Carnegie Mellon University

Eberly Center

Teaching Excellence & Educational Innovation

Labs / Studios

Labs and studios provide opportunities for students to learn procedural skills in a setting where they can observe, practice, explore, solve problems (whether scientific or artistic), and gain mastery through hands-on use of disciplinary tools and techniques. Labs and studios come closer than conventional classroom teaching to replicating a traditional apprenticeship model of learning, in which the instructor models expert practice (through demonstrations), coaches as students practice, and gradually fades his/her own participation to allow students greater and greater independence. Students, for their part, work towards what Collins, Brown and Newman (1989) call “successive approximation” of expert practice.

Labs

(this section borrows heavily from McKeachie & Svinicki, 2006)

Approaches to Teaching Labs

The approach one takes to laboratory instruction has important consequences for student motivation and learning. Domin (1999) distinguishes four different approaches to laboratory instruction, ranging from those in which students have little ownership over their own learning to those in which they have considerably more control, motivation, and incentive to work together to solve problems. The following description of Domin’s four approaches, along with examples, is adapted from McKeachie & Svinicki (2006).

Expository Instruction:

Students follow prescribed directions to verify a preordained result. The focus is on developing manipulative or kinesthetic skills (using laboratory tools, taking measurements, etc.) While expository instruction can be done on a large scale with minimal instructor involvement, students do not necessarily engage in scientific inquiry in a manner that promotes motivation or learning. This style of laboratory instruction has been criticized as a "cookbook" approach to laboratory experimentation.

- Ex. Students all receive a block of aluminum and are asked to follow an exact procedure for determining its density, the value of which is provided.

Inquiry Instruction:

Students are provided with materials, information, and a question to answer, but are given latitude in how to go about designing the experiment or interpreting the results, which are not preordained.

- Ex. Students are given different-sized samples of aluminum and asked: "What is the relationship between mass and volume in this material?" They are provided with different procedures for measuring volume and asked to evaluate the results derived from different methods. Follow-up questions are posed by the instructor, e.g., "Is density an intrinsic or extrinsic property?" or elicited from the students.

Discovery Instruction:

The instructor has a particular outcome in mind and directs students towards that outcome, encouraging students to make predictions, formulate hypotheses and design and evaluate the experiment themselves.

- Ex. The instructor holds a pre-laboratory discussion in which the question is posed: "What measurements can be made to determine the physical properties of materials?" Students are encouraged to make predictions, formulate hypotheses, and propose experimental designs, while the instructor raises questions and reminds them of pertinent information from previous classes. Students then conduct their experiments individually or in groups. Afterwards, the instructor leads a discussion about the approaches taken, drawing attention to the intended lessons.

According to McKeachie (2006) and Horowitz (2003), discovery-based instruction motivates and capitalizes on student curiosity, gives students greater ownership over the process of investigation, and thus results in deeper understanding.

Problem-Based Learning:

Problem-Based Learning gives students still more ownership over the process of discovery, while incorporating a greater dimension of teamwork and interdependence. In problem-based learning, students are asked a question that motivates curiosity and which they must work together to answer, i.e., it cannot be answered by an individual working alone, but must involve communication and comparison among students. In problem-based learning, there are multiple and equally valid strategies that can be used to solve the problem, and experimental procedures are viewed as a means to an end, not an end in themselves.

- Ex. Students are each given differently sized and shaped pieces of metal, painted with black paint to conceal their surface features. They are then asked: "Who else in class has the same metal as you?" Students must work together to compare their metals and pose experimental methods to answer the question. The purpose of the experiments is solely to answer the original question, and there is not a single correct approach. At the end of the exercise, the class discusses their reasoning, methods, and results, and the instructor helps guide them to general principles, new questions, and potential follow-up work.

Inquiry, discovery, and problem-based approaches to laboratory instruction are generally preferable to exposition in that they give students more practice developing the kinds of thinking scientists engage in. Two specific instructional models are Predict, Observe, Explain (POE) (White & Gunstone, 1992) <http://arb.nzcer.org.nz/strategies/poe.php> and Model-Observe-Reflect-Explain (MORE) (Tien et al, 1999).

