching. At a liberal arts college, small classes and frequent contact with undergraduates, both in and out of class, will make a range of active-learning techniques easier to employ. At a large research institution, with much larger classes and far less contact with undergraduates, you will have to try harder to introduce active-learning strategies and assessments, particularly in introductory science courses. In addition, many classes are "team taught," and getting agreement to use active learning in the classroom from all team members might be a challenge. Upper-level courses and other small-size classes are excellent opportunities for departures from straight lectures. The information in this chapter offers many workable techniques to change your lectures into more dynamic experiences for students. Although you might not teach the labs associated with your courses, you can train the graduate students teaching your tutorials or lab sections to use a range of inquiry-based strategies to help students understand the practice of science.

Implementing Active Learning in the Classroom

Most scientists will have experienced learning as undergraduates or even graduate students with the "sage on the stage" approach. If you are like most, delivering a lecture is the way of teaching that will be most natural to you. You can, however, start to integrate some active-learning components in your lectures to make the material more engaging to your students. You might lecture for 10 to 15 minutes and then carry out an activity, or conduct an activity first and then lecture for another 10 to 15 minutes. You might present the results of a scientific study and

ask students to make a prediction, or ask students to write the most important concept they learned in the class on a note card. Or, you could present the class as a whole with a problem and ask students to consult and debate with other students who are sitting near them and then report to the whole class—a strategy that requires students to critique the understanding of others in the group and to explain concepts to each other. (Three useful articles on effective lecture preparation and delivery can be found at *http://www1.umn.edu/ohr/teachlearn/guides/ lecture1.html, http://www.ncsu.edu/felder-public/Papers/Largeclasses.htm*, and *http://teaching.berkeley.edu/bgd/largelecture.html*.)

As you incorporate active learning in your classroom, keep the following pointers in mind:

Don't try to cover too many topics. To make active learning work well, especially within the large lecture format, pare down each lecture to the core concepts you want or are required to introduce and organize the concepts in a meaningful sequence. (See page 226, "Course Design," for more about course structure and organization.)

Provide an appealing context for the concepts you highlight. While you might find a lecture on metabolic pathways exciting, your students would probably prefer to learn about an absorbing case problem to which the metabolic pathway might hold a key.

Start gradually and then add more. You can introduce active-learning components slowly and experiment with different ways of teaching the material to engage students. For example, you could start by stopping your lecture for a few moments to ask students questions, which you can formulate in advance, about the content you are teaching:

◆ *Description:* What do you see? What happened?

◆ *Common purpose:* What is the purpose or function of?

◆ *Procedures:* How was this done? What will have to be done?

◆ *Possibilities:* What else could…? How could we…?

◆ *Prediction:* What will happen next?

◆ *Justification:* How can you tell? What evidence led you to…?

◆ *Rationale:* Why? What is the reason?

◆ *Generalization:* What is the same about…and…? What could you generalize from these events?

◆ *Definition:* What does…mean?

Encourage student questions.

◆ Don't ask, "Any questions so far?" Rather, answer a question with a question to encourage students to define concepts in their own words. For example, if a student asks, "What is polymerase chain reaction (PCR)?," answer the question but then ask a related question that will test the student's ability to apply the knowledge that you just gave them: "Can anyone think of why a researcher would want to use PCR?"

◆ Encourage students to question concepts, ideas, and theories by using examples from your own research to explain how the scientific process is carried out.

◆ One of the problems of asking someone to answer questions in class is that it can become a private conversation with a few students who volunteer answers. Instead, you may try asking students to write the answers individually or work on the answers in a group.

◆ At the end of a class, ask students to write down two good questions or test problems related to the material you presented, and start your next lecture with a reference to those questions. You can also ask a question that can be answered by those who read the material for the next class, and then ask any student to present his or her answer at the beginning of the next session.

◆ Use Web-based resources such as a discussion board to encourage students to go through the reading material before class and come up with questions.

Question: How do I get students to respond to my questions and not be met with thundering silence?

Answer: Make it clear that you expect participation, but develop the patience to deal with at least 10 or 15 seconds of silence when you ask a question. Even if you feel frustrated when no one speaks up, refrain from answering the question yourself, or you will set the wrong tone for the rest of the course. Frame an opening question in the form of "Choose one of these answers." Call for a vote, either by a show of hands or through the "clicker" system described on page 223. To encourage more discussion, ask students to explain why they voted the way they did.

Use a variety of in-class exercises.

◆ Assign a task and give students—working in pairs or small groups—time to write responses. You can also ask students to work individually and then to form pairs in order to combine and improve their individual responses (called the "think-pair-share" approach). Then you can randomly call upon a few pairs to give brief summaries of their joint answers. (For general guidelines and suggestions for paired activities, go to the University of Minnesota's Center for Teaching and Learning Services at *http://www1.umn.edu/ohr/teachlearn/ guides/active.html*.)

◆ Use case-based problems that develop critical thinking and analytical behavior. Find examples of cases that are meaningful and relevant to students— on topics such as human pathologies, bioterrorism, cancer, genetically modified foods, mad-cow disease, or other current issues. Use cases not only to

teach concepts but also to start students thinking about the relevance of science and its impact on society. (For examples, go to The National Center for Case Study Teaching in Science, which has case ideas and a case study collection, at *http://ublib.buffalo.edu/libraries/projects/cases/case.html*.)

◆ Ask students to create a drawing, diagram, or chart to help explain an idea, relationship, or process. Tell them to share their drawing and discuss it with a classmate.

Use real-world examples.

◆ Use current newspaper and magazine articles to show the relevance of the topics students are studying. For example, if you are teaching about DNA sequencing, bring in articles about the sequencing of the human genome or ask students to locate relevant articles by searching the Internet and bring them to class.

◆ Involve the class in assessing the biological implications of a real or planned community project, such as a plan to control communicable diseases or to manage the deer population. Assign student groups to investigate various aspects of the project, collect field data, and present evidence-based recommendations to the class.

Use technology to enhance teaching.

◆ Provide some historical background to key discoveries in biology by showing films or news clips of early, groundbreaking experiments.

