Chapter 5  
Problem Sets and Laboratories

Much teaching in mathematics, the natural sciences, and foreign languages involves a “hands-on” approach. In other fields, classes in methodology, data collection, and statistics have incorporated a similar kind of learning. Teaching in these fields differs, in some significant ways, from much of the teaching in the humanities and social sciences. This chapter is designed to address issues specific to teaching assistants who teach from problem sets or exercises or who run laboratories.

Teaching with Problem Sets

Most mathematics courses and many courses in the hard sciences require students to complete problem sets on a regular basis. All courses in foreign languages require students to complete practice exercises. For the teaching assistant, this means that much of the section or the course itself will involve reviewing or otherwise incorporating these homework assignments. The key is to find ways to make this activity productive and participatory—an active learning experience for the students. In the remainder of this section, the term problem set is used to apply to any assignment of questions students are expected to answer.

The Function of Problem Sets

Problem sets are important and useful as a tool through which students acquire skills and demonstrate an understanding of larger concepts. Your teaching of problem sets should reinforce this relationship between problem sets (the “hands-on part”) and the material of the course (the “abstract part”). Your job is not over when students have all the correct answers to a problem set in hand; they must also understand the concept behind the answers and how this concept could be applied to other problems.
Setting Ground Rules at the Beginning of the Semester

Many students walk into math, science, and language classes expecting the focus to be on right and wrong answers. Instructors reinforce this expectation when their sole aim is to provide correct answers. Although accuracy is, of course, critical to math, science, and language learning, you need to stress for yourself and for your students the importance of good problem solving over perfect solutions. In the educational process, the key is often the journey, not the destination; students need to be able to chart their way through new problems in the future without your assistance.

From the beginning of the semester, make it clear to your students that you are an instructor who believes in the importance of persistence and risk taking as much as correct answers. For students to take this statement seriously, you need to structure the course so that it emphasizes the problem solving process.

In lower-level courses, students will often come in with vastly different backgrounds, particularly in math. You will undoubtedly encounter “math anxiety” in at least a few students; you may find this kind of anxiety to be more common with female students entering the sciences, which have historically been male-dominated disciplines. You may overhear students explaining their dislike or lack of success with comments such as “I’m just bad at math.” It is important for you to remember that the same problem set can be simple for some students and almost impossible for others, and that competent students may feel doubtful of their abilities.

At the beginning of the semester, gauge the range of abilities and experience in the class. Emphasize to all students that everyone has to put in time and hard work to succeed in these fields and make yourself available to provide support for those students who need it (and who are willing to work for it). However, you cannot emphasize enough that it is up to the students to learn the material; you cannot do it for them.

Preliminaries for Lesson Plans

When you think about how to present material in math, science, and language classes, be creative in your approach. The traditional, linear approach to teaching this kind of material is often not the most effective. Students will see the material in this form in the book; you do not want to present it to them in the same form in class. You will need to
decide how much time to spend lecturing, reviewing problem sets, and answering questions.

**Writing Creative Lectures**

Employ different strategies that will help illuminate the concept you want to cover. You can use visual aids (pictures, charts, graphs), verbal descriptions (story problems, real life applications), or physical props (tennis balls, Lincoln logs, pulleys and levers).

**Example** To teach the concept of pipelining in computer science, send pieces of paper down a row of students with each student drawing their own shape and passing on the paper each time you snap your fingers. They will then see the simultaneous functioning of the many parts of a multiple task.

With difficult concepts, use building blocks. Start with a simpler explanation or example of a concept and make sure that everyone understands. Then substitute gradually more difficult material into the example.

**Example** Set up a story of a farmer with a certain amount of fence with which he wants to enclose the largest possible area. Review how students might try to calculate this area. Then begin to substitute calculus symbols for the entities in this “real life” equation.

Metaphors and analogies can also helpfully explain complex and/or abstract concepts.

**Example** “This mathematical relationship can be paralleled to the codependence of foxes and bunnies. A certain number of foxes eat a certain number of bunnies to survive. Now, what happens to the bunnies if the fox population suddenly grows larger?”