General Strategies for Teaching Labs

Determine and share learning objectives

Despite the exciting potential of labs as a site of meaningful, hands-on learning, "[s]tudents frequently find laboratory work aimless and inefficient, merely a hurdle to overcome" (Gastel, 1991; p.80). This can happen when instructors are not clear about their goals. Depending on the course, these goals might include:

- giving students practice using disciplinary vocabulary and concepts
- reinforcing and building on materials presented through lecture, discussion, and independent study
- showing students how data are obtained and demonstrating the uncertainty inherent in research
- providing chances to talk informally with instructors
- helping students develop skills in observation, problem-solving, analysis and critical thinking
- helping students develop procedural skills (such as the proper use of instruments and tools)
- helping students develop skills in problem-solving, analysis and critical thinking
- learning to work in groups
- improving skills in oral or written communication

The first step to making labs productive is to clearly identify your learning objectives (for labs in general as well as particular exercises) and to communicate these to students, perhaps on the blackboard at the start of the class. You should also keep these objectives in mind as you guide the lab, and reinforce them at the end of the session.

Your objectives will help you determine the kinds of questions you ask, the sorts of preparatory and follow-up assignments you give, and even the amount of digression you allow during the lab. Gastel, for example, points out the utility of encouraging any discussion that helps students understand how scientists work and think, even if it is off topic. He writes:

"Acquainting students with scientists and their world is often a goal of science teaching in college and professional school. The informal, unstructured atmosphere of laboratories tends to promote such acquaintance. Therefore, do not feel constrained to limit discussion to the exercise at hand. If opportunity arises, feel free to discuss issues in research and in science policy and scientific ethics; do not shy from mentioning the proposal you are writing or the consulting you are doing or the conference you just attended…For many a student, acquaintance with the culture of science, and with scientists as humans, may be among the most useful and lasting lessons taken from the laboratory – and the one that will benefit science the most." (Gastel , 1991; p.83)

Provide safety instruction

Proper safety orientation is critical in laboratories. To prevent accidents, instructors should orient students to basic lab safety as well as to precautions for specific exercises. Students should have the chance to practice with equipment and procedures before using them in potentially dangerous exercises.

While live demonstrations by the instructor are the most common ways to model safe procedures, slides, films, videos, and computer simulations can also be used to illustrate proper techniques -- or to demonstrate the consequences of unsafe or sloppy techniques.

Do a dry run

It can be helpful for you and/or your TA to prepare and do the experiment (including analysis) in advance to determine what equipment and supplies you will need, and to think through potential problems. Many faculty members have found that a dry run exposes shortcomings in the lab manual that you might want to address with supplemental handouts or additional instruction. It can also help you anticipate how much time each aspect of the exercise will take, and to find creative ways to deal with time constraints (e.g., have different groups of students do different pieces of a lengthy exercise and discuss and consolidate their findings.)

Situate particular exercises

While the connection between labs and other course materials might seem obvious to you, students often do not make these connections. Thus, it is important to explicitly situate each lab within the course as a whole and help students to see the larger relevance. Give a mini-lecture at the beginning of class that sets out the objectives of the exercise and links them to material from previous classes. Ask questions that require students to connect what they are doing to other materials in the course. Refer to assigned readings. Connect the lab exercise to problem sets students do as homework.

Distribute attention and provide feedback

Once students are properly prepared for labs, the role of the instructor is to provide guidance, stimulation, and feedback as students work independently, in pairs, or in groups. Providing equitable help to students and making efficient use of your time is not always easy, however. As Gastel points out, instructors tend to "hover around those students who are most able, most demanding, or most sociable" (1991, p.82) To distribute your attention equitably and effectively, consider your goals (to what extent are you trying to encourage independent exploration? what kinds of support will students need to achieve this?) and your constraints (class size, number of instructors, physical layout, the range of student skill levels) and assess options, whether these involve simply circulating among groups yourself, taking care to allocate your attention fairly, or:

- demonstrating a procedure or giving an explanation to one group and asking that group to teach other students
- (if there is more than one instructor and/or you have TAs) dividing the class, each of you taking a different group, but rotating periodically so that students have the benefit of several instructor's perspectives
- (if there is more than one instructor and/or you have TAs) dividing tasks (e.g., one of you teaches students how to use a particular instrument while the other walks students through a different part of the exercise.)