◆ Integrate new media technology such as animations or virtual labs to make biology more vivid and accessible to a generation raised on video games. Slides, photos, and film clips will also get your students' attention and will open familiar material to surprising new questions.

◆ Use interactive demonstrations and simulations to illustrate concepts. Or show maps, photographs, or diagrams and ask students to make their own observations and interpretations.

◆ Use an online discussion/bulletin board as a forum to talk about ideas. Be active in the discussion without dominating it.

◆ Engage students by having them use electronic keypads (clickers) to answer your questions (see page 223 for more about clickers).

◆ If you decide to use PowerPoint in class, learn to make your presentations visually dynamic and engaging to students. (For an online tutorial on active learning with PowerPoint, go to *http://www1.umn.edu/ohr/teachlearn/workshops/powerp*.)

Set the stage for active learning.

◆ Arrange the lecture classroom to encourage active participation. If chairs are bolted to the floor and cannot be moved, use a microphone with a long extension cord so you can move around the lecture hall while you are talking and listening. If chairs can be moved, arrange them in circles and banish the lectern to a corner of the room.

◆ Set the pattern for active participation from the very first day. Remind students of the value of active learning, ask questions that call for genuine discussion, and get students talking several times during the first session.

◆ Learn as many students' names as you can. At the first class, tell students to choose their seats for the semester and then make a seating chart, which you can study while students are working on in-class exercises.

Going from Passive to Active

It's easy to shift from making passive statements in a lecture to asking questions that encourage student discussion. Here are two examples:

◆ *The passive approach:* Every cell in an organism has the same DNA, but different genes are expressed at different times and under various conditions. This is called gene expression.

◆ *The active learning approach:* If every cell in a plant has the same DNA, how can different parts of a plant look different? Work with a neighbor to generate a hypothesis.

OR

◆ *Passive:* Based on the data shown in this slide, researchers concluded the following.

◆ *Active:* Let's look at the data from this experiment I just described. Which of the following conclusions can you draw from the data? Let's take a vote and then discuss it.

Source: Jo Handelsman, University of Wisconsin–Madison.

Active Learning in the Lab

The college laboratory is the perfect place for students to actually practice science by designing experiments, gathering and analyzing data, and presenting their findings. Too many labs rely on "cookbook" experiments—experiments that have been done thousands of times before and whose outcomes are already well-known. What do students learn from cookbook experiments? They chiefly learn to follow instructions so that they can complete the lab successfully and earn a good grade.

If you want your students to experience the thrill of science, consider taking a different approach by either designing or adapting existing inquiry-based experiments. When they are properly designed with discovery-based learning activities, labs can provide rich learning experiences for students that help them develop a variety of professional and technical skills.

Most inquiry-based labs begin with a question—either one generated by the teacher or preferably one generated by the students—that provides students with a specific issue or topic to explore. Students research the topic, offer a hypothesis, design an experiment to test the hypothesis, analyze the collected data, and determine if their hypothesis was confirmed. The students then present and explain their findings to the class as a whole.

As students start to understand and apply the scientific method, they can begin to experience the joy of discovery. From inquiry-based labs, students can also develop better communication and critical-thinking skills and learn to work together as part of a problem-solving team.

A well-designed inquiry lab takes time and resources to develop, however, so it might be best to start small. Below is one example of an approach you can take to "uncooking the lab," and you can find additional ideas, tools, and references for developing inquiry-based labs at *http://scientificteaching.wisc.edu/products/Uncook_handout.pdf*.

In a standard laboratory exercise, students may be instructed to make 10-fold dilutions of soil samples and apply each solution to a culture medium. After incubation, students count the number of colonies on each plate and calculate the number of bacterial organisms in the sample.

A similar laboratory exercise using an inquiry-based approach would ask students to bring in two soil samples. The instructor would then challenge the students to generate a hypothesis about the microbes in the soil samples and design an experiment to test it.

ACTIVE LEARNING AT A MEDICAL SCHOOL

Many of the principles of using active learning discussed above apply to teaching at a medical school, but, as an instructor, you must be aware of the challenging examinations your students will soon face and their need to be rigorously prepared. Medical students carry a heavy course load in the basic sciences during most of their first two years, but unlike undergraduate students, who take exams prepared by their teachers (or, occasionally, by their departments) on specific semester-long courses, medical students completing their second year take step 1 of a national exam—the three-part United States Medical Licensing Examination (USMLE)—which will test their knowledge of basic sciences and their ability to interpret data. (This is in addition to one or two midterm tests as well as a final examination.) After the fourth year of medical school, they take step 2 of the USMLE, which will test their knowledge of clinical care and their ability to interpret clinical data.

In incorporating active-learning components, you should carefully consider two fundamental educational needs of medical students: to master core science concepts and to gain the skills they will need to become doctors. One good approach is to couple a lecture—which might be necessary to explain core concepts—with a small-group discussion of a medical case or disease—a method called case-based learning.

> *Most of us use lectures because it's what we know. If teaching is to be considered valuable and not just necessary, we should invest the time to design active-learning strategies. These strategies don't have to be done in the absence of lectures; they can be used when students break up into small groups for case-based discussion following a lecture.*
>
> —Curtis Altmann, Florida State University College of Medicine

Case-Based Learning

Case-based learning allows students to learn science in a very practical way, by exploring the kind of issues they might actually confront in medical practice. Students meet in small groups with a faculty member who acts as a facilitator. They are then assigned roles, such as discussion leader, reader, scribe, or timekeeper. For each case, which they will have read and thought about ahead of time, they receive a list of objectives; a narrative description of a medical issue, a disease, or an advance in biomedical science; and a list of questions to address and problems posed by the narrative. The exercises are designed to integrate previously learned curriculum content, so students are expected to refer to material they have studied before to answer the questions. In addition, students are encouraged to pose hypotheses, access information on the Internet, present new information, reach conclusions as a group, and evaluate each exercise. Typically, each group completes two exercises in every two-hour session.

Your role as facilitator. In a case-based learning setting, you role is likely to be that of a faculty facilitator. Your goal should be to assist your group to function smoothly to maximize learning. You should not assume the role of an instructor or a lecturer, but should, in fact, consider yourself a co-learner who happens to be especially experienced in scientific inquiry and in assisting others to learn. You should, however, correct any misinformation that might arise during student discussions. Below are some tips for facilitating successfully (obtained from *Guide to Small Group CBL Exercises, BMS6204: Medical Biochemistry and Genetics,* Florida State University College of Medicine).