**Ways to Review Problem Sets**

There are probably as many different variations on ways to review problem sets as there are different kinds of problem sets. Here are a few general types of reviews with sample lesson plans and guidelines.
Teaching-Assistant-Led Review

At times, it may be most efficient and effective for the teaching assistant to lead the problem set review. Encourage as much student participation in this process as possible.

Steps for the Review

1. Start by establishing the goals for the review: for example, how many problems you expect to cover and how thoroughly; how students should be involved in the review process.

2. Begin with a problem of your choosing or ask students to decide which problem they would like to cover first.

3. If a student chooses the problem, ask them where they got stuck and then determine how many other students got stuck at this same level. If you have chosen the problem, poll the class on where they ran into difficulties.

4. Once you have determined the area(s) of difficulty, respond with questions to the class (not just to the student asking the question) about how to begin working on a solution. You may want to ask them to choose among several options about how to proceed; if you offer only one suggestion, most students will agree to it, whether it is the most helpful option or not.

Examples

“Do you want to draw a picture?”

“Do you want to work backward from the answer?”

“Do you want to solve a simpler problem first?”

“Do you want to substitute easier numbers for harder ones in the equation?”

5. If one student in the class has figured out how to do the problem and volunteers this information, you can ask them to explain the solution to their classmates if they are comfortable doing so.

See “Student Presentations” in this chapter for more information on spontaneous student teaching.
6. As you continue to review more problems, you may find that you want to be more thorough in your responses to the first few questions and then provide more summary or specific help with later questions.

7. End the review by telling students how you expect them to follow up on this material: for example, correct the problem set and turn it in next class; take five minutes and write down lingering questions so you can know where there is still confusion; try the next few (perhaps harder) problems in the book to see if they can apply their new understanding.

Guidelines for the Review

- Use questions from students to focus your teaching efforts. They are showing you what they do not understand and where they need your assistance.

- Never humiliate students who ask questions, however simple. They (and their classmates) will only be reluctant to ask again if they feel singled out for having revealed their confusion or lack of understanding.

- Be conscious of how much and how often different students are talking and encourage equal participation by students of different genders, races, and ages.

- Because time in section is precious, do not feel you have to work through the entire solution. If you know what caused the confusion, you can clarify that aspect of the problem and then allow students to complete their work independently.

- Remember: your goal is not simply to provide correct answers to the assigned problems but rather to foster your students’ conceptual understanding.

Student Collaboration in Class

Students learn effectively from each other when working through problem sets. Different students understand different aspects and applications of concepts, and they can often explain them in ways their peers can understand. Do not hesitate to employ group learning during class.
Steps for Group Collaboration

1. Put students into groups of three or four students.
   See chapter 6, “Debate: Grouping Strategies,” for more information on assigning students to groups.

2. Assign or hand out a set of problems and tell students how many problems they should try to do and how far along toward the answer they should try to get.

3. Walk around the room while students work and encourage them to work together, rather than sitting together and working alone. Feel free to sit down and participate in the solution of a problem, particularly if a group is struggling. Make yourself available to all groups to answer questions.

4. During the session, determine which groups have a solid understanding of which problems.

5. At the end of class, you can ask representatives from various groups to explain their solutions to the class. For example, one student can write out the problem on the board while another provides a “play-by-play” explanation.

Steps for Pair Collaboration

1. Put students into pairs.

2. Assign or hand out a set of problems and tell students how many problems they should try to do and how far along toward the answer they should try to get.

3. Have one student be the “talker” and the other be the “listener.” The talker must explain to the listener (who can always ask questions) how they would work through a problem or set of problems.