Use questions to encourage critical thinking

It is important that students think about what they are doing and why. To encourage critical reflection, use questions that probe for deeper thought. These might be questions about observations and preliminary analyses (e.g., What patterns are you seeing, and what do you think they may indicate?). They might be questions asking students to predict a result before they try the experiment, to offer an initial hypothesis, or to provide evidence to support an assertion. They might be hypothetical questions (e.g., What do you think would happen if you turned up the heat? How would your results differ if the experiment were performed at high altitude?), or questions about implications (e.g., What is the significance of this result vis-à-vis X, Y, or Z?). Often the best questions are the questions students raise themselves. Depending on the question a student asks, you may choose to (a) answer it, (b) throw the question back to the student to answer (i.e., That's an excellent question: what do you think?), or (c) open the question up to the entire class (e.g., .

Stress the importance of clear communication

Science students sometimes feel that writing is an issue for English classes, and that they should be assessed solely on content, not form. Emphasize to them that form and content are not separable, and that clear communication (whether written or oral) is as critical in science as it is in other professions. Clearly define the elements of effective lab reports (using performance rubrics, for example), and give students ample practice developing the skills they will need to write successfully in the context of your course. Since technical language is sometimes intimidating, it can be productive to give students opportunities to talk or write about scientific issues in non-technical language before they are expected to use technical terms or scientific conventions. Communication, moreover, need not be verbal. Students can be encouraged to create diagrams, flow-charts, and other illustrations to demonstrate processes or show results.

Bring closure

Having introduced learning objectives at the beginning of a lab, revisit them at the end of the session, asking students to report on what they have learned. Students can be asked to synthesize knowledge in any number of ways, including:

- engaging in a group discussion in which they share results, work through problems, and reflect on what they have learned
- writing a formal or informal lab report
- giving a formal or informal oral presentation
- taking a quiz
- completing a worksheet

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Studios

Studio classes teach procedural skills (the use of specific techniques, approaches, tools, and media) in relation to concepts and ideas (schools of art/design, architectural movements, dramatic styles, intellectual, social, and political trends, etc.) while setting the conditions, examples, and inspirations to spark creativity and exploration.

Rosenberg, along with others, argues that "teaching people to be artists is impossible" (p.136). Nevertheless, creative imagination can be fostered when students have the opportunity to observe artists (or architects, actors, directors, etc.) working, talking, and interacting. Part of the task of the instructor, therefore, is to allow students glimpses into her own and other artists' creative processes and the artistic community that sustains them. Students, therefore, should not just be taught technical skills -- though these are important -- but exposed as extensively as possible to art and the people who create it. Guest artists/lecturers, master classes, field trips, demonstrations, etc. can thus be a valuable dimension of studio courses.

One of the challenges in studio courses is to balance the development of technical proficiency with conceptual understanding. As Walker writes: “Materials, techniques, subject matter and formal qualities deserve attention in planning studio instruction, not at the expense of interpretive meaning, but in relation to it” (1996, p.14). Instructors should ask questions and design exercises that require students to reflect deeply on what they and other artists are trying to express.

Depending on the discipline – art, architecture, design, music, drama – there are significant differences in how studio classes are conceived, making generalizations about teaching strategies difficult.

A general model for teaching procedural skills that can be adapted for different studio contexts:

Situating

- The instructor situates the particular exercise or task within the context of the course and discipline, so that students can see its relationship to other core concepts, practices, etc.
- The student listens, thinks, answers questions

Modeling

- The instructor models expert practice while describing and explaining each step of the process from planning (selecting materials/tools, organizing work space, conceptualizing the task) through execution; answers student questions
- The student observes, listens, asks questions

Scaffolding

- The instructor provides guidelines, steps, and parameters to structure student exploration
- The student conceptualizes the task and begins planning

Coaching

- The instructor provides coaching and feedback while students engage in the exercise themselves
- The student engages in the practice, asks questions, reflects on own practice in relation to expert practice

Fading

- The instructor gradually decreases coaching and scaffolding, allowing students greater independence
- The student operates with increasing independence in more and more complex situations (less structure, more choices/complications, etc.)

Self-Directed Learning

- The instructor assists only when requested
- The student practices the real thing alone or in groups

Generalizing

- The instructor guides students from their own process to larger insights and useful generalizations
- The student generalizes from own practice to larger principles, concepts, or interpretations

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