◆ Encourage the group to recognize and formulate problems—by asking students to brainstorm and make a list of possible causes of the disease being discussed.

◆ Give group members opportunities to demonstrate their learning—by asking them to describe new information they might have learned from the Internet or other research.

◆ Ensure that all group members have a chance to contribute—by delaying the "talkers" from answering too quickly while encouraging quieter students to participate. If that strategy does not work, break up the larger questions into smaller segments and go around the room, calling on each student. Don't dominate the discussion.

◆ Encourage the group to critically evaluate ideas—by asking probing questions and suggesting other avenues to explore.

◆ Provide timely, constructive feedback—-by helping the group analyze what went well and what went wrong in the discussion.

◆ Model respectful and professional behavior—by showing respect and support to all students while making the rules of small-group discussion very clear.

ASSESSING STUDENT LEARNING

Assessment is an important part of your job as a teacher, as you will use the information to evaluate students and also to determine what teaching strategies worked best and which ones you want to refine. While you can use end-of-semester multiple-choice examinations as one evaluation component, you will also want to use small, more frequent, and informal assessments of knowledge. So-called "active" assessments can give you frequent readings on students' levels of understanding, so that you can make midcourse corrections when you see the need. (See appendix 1 for a variety of ideas for active assessments that are easy to use.) You can also get immediate feedback by using innovative technology such as clickers to ask students questions and find out how much they know or don't know.

Clicker Technology

"Clickers," known as personal, audience, or classroom response or performance systems, allow teachers to inject active learning into a lecture and to immediately assess whether students understand the material being presented. The clicker technology can also be used to create multiple-choice and other questions, to take attendance, and to grade quizzes and exams.

Similar to a television remote control, the clicker is a wireless handset with a variety of response buttons. Students use it to answer questions posed by the instructor. Their answers are sent by infrared signals to a receiver, where the data are instantly tallied and analyzed by a computer, and the results are displayed graphically. Teachers can display the responses on a screen, post them on a Web site, or save them for later reference. Students can respond anonymously or can be identified by a serial number in each transmitter.

Several manufacturers, including GTCO CalComp in Maryland and eInstruction Corporation in Texas, offer the technology. Prices vary depending on arrangements an institution might make with a manufacturer or a textbook publisher, if the clicker system is used with required texts.

If you are interested in using the technology, contact your campus teaching and learning center or instructional technology department. (For an article about one university's use of classroom clickers, go to *http://www.news.wisc.edu/11142.html*.)

Bear in mind, however, that it is not always easy to tease out the specific impact of your innovative learning techniques. In a classroom setting, you will generally not be able to implement a true experimental design, in which students are randomly assigned to different groups, where only one variable (the learning innovation) changes. However, by using a variety of techniques, such as pretests and control groups, you might get a better sense of the ways in which your active-learning strategies are improving your students' learning. (For a more in-depth discussion of these issues, challenges, and steps involved in developing and appropriately using assessment tools, see the articles on assessment and educational research at *http://www.aaas.org/publications/books_reports/CCLI.*)

Developing Exam Questions

Regardless of the types of assessment tools you favor, you will not be able to escape midterm and final examinations. Bloom's Taxonomy (described more fully in appendix 2) can be a useful guide for preparing examination questions. It depicts six successive levels or categories of learning—knowledge, comprehension, application, analysis, synthesis and evaluation—that ascend in difficulty from factual knowledge to evaluation. Many tests that faculty administer rely too heavily on students' recall of information. But Bloom contended that it is important to measure higher learning as well.

Use a wide variety of questions to evaluate students' different content and skill levels so you can make sure students are deepening, broadening, and integrating their knowledge as well as learning factual information. Here are some standard kinds of test questions, with their advantages and disadvantages and correlations to Bloom's Taxonomy, obtained from the University of Wisconsin Teaching Academy Short Course in Exam Question Types and Student Competencies (*http://wiscinfo.doit.wisc.edu/teaching-academy/Assistance/course/questions.htm*).

True/false questions. These present a statement and ask the student to decide whether the statement is true or false. While the tests are among the easiest to write and score, they are limited in the kinds of student mastery they assess and have a relatively high probability of students guessing the right answer. They correspond to Bloom's levels of knowledge and comprehension.

Short-answer questions. These are "constructed response" or open-ended questions that ask students to create a short answer (one sentence or several sentences), fill in a blank, or complete a sentence. Although the questions are relatively easy to write, they are harder to score because students are free to answer the question in any way they choose. They correspond to Bloom's levels of knowledge, comprehension, and application.

Multiple-choice questions. These present a question and ask students to choose from a list of answers. Questions can be statements or complex cases or scenarios that require careful consideration on the part of students. The questions can be more challenging to answer (if they require both one correct answer and several false "distracter" questions) but easy to score. They correspond to Bloom's levels of knowledge, comprehension, application, and analysis. (See the box "Multiple-Choice Questions" for an example of a case-based multiple-choice question.)

Essay questions. These allow students to focus on broad issues, general concepts, and interrelationships, rather than on specific facts or details. The advantage is that the tests allow you to see the quality and depth of each student's thinking. However, they can be difficult and very time-consuming to score, because the answers vary in length and variety and you might tend to give students a better grade if they have strong writing skills. Essay tests can effectively assess all six levels of Bloom's Taxonomy.

If you find Bloom's Taxonomy too cumbersome to use, you can choose a simplified version that collapses the taxonomy into three general levels:

◆ Knowledge (recall or recognition of specific information)

◆ Comprehension and application

◆ Problem-solving, or transferring existing knowledge and skills to new situations

Other types of exams. You can also consider using alternative types of exams, such as group exams, which can be given either in class or as take-home exams and which use open-ended questions that have no right or wrong answers. However, since you will be giving each individual a grade for the course, you will want to allow each student to write an answer to a question or questions, as well as to participate with the group.