4. Halfway through the session, you can have students switch roles.

5. Leave time at the end of class for a full-class review of at least a few problems. Choose one or more problems and ask the listeners to volunteer their partner if their partner provided a clear and detailed answer; if so, ask the talker to speak to the entire class (they have the advantage and confidence of having practiced the explanation once).
Guidelines for In-Class Collaboration

- Inevitably, some groups of students will contain classmates with similar levels of understanding, while other groups will have a wide range of abilities. It is important, therefore, that you keep reshuffling groups during the term so that students do not get trapped in particular roles within a group’s dynamic (e.g., talker, listener).

- Find out your department’s policy on encouraging and grading group work if the in-class work will be graded.

- Be very clear and explicit about what you expect and allow in terms of collaboration, both inside and outside of class. Students may come to your class with different expectations for how much collaboration is permissible on graded work.

- Be vigilant about keeping all group members engaged in the problem solving. Since they will be working individually on exams, they need to develop their own skills as well as their ability to work in groups.

- Some students work better alone and prefer to do their work that way. Different students benefit from different learning methods; you will be helpful to the greatest number of students if you vary your class plans from week to week.

Student Presentations

Student presentations reinforce the importance of risk taking and help create a learning community in which the process is valued as much as the product. Students can present completed problems to the class either on a spontaneous basis or with advance preparation.

Steps for Student Presentations

1. At the beginning of the term, establish a set number of points students will receive for a presentation (or credit that will go toward their participation grade). Tell students they always get full credit for a presentation as long as they have the material prepared; reinforce that they do not have to be correct but they do have to be prepared to talk through the solution. They must be able both to
re-create the solution on the board (or overhead projector) and to explain it as they go.

2. Tell students at the beginning of the term that they should be prepared to be corrected if necessary during their presentation in exchange for full presentation credit, given appropriate preparation. Again, you can remind students that they are working with difficult material and if they already had it perfectly mastered, they wouldn’t be in the class. The key is the process and risk taking.

3. For a spontaneous student presentation ask the class if anyone is prepared to present a solution to a problem that another student has asked about. If so, turn over the front of the room to the student who feels prepared to present the solution. After you do this a few times, students will begin to prepare problems for presentation while they are doing their homework.

4. To organize students for prepared presentations of a problem set during the next session, ask which specific problems students do not understand or select a few problems you think will be particularly difficult for them. Then ask if there are any volunteers to present solutions for those problems in the next class. Make yourself available to those students for help before the next class so that they can feel confident making the presentation.

5. Once you turn over the front of the classroom to the student presenter, seat yourself near the front (perhaps off to one side) where you are available to help but not a dominant presence.

6. Be prepared to step in to correct mistakes if the presenter’s classmates do not see the mistakes or are unwilling to correct them.

7. After a student presentation, thank the presenter for their work and, if applicable, point out strengths in their solution and presentation so that other students can identify key components of the process.

**Guidelines for Student Presentations**

- Alleviate as much anxiety as you can for student presenters by continually reinforcing that you see presentations as a useful way to assess student understanding.
• Stress that students always get full credit for the presentation as long as they have material prepared, even if the presentation is not perfect.

• Set yourself up as a support system for presentations, not a judge; students should know they can look to you for guidance if they are feeling lost or anxious during the presentation, particularly early in the term.

Eliciting Student Feedback

In-class questions obviously provide the most frequent and direct form of student feedback. You can also elicit feedback about how well students understand the material using one of the following “mini” lesson plans.

Sample Precinct

Choose a “sample precinct” (a row or a cluster of students). Admit that you are going to put them on the spot by asking them all a series of questions but make it clear that they are just the sample group. You are using these questions to assess overall class understanding, not to highlight their shortcomings and/or brilliance. Choose different precincts over the course of the term.

Initial Freewriting Activity

Ask students to take a few minutes at the beginning of class to write down what they recall from the last lecture or what they found confusing in the reading. Then ask for volunteers to share one of their responses; you can keep a list of the responses on the board. This activity can help provide continuity between lecture and section and help you focus your teaching on problem areas.

Final Freewriting Activity

Ask students to take a few minutes at the end of class to respond in writing to a question you ask. Depending on the question, you can make these responses anonymous or not.
Examples

“Tell me what you now know about derivatives.”