Whatever exam or combinations of exams you use, remember that writing exam questions takes time; don't try to "throw it together" at the end. Before you start, make sure you ask your institution if it has any established formats to which your exam questions must conform. For example, in medical schools, tests might need to conform to standards set by the Liaison Committee on Medical Education, which accredits medical schools in the United States. Think carefully about the learning outcomes you want to measure, so you can match your questions to the content. If you are working with graduate students who are your TAs, involve them in writing the exam or in reviewing a draft of it to make sure your instructions are clear and that the test can be completed in the time allowed. (For a comprehensive book chapter on quizzes, tests, and exams, go to *http://teaching.berkeley.edu/ bgd/quizzes.html*.)

Multiple-Choice Questions

Short case studies that use authentic data can make powerful multiple-choice questions that test scientific literacy and fluency, as well as core concepts. Here is an example:

The sexually transmitted disease gonorrhea is becoming difficult to treat because the causative bacteria, *Neisseria gonorrhoeae,* are evolving resistance to antibiotics. For example, in Hawaii between 1997 and 1999 resistance to fluoroquinolones increased from 1.4 to 9.5 percent. Scientists attribute this to natural selection. What does natural selection mean in this context?

A. *Neisseria gonorrhoeae* have learned to avoid that particular class of antibiotic.

B. The antibiotic has changed the genetic structure of the *Neisseria gonorrhoeae,* allowing them to become antibiotic-resistant.

C. The *Neisseria gonorrhoeae* changed their genetic code in order to avoid being killed by the antibiotic.

D. The antibiotic created an environment in which *Neisseria gonorrhoeae* harboring antibiotic-resistant genes could thrive at the expense of those susceptible to the antibiotic.

E. The mutation rate for antibiotic resistance increased during this time period.

[Answer: D.]

Source: *http://www.saltspring.com/capewest/mc.htm*.

COURSE DESIGN

Some of you will be asked to design a new course from scratch or will want to redesign an existing course to better suit your teaching style and knowledge. Since course design is a complex and time-consuming undertaking, give considerable thought to a wide range of issues and questions before starting down this path.

> *I would highly recommend that you try, when you are assigned a course, to negotiate up front to be able to teach it for three or four consecutive years. That way you will make the most of the time and effort you put into preparing your material and will have a chance to refine it each year.*
>
> —Thomas Cech, HHMI

Improving an Existing Course

As a new teacher, you will most likely be asked to teach a course previously taught by another faculty member. You might find that the course is a perfect fit for you and that you will have to change very little. More likely, however, you will want to undertake some revisions. Here are some tips for helping you achieve your goal:

Do your homework.

◆ Clarify your department's expectations for this course. If you are teaching a course for only one year and must hand it back to your colleague when he returns from a sabbatical, you might want to invest minimal time and effort. If you can get a commitment to teach the course for several years, revising it will make more sense.

◆ Review and evaluate the course syllabus, lecture notes, textbooks, and other assigned readings, assessment questions, and other materials the faculty member who previously taught the course will make available to you.

◆ Review students' final exams to learn where the course was strong or weak in teaching key concepts. Skim a few years' worth of students' course evaluations if they are available.

◆ If possible, ask the faculty member who is turning the course over to you to describe his or her impressions of what worked and what didn't, or observe this person teaching a class and jot down your thoughts about what you would keep or change.

Determine what changes to make. If you do decide to make changes to the course, figure out what and how much you want to change. Even if the faculty member who previously taught the course makes his or her notes available to you,

you should rewrite them in your own style. This will help you master the material and allow you to insert your own examples and active-learning exercises.

If the content of the course seems satisfactory overall, you can focus more on your presentation. But if you think it's necessary to introduce a substantial amount of new content or make major structural changes, then it may be helpful to read the section below on designing a new course.

Remember that it's advisable to make changes incrementally, based on student feedback.

Designing a New Course

Creating a new course is more difficult and time-consuming than revising an existing one. Before starting, ask yourself why you want to design a new course. Has your department chair requested you to fill a gap—and can you earn good will for being viewed as a team player? Do you have a special research interest that is not represented in the curriculum? If so, can you acquire educational support funds that will enable you both to teach the course and buy a piece of equipment for your research lab that can also be used in the lab component of the course?

Most large research schools allow new faculty members one or two semesters to set up a lab and write research grant applications. Liberal arts colleges may not be able to give such an opportunity. Try to at least negotiate part of your workload during the first semester to allow you the time to construct the course so that you can teach it second semester. If you try to do too much too soon, the balance of your teaching and research responsibilities might get out of sync.

You will face three critical decisions: what to teach, how to teach it, and how to ensure that students are learning what is being taught. Ideally, you should begin planning your course several months ahead of the semester in which it is taught to give yourself time to order textbooks and request other resources and prepare your course handouts. But even if you are assigned a course at the last minute, you can still use many of the planning guidelines described below.

Determine what to teach.

1. Determine how the course relates to other courses in the departmental curriculum by asking these questions:

◆ Will the course be a prerequisite for higher-level courses? If so, talk to the instructors of the advanced courses to see what kinds of knowledge and skills they expect from students.

◆ Is it an advanced course? If so, talk to the instructors who are teaching prerequisite courses so you can better understand what skills students will have when entering your course.

◆   Are there major departmental changes under way that might affect your course? If, for example, your university is considering new approaches—such as doing away with introductory biology and chemistry and replacing them with a multidisciplinary life sciences course—you will want to keep that long-term agenda in mind.

Knowing how your course fits into the entire structure is important and will call for discussions with other faculty and perhaps a collaborative or interdisciplinary approach.

2. Establish course content goals. Identify three to five general goals (e.g., "understanding the concept of antibiotic resistance") for the course that will explain what you want your students to know and do when the course is over. If you include noncontent goals (such as "work collaboratively with other students"), keep in mind that these are harder to assess.

3. Identify major course themes. These principles or fundamental postulates lend continuity and provide perspective on the entire course. For example, a year-long course in introductory biology might involve three broad themes: information and evolution in living systems, development and homeostasis, and energy and resources.

4. Identify core concepts within your major themes. Try to provide a balance of concrete information and abstract concepts, and balance material that emphasizes practical problem-solving with material that emphasizes fundamental understanding.

5. Define the objectives of individual units or lessons. For example, one objective might be that students will be able to propose tests of evolutionary hypotheses or critique arguments pertaining to evolutionary evidence. Such definitions will help structure the content of each lesson

Note: Your opportunity to develop new courses in a medical school will likely be very limited due to the need to prepare students for the USMLE step 1 exam.

> *When you plan your course, don't overdo it. We feel we have so much to teach, but when we impart too much knowledge, students get the impression that everything is known and that there is nothing interesting left for them to discover.*
>
> —Manju Hingorani, Wesleyan University

Determine how to teach it.

1. Determine the general structure of your course. Ask yourself these kinds of questions:

◆ What combination of lecture and assignments, lab, seminars, and journal club do you want to use?

◆ What will be the balance of faculty lecture and demonstrations versus student presentation or student-led discussion or laboratory work in the course?

◆ Can you incorporate any extracurricular activities into the course to enhance learning?

◆ Do you want or have to include other faculty presenters?

2. Select resources. Choose textbooks—-using letterhead to contact publishers for review copies—and journal articles, and investigate the use of technology enhancements, such as animations, videos, simulations, or virtual labs. Make sure the textbooks match your idea of the goals and objectives, or be prepared to tell students how to make the best use of the reading resources. Think about guest speakers or faculty members who might be appropriate and willing to teach several classes. Determine what other resources you need—such as TAs, laboratory space and supplies, and library resources—and determine whether these will be available.

3. If you plan to have a Web site for your course, familiarize yourself with your institution's course management system, which will enable you to put various components, such as lecture notes and discussion forums, online. See the box "Setting Up a Course Web Site" for further details.

Setting Up a Course Web Site

Increasingly, faculty members are using Web-based course management systems (CMSs) to deliver entire courses or certain components of courses online. In essence, a CMS allows an instructor to post information on the Web without having to know HTML or other computer languages and provides a set of tools and a framework for teaching and managing the course and evaluating student progress. Such a site can also be used to field questions from students and then to post answers for all others to see. For ideas about using a CMS to its fullest potential, see "Course Management Systems and the Reinvention of Instruction," by Craig Ullman and Mitchell Rabinowitz, at *http://thejournal.com/magazine/vault/A5070.cfm*.

CMSs can be commercial, campus-specific, or open source. (Open-source systems have no upfront license fees, but the software is not necessarily free.) Popular systems include those developed by Blackboard (*http://www.blackboard.com*), Moodle (*http://moodle.org*), and the Sakai Project (*http://www.sakaiproject.org*). To learn more about the different CMS options that are available, you can go to EduTools (*http://www.edutools.info/index.jsp?pj=1*). Speak with colleagues and administrators to determine what is already available at your campus. To see the components of one university's Blackboard support site, go to *http://www.utexas.edu/academic/blackboard*.

4. Determine how you will assess student learning for each goal. Do this on the basis of the goals of the course. You can use the kinds of "active assessments" described in appendix 1, as well as more traditional quizzes, in-class or at-home examinations, papers, problem sets, in-class presentations, and projects.

5. Divide the course into manageable pieces. Divide the larger units into individual class sessions with objectives, methods, and evaluations for each. Choose activities for each class and create a table or grid for each class to plan each of these elements.

6. Check your college or university's calendar. Look for exam dates, holidays, and other events that might affect class schedules. Try to avoid having sessions that cover related material span major holidays.

7. Prepare your syllabus using the checklist below as a guide.

- ◆ Name of the course, number of credits, classroom meeting place and time, and semester and year the course is given

- ◆ Name and contact information for you and any other faculty or TAs involved

- ◆ Course Web site, if there is one

- ◆ A brief course description and statement of overall course goals

- ◆ A brief statement of objectives

- ◆ A description of course format

- ◆ A statement of assessment techniques

- ◆ A schedule of class dates and topics

- ◆ A schedule of due dates for papers, tests, and projects

- ◆ Pertinent information about academic policies and procedures such as class attendance, make-up assignments, late work, group projects, and grading

Determine if students are learning.

Feedback can be obtained by reviewing student performance; student evaluations, from informal consultations with students; and evaluations from your peers. In addition, you might want to have an informal consultation with your teaching mentor. It might be useful to conduct such evaluations periodically during the course, particularly if it is a new one.

Once you have taught your course, you will probably want to revise it based on your sense of whether the objectives were met and on feedback from students and colleagues, but resist the urge to change or correct everything all at once. Instead, make small adjustments over time.

TEACHING OTHERS TO TEACH

As principal investigator of a laboratory you will mentor graduate students and postdoctoral fellows to be successful in the lab and in their future endeavors. You may also have opportunities to help them get teaching experience and improve their skills as teachers.

Teaching the Teaching Assistants

Graduate student or postdoctoral fellows are often so immersed in their own research projects that they may regard teaching as something to stay away from or to quickly get out of the way. You will need to reinforce the value of teaching effectively—for the sake of their own careers and the undergraduates they teach—and involve them in the process of developing a course. Start by scheduling weekly (or more frequent) meetings with all TAs. At these meetings you can describe your goals for the course and for the coming week, and give TAs an opportunity to discuss problems they are encountering and ask for your advice. Other ways to get them involved include the folllowing:

Encourage TAs to seek professional training.
◆ Encourage TAs to take advantage of any formal training offered by your college or university, which can range from a short orientation to a week-long program.

◆ Invite faculty from other disciplines or outside speakers who can talk about such topics as inquiry-based learning or the innovative educational projects in which they are involved.

Foster "scientific" teaching.
◆ If you are developing a new course, build in a component that is designed to be taught by a TA. Be sure to provide TAs with all resources (e.g., text-books, readings, your lecture notes) necessary.

◆ Review a range of active-learning strategies and assessments with TAs, and brainstorm about which ones might work best.

◆ Don't expect TAs to be comfortable using teaching techniques that they have never used as students. Demonstrate active-learning techniques with the TAs being the students. You may spend only an hour running through a few examples, but it will make the difference between your TAs shying away from these methods and being willing to experiment with them.

◆ Help TAs understand that teaching is an experimental situation and empha-size that they don't have to be perfect teachers. Scientific teachers continue to experiment and revise their courses, even after years in the classroom.