“Summarize for me what we talked about in class today.”

“What concept is feeling the most confusing to you right now?”

“If we could review two things in class on Wednesday, what would they be?”

You can then use their answers to give students feedback about their progress or concerns as a class and to focus your teaching in the next class. Always read what they have written but do not feel compelled to respond individually (in writing or orally) to each student.

Grading Problem Sets

In math and in the sciences, exams are often graded on a curve, which can accurately and fairly reflect students’ relative mastery of difficult material. With problem sets, you may want to dispense with a grading curve in order to encourage collaborative learning and create a more supportive learning community among the students. Find out your department’s policy about encouraging and grading group work. Assuming group work is acceptable, encourage students to seek outside help (tutors, classmates, you); in the end, however, the work must be their own. Tell them you expect they will be able to explain the solution to any problem they answer. Remind them that they will be working individually on exams.

You may not have the power to determine how students are graded in section or to create extra graded assignments. If it is possible for you to develop a grading scheme, use quizzes (five- to ten-minute events) to encourage students to come to class prepared and to assess where students stand with respect to the material.

You can also consider developing a system that credits students for learning activities in which they demonstrate initiative, persistence, risk taking, and overall hard work. For example, you can create a system in which students receive credit for creating study sheets for exams (and turning them in), doing extra homework assignments or “stumper” problems, and giving class presentations. Enough credit at the end of the term can boost a borderline grade.
Running an Experimental Lab

Many courses in departments such as physics, biology, chemistry, or natural resources incorporate experimental labs into the teaching of the material. Teaching any particular lab requires a great deal of highly specific information and expertise in the relevant area. This section will address only general information applicable to experimental labs in most natural sciences.

Weekly Preparation

Many teaching assistants meet in weekly preparation sections with the course professor or laboratory instructor. In these sessions, the professor typically discusses the upcoming experiment, notes potential problems, and answers questions. The professor often addresses issues related to lab equipment, supplies, and safety. Use these sessions to familiarize yourself with the laboratory procedure and with the professor’s expectations.

If it is possible, you should run each experiment yourself before your students come to the laboratory. This practice is time consuming, but it will save you a great deal of difficulty in the long run. Once you have worked through the experiment yourself, you will know

- exactly what equipment you will need for the day of the laboratory class;
- how much time students should allow for each part of the experiment;
- what material you can prepare as “backups” in case students fail to get the proper results in early stages of the experiment and their materials are unusable;
- which parts of the experiment are most likely to cause problems for students and how to fix them;
- what you should hope for in students’ laboratory reports.

If it is impossible for you to run a laboratory experiment before the class meeting, carefully read the lab manual in advance and take note of the procedures or concepts that you cannot visualize without having run the experiment. Raise any questions you have during the preparatory session with the professor. Also, be sure to clarify these same points with your students; if it confused you, it will confuse them.
Laboratory Equipment

Prior to the first day of class, find time to go to the laboratory where you will be teaching. Make sure that you have the necessary access to the lab and to its materials. Check the equipment standard to the lab to see that it works. Even if the lab is in good working order, find out how to report equipment that needs to be repaired or replaced. For labs in which materials will be supplied on a weekly basis, find out who is responsible for maintaining and distributing the supplies and what teaching assistants are expected to do with regard to getting and returning supplies. Finally, locate the lab safety equipment (eye wash, fire extinguisher, etc.) and be sure that it is also in working order.

Laboratory Safety

Most laboratories involve a safety hazard of some kind. Be sure that you take time at the beginning of the semester to give your students clear instructions about the safety precautions of your laboratory. Once you have established the rules for safe laboratory procedures, enforce them vigilantly. If a student is being lax about safety (e.g., using a Bunsen burner for entertainment purposes) correct the student and alert them to the potential dangers of their behavior. If the student’s dangerous behavior persists, you should—after appropriate warning—dismiss them from that particular lab and give them no credit for the lab or for the write-up.