Support TAs' classroom efforts.
◆ Visit sections led by TAs often and offer useful feedback soon after you visit, but be sure to provide the feedback privately to the TA.

◆ Before allowing a TA to grade papers, circulate a sample of papers and have each TA grade them independently, using a rubric developed in advance. Devote a TA meeting to discussing and resolving differences in grading on that sample.

◆ Tell your TAs to come to you when serious problems arise—such as encountering students with obvious behavior or psychological problems or situations that could lead to litigation or violence. Direct your TA to the right professionals on campus or call in the professionals to help resolve the situation.

◆ Be sure you brief your TAs on professional standards of behavior, such as treating students with fairness; maintaining confidentiality (e.g., not talking about students with other students; not talking about students in public places); refraining from socializing with students (including, but not limited to, dating them); and conducting meetings with students in an office with the doors open and other people around to protect themselves from being physically vulnerable or falsely accused of inappropriate behavior.

Provide or suggest opportunities to teach.

◆ Allow postdocs, or in some cases, advanced graduate students, to occasionally give a lecture—either by taking over one of your class sessions and modifying the lecture you might have given, or giving a lecture in their own areas of interest or specialty. You would have to be sure that the lecture complements the course. Give the postdocs or graduate students constructive criticism on their teaching style and presentation of content.

◆ Make other teaching opportunities available. For example, encourage your graduate students or postdocs to go to a local high school and give a presentation, or invite high school students to your lab and allow the grad students or postdocs to answer questions and prepare presentations of the research in your lab.

◆ Encourage postdocs to become adjunct professors at community colleges, to teach summer-school courses, or to teach a session at your institution's "mini-med school," a program for public education that exists on many campuses.

◆ Arrange to have your graduate students and postdocs mentor high school science teachers in a public or private school in your community. Since high school teachers often use active-learning strategies, they might give your postdocs some valuable teaching tips in return for gaining a better understanding of contemporary science content from your postdocs.

◆ Create an education group that meets monthly or quarterly in your lab as a resource for postdocs and graduate students looking for more opportunities to become involved in teaching.

Creating a Learning Environment in Your Lab

In a very real sense, your laboratory is also a classroom—one in which the scientific process often results in something new, exciting, or unexpected. In the lab, as in the classroom, you will want to avoid lecturing and giving students answers too quickly and, instead, emphasize questions and encourage reflection. You can create a culture of learning in your lab for all the students—from postdocs to undergraduates—by using active-learning strategies and by encouraging members of your lab group to learn from each other. Try not to turn away anyone who is asking a question—even if you are in the middle of an experiment. Here are some other ideas to encourage active learning in the lab:

Start a journal club. It's a great way to examine current literature and to let students know there are many questions left to be answered. Ask a postdoc or grad student to select an original peer-reviewed journal article, distribute it in advance to the group, prepare an introduction to the paper, and provide any relevant or background information. If you have a large group, lab members can break up into smaller groups to discuss research-related issues (How good are the data? Should more experiments have been done?), reconvene, and share their thoughts with the group as a whole. While your students are learning about experimental design and other research issues, they will also be learning to collaborate and communicate. Ideally, journal club should be held on a weekly basis, but if that's not possible, one good way to keep everyone up on current literature is to ask each member of the group to present briefly the abstract of at least one paper at the beginning of weekly lab meetings.

Start a monthly film club. Bring popcorn and invite your laboratory group to watch a science-related film such as the 1987 movie, "The Race for the Double Helix," which depicts the events leading to the 1953 discovery of the structure of the DNA molecule. Ask questions that stimulate thinking about a range of science issues. For more film ideas, go to the National Institutes of Health (NIH) "Science in the Cinema" site at *http://science.education.nih.gov/cinema*, or to the NIH site on historical video collections, administered by the National Library of Medicine, at *http://www.nlm.nih.gov/hmd/collections/films*.

More advice on creating a culture of teaching in your lab can be found in chapter 5, "Mentoring and Being Mentored."

> *When students come to you with research results, let them explain their data before you tell them what it means. Then you can nod appreciatively and say, "Well, could be, or have you thought of…?" Students who have put in hard work on an experiment deserve—and need, for their own professional development—the chance to interpret and communicate their data.*
>
> —Thomas Cech, HHMI

PROFESSIONAL CONSIDERATIONS

Balancing research, teaching, and service is not easy, and requires the time management skills noted in other chapters of *Making the Right Moves*. At a research university, most tenure requirements generally give greater weight to research and publications than to teaching. But that situation is changing, as an increasing number of colleges and universities begin to embrace the concept of the scholar-teacher in promotion and tenure decisions.

However, as a practical matter, particularly in the pretenure years of your career, you will want to teach effectively while minimizing the time spent on it and maximizing the recognition you will get.

Time Management

The amount of time you devote to developing a course or teaching it will depend in part on what priority your institution places on teaching. If your institution makes research its top priority, keep in mind that; while you will want to be the best teacher you can in the time allowed, you should not permit your teaching obligations to undercut your commitment to research. Volunteer to teach the courses your department particularly needs but are not as difficult to teach—that way you can legitimately say, "Sorry, I am already committed" when you are asked to teach a course that would be more time-consuming to develop or teach. For example, you may choose to teach a graduate class or seminar in your research area, or use a simplification of your research problem as a project for an undergraduate class. Or you may teach a course without a lab or a class with fewer students. Regardless of the course you teach, here are some tips for making the most of your time.

Borrow, adapt, and recycle.

◆ Teach the same course several times, so that you are making adjustments to it rather than starting from scratch every year.

◆ Teach a course previously taught by someone who is willing to lend you copies of his or her notes, exams, and homework assignments.

◆ Borrow or adapt high-quality curricula that are already available. For example, the Massachusetts Institute of Technology is gradually making available on the Internet the primary materials for nearly all of its 2,000 courses through its OpenCourseWare Initiative (*http://ocw.mit.edu*). Currently, more than 900 courses, such as experimental biology, are available. These materials include lecture notes, syllabi, problem sets, and exams, which you can use to prepare your own classes.

Know yourself.

◆ Consider your personal rhythms. Choose a class that does not disrupt your day. For example, you could teach two back-to-back classes or schedule days without classes so you can find time for your research.

◆ Set realistic limits on class preparation and don't be a perfectionist.

Question: Is it possible to ask for a reduced teaching load when I negotiate the terms for a faculty position?

Answer: It is certainly possible, but your chances of negotiating a reduced load will likely be better at a university that stresses research productivity than at a liberal arts college that puts its chief emphasis on teaching. Even at a research university, however, this is not easy to do. A new faculty member may be given some free time to write grant proposals, especially if the time between the decision about the appointment and the arrival of the new faculty member was brief. If you are successful in obtaining a reduced teaching load during the job negotiations it is important to get it in writing. It might be easier to negotiate specific courses than fewer courses.

Even if you cannot reduce the number of hours, perhaps you may be able to stack your teaching load so that you teach all classes in one semester and arrange to have a term with no teaching. You might also ask to teach multiple sections of the same course to reduce your preparation time, and request graduate assistants to help you grade exams. At the very least, you should try to clarify your teaching load: How many classes will you have each term? What are typical enrollments in each class? How much time will you be expected to spend advising students or supervising theses or dissertations? Does supervising undergraduate research count as teaching? How much credit do you receive for teaching the lab sections of a course? Armed with that knowledge, you might be able to make trade-offs that help you manage your teaching load more effectively.

The Teaching Portfolio

You want to make sure that your teaching successes are favorably considered as part of your tenure review. One way to do this is to develop a teaching portfolio. This document is an important asset not only for your career but also for your own professional development. Compiling your portfolio will force you to reflect on your teaching so you can continue to analyze and improve it.

While there are many ways to compile a teaching portfolio and many items you can include, typical portfolios include a personal statement about your teaching philosophy, evidence of your teaching, and supporting materials. Unlike your scientific curriculum vitae (CV), which lists all publications you have ever written, the teaching portfolio is more selective and has been compared with an artist's portfolio—a sampling of the breadth and depth of your work (see box "Sample Teaching Portfolio" on page 236).

Becoming a good teacher may seem like a lot of work with little reward, but remember that your research and teaching careers can work hand-in-hand. Your research can inform your teaching, and your teaching can inform your research. Learning to be an effective teacher is worth the time and effort. Not only will you be instrumental in inspiring and educating a new generation of scientists, but you will also enhance your own skills, confidence, and creativity. Remember, too, that teaching can be a stabilizing force in your life, especially if your research becomes discouraging or you lose ground in the laboratory. The time you spend in preparing an effective course with active-learning activities can give great personal rewards, as your students demonstrate their knowledge on a test or tell you that, for the first time, they really understand DNA structure and function. And, since teaching is one of the three pillars on which decisions about tenure and certain grants are made, your success in teaching and course design will only improve your chances of having a long, productive, and well-funded career in academia.

Sample Teaching Portfolio

A teaching portfolio includes these items:

◆ *Personal material:* A short statement of your teaching philosophy, a broader statement of your teaching responsibilities, representative course syllabi, and steps you have taken to enhance your teaching skills or background knowledge

◆ *Materials from others:* Student and course evaluation data from present and former classes, statements from colleagues who have observed your classroom teaching, statements from TAs you have supervised, and any honors or other recognition you received for teaching

◆ *Products of teaching:* Student scores on class, departmental, and national certification exams, samples of student work, and testimonials from alumni or employers of former students

While the list might seem overwhelming at first and could take years to develop to the fullest, it is manageable if you take it in steps. The most important thing is to start collecting and organizing data related to your teaching philosophy and accomplishments and to start compiling those materials in a box, a loose-leaf notebook, or another format that can easily be updated and supplemented. (For a good introduction to teaching portfolios, go to *The Teaching Portfolio,* by Hannelore B. Rodriquez-Farrar, Harriet W. Sheridan Center, Brown University, at *http://www.brown.edu/Administration/Sheridan_Center/publications/teacport.html*, or *Preparing a Teaching Portfolio, a Guidebook,* Center for Teaching Effectiveness, University of Texas at Austin, *http://www.utexas.edu/academic/cte/teachfolio.html*.)

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APPENDIX 1: EXAMPLES OF ACTIVE ASSESSMENTS FOR LARGE LECTURES

The goal of active assessments is to provide feedback about learning to both instructors and students. While instructors may choose to grade these assessments, they are also helpful to give context to the topic they are lecturing about, motivate students to participate in and take responsibility for their own learning, and offer them the opportunity to think critically. Many of the active assessments work best when students work together in pairs or groups of three to five, but some work best as individual activities. In addition, the active assessments can help instructors determine what works best for their own teaching style.

Brainstorm. Brainstorming is possibly the fastest and easiest way to incorporate active learning into a large lecture, and it is a quick way for students to assess what they already do or don't know.

Example: *What does a plant need to survive?* This activity works well for any organism and drives home the point that students already know more than they think they do. The list can go on and on, if students start to list individual minerals and other components. But no matter what they come up with for the brainstorm list, it can always be separated into two categories. For example, abiotic versus biotic factors or environmental versus genetic requirements. These categories can then be used as the basis for a subsequent lecture or laboratory exercise.

Pre/posttest. Pre/posttest is another simple way to help students gauge what they've learned. If their answers don't change over time, it tells the instructor that something is amiss with the learning, the teaching, or the assessment.

Example: *Describe two ways a bacterium could harm a plant.* Have students write down their answers during the lecture, and then finish the class and have them answer again (posttest). Have students compare their two answers.

Think-pair-share. Think-pair-share activities work well to encourage group learning. Students answer a question individually, then share their answers with other students nearby and discuss which answers make the most sense. After 35 minutes, some of the groups report their conclusions. An optional step can be added to include experimental results. It's helpful to compare student answers from before and after discussion. This activity works well with electronic audience response systems, or "clickers."

Example: *Experimental design consists of three treatments of radish seed sets:*
> *(1) light, no water*
> *(2) light, water*
> *(3) no light, water*

Which set of plants will have the lowest dry weight after 3 days?

First, students answer the question individually for one to two minutes. Next, they work as groups to share and discuss their answers and come to consensus. After

three to five minutes of discussion, the students answer the question again. Finally, show the actual experimental results: *Treatment #3 has lowest biomass.*

It's important that students discuss the experimental results with their group so they can figure out themselves that the result makes sense only if they understand that respiration, in addition to photosynthesis, occurs in plant cells. (This example is used with permission from Ebert-May, et al. 2003)

One-minute paper. One-minute papers are a great way to capture what students are thinking. For example, when used at the end of class, the instructor can gauge what students have learned by asking them to list the three most important things they learned that day in class. At the beginning of class, the instructor can gauge what students retained from the previous lecture or a reading assignment.

Example: At the end of a lecture about the structure of DNA, have students read about the structure of DNA online (*http://www.dnai.org/a/index.html*) in a text-book chapter. Students are expected to write a one-minute paper at the beginning of the next class period about DNA replication: *What about the structure of DNA suggests a mechanism for replication?*

Predict-observe-explain. A predict-observe-explain activity is a simplified version of the scientific method in which students make *predictions* based on a hypothesis, observe results, and explain how the predictions and observations relate to each other. In this activity, students need to identify what they don't understand about bacterial growth.

Example: *Microbes are everywhere. Touch an agar medium with your fingers and predict what you'll see in a week. A week later, observe what grew on the medium, describe whether the observations support the hypothesis and match the predictions, and explain why.*

Alternatively, the instructor provides data for an experiment that students explain.

Concept map. Concept maps can be a powerful tool for students to assess their own learning because they need to create a visual representation and verbal explanation for complex concepts.

Example: *Explain how these terms relate to each other by arranging them in a logical order: Protein, tRNA, DNA, transcription, amino acid, translation, replication, gene expression, promoter, nucleotide.*

What's wrong with this statement? One of the most powerful learning tools is to have students explain why a statement is incorrect.

Example: *I don't want to be eating any viruses or bacteria in my food, so I won't eat genetically modified plants.*

Cases. Cases offer the opportunity for rich exploration into many concepts in the context of a real-world scenario.

Example: *A patient had itchy, goopy eyes, so he went to the doctor. The doctor diagnosed the irritation as conjunctivitis and prescribed antibiotics. Symptoms cleared up within a few days. The infection reoccurred two weeks later. The patient called the doctor, and she advised taking antibiotics again. The patient washed his sheets in hot water, washed his hands incessantly, cleaned his keyboard with soap and water, and bleached the washcloths he used to wash his face. The infection reoccurred again two weeks later. The patient called the doctor, who advised taking antibiotics again.*

> *(1) Write three hypotheses to explain why the infection reoccurred.*

> *(2) What should the patient do? Should he take the doctor's advice? Describe any assumptions you make and justify your recommendation with biological reasons and principles.*

Source: Handelsman, Jo, Sarah Miller Lauffer, and Christine Pfund. *Scientific Teaching: A Guide to Transforming Undergraduate Biology Education*, Greenwood Village, CO: Roberts and Company Publishers, in press.

APPENDIX 2: BLOOM'S TAXONOMY

Bloom's Taxonomy is a well-known way to classify and test cognitive abilities. Developed by educational psychologist Benjamin Bloom and four colleagues, the system is based on the premise that students engage in distinct behaviors that are central to the learning process. Bloom classified the behaviors into six categories that become increasingly more complex as they ascend from knowledge to evaluation.

Knowledge. Knowledge questions require students to recognize or recall pieces of either concrete or abstract information, such as concepts, dates, definitions, events, facts, formulae, ideas, terms, persons, and places. Typical exam wording includes choose, define, find, identify, label, list, match, name, recall, select, show, state, translate, true/false, who, what, where, when, why, and which.

Example: *Which of the following is not an event that occurs during the first division of meiosis?*
*   *1. Replication of DNA*
*   *2. Pairing of homologous chromosomes*
*   *3. Formation of haploid chromosome complements*
*   *4. Crossing over*
*   *5. Separation of sister chromatids*

Comprehension. Comprehension questions ask students to demonstrate their understanding of the subject matter. Typical exam wording includes arrange, classify, compare, compute, contrast, demonstrate, describe, discuss, distinguish, explain, extrapolate, group, interpret, illustrate, order, outline, paraphrase, provide example of, relate, rephrase, show, summarize, and translate.

Example: *How are proteins destined for export from a cell typically modified prior to secretion?*

Application. Application questions challenge students to use and apply abstractions (e.g., ideas, concepts, principles, models, methods, theories, and formulae) to explain concrete situations or solve problems. Typical exam wording includes apply, build, calculate, choose, classify, demonstrate, experiment with, how, interpret, make use of, organize, relate, solve, and utilize.

Example: *Given what you know about the life cycle of a virus, what effects would you predict antiviral drugs to have on viruses?*

Analysis. Analysis questions ask students to break down a whole into identifiable parts so that organizational structures, patterns, and relationships between the parts can be made explicit. Typical exam wording includes analyze (e.g., a case study), categorize, classify, compare, contrast, differentiate, discover, dissect, distinguish, divide, examine, inspect, recognize, relate, separate, solve, survey, and test.

Example: *What distinguishes the replication processes of RNA and DNA viruses?*

Synthesis. Synthesis questions ask students to recognize relationships between parts, combine and organize components, and create a new whole. Typical exam wording includes build, combine, compile, compose, create, construct, design, develop, estimate, formulate, imagine, improve, invent, modify, order, predict, propose, reconstruct, solve, summarize, and theorize.

Example: *Propose a way in which viruses could be used to treat a human disease.*

Evaluation. Evaluation questions challenge students to use certain criteria in order to appraise the degree to which a concept (e.g., ideas, solutions, work, theory) is satisfying, effective, or valid. Typical exam wording includes appraise, assess, choose, conclude, critique, decide, defend, determine, dispute, estimate, evaluate, judge, justify, measure, opinion, prioritize, prove, rate, recommend, select, and support.

Example: *Should the classification of living things be based on their genetic similarities or their morphology/physiology? What are the reasons for your choice?*

Source: Allen, Deborah, and Kimberley Tanner. *Cell Biology Education* 1:63 (Fall 2002); adapted from Bloom, Benjamin S., ed. *Taxonomy of Educational Objectives: Handbook 1,* Cognitive Domain. New York, NY: McKay, 1956.