Do not “bend” laboratory safety rules; if someone gets hurt under these circumstances, you will be held partly, if not fully, responsible. Be sure to lay out the laboratory safety rules and the consequences for breaking them in your syllabus. While it may feel like a hassle to send a student home when they show up wearing sandals or contact lenses to a chemistry laboratory that prohibits them, you are protecting the student and yourself by doing so.

Assigning Laboratory Groups

While some teaching assistants leave it to students to form their own groups, we recommend that you assign groups yourself according to the following guidelines.

- Separate friends; this often helps students stay focused on the task at hand, and it reduces opportunities for lab report plagiarism.
• To the degree that it is possible, evenly divide the men and women in your class among the laboratory groups. As science students are often predominantly male, you may find that your female students have trouble asserting themselves as equal partners in their groups. If this is the case, you may want to consider having some all-female groups.

• If you are aware that you have some students with more laboratory experience than others, you may want to pair them with less experienced students in order to ensure that most groups will finish the lab in a reasonable period of time. Make sure that the less experienced students are fully engaged and that the more experienced students are patient with them.

In extreme circumstances, students may need to switch lab groups. If such a situation arises, consult with the professor about how to approach the problem. You may be able to rearrange groups; you may have to move a student to another lab. Talk through with the professor how to present these changes to the students.

**During the Laboratory**

It is often effective to write an outline of the experiment steps on the board before class begins. When students arrive, talk them through the steps of the experiment and ask what questions they have about the procedure. Also, remind students of the aim of the lab and how it is relevant to lecture material. Once the experiment is under way, walk around the lab continuously and check in with each group. Students are far more likely to ask you important questions if you come to them than if you are sitting at a desk, away from the main activity of the lab. This also increases the energy level of the class and makes the whole thing more fun for everyone.

**Answering Questions and Correcting Mistakes**

When students have questions about the lab experiment, or when they are struggling with an experimental procedure, do not come to the rescue right away. Keep in mind that lab experiments are a vehicle through which students are taught about scientific methods and principles; it is far more important that your students understand the “big picture”
behind a given experiment than that they achieve perfect experimental results. Student experiments have already been simplified and distilled to the level where they are manageable in a few hours. It can be important for students to see that experiments derail, that the next step is not always clear, and that decisions about how to proceed depend on the goal of the experiment.

Relate specific questions from your students to their broader understanding of the goals of the lab and ask them to make specific experimental decisions with this “bigger picture” in mind. Encourage students to work together to figure out an answer or how to get back on track with the experiment. Ask your students questions that will guide their thinking toward the information they need. Offer answers only when absolutely necessary.

Example  “So, your bacteria didn’t grow. Think of all the reasons why bacteria might not grow. Which ones might apply here?”

Keeping Students on Track and Involved

Experimental labs often involve periods of waiting between different phases of an experiment. You can use this time to engage students in question and answer periods designed to develop their understanding of the larger lesson behind any particular experiment. Ask your students questions that test their understanding of how the different parts of the lab experiment are related to the overall goals of the lab. You can also ask them questions about the lecture or present them with data or other information with which they have to generate a hypothesis. The point is to keep them immersed in the process of mastering the scientific method.

You are also likely to come across students who are happy to let their lab partners work on the experiment while they work on the crossword puzzle. This can be especially tricky when there really are more lab group members than tasks for particular parts of an experiment. Make a point of asking a crossword puzzler questions about the lab: what their partners are working on, the importance of this step in the experiment, and so on. Show students that you expect them to be fully involved in the lab and to understand what is happening, even if they have no specific task at that moment.
Wrapping up the Lab

Because different lab groups will complete the experiment at different times, it is often impossible to give a final summary statement about the point of the lab. Instead, try to meet with each group of students as they are finishing to see how their experiment went and to answer questions they may have about how to summarize their findings in their lab reports. If necessary, you might want to institute a “formal” procedure in which groups are required to check in with you before leaving. This is also a good time to make sure that each lab group is cleaning up their equipment and returning their work space to its original condition.

Common Problems in Labs

It is unlikely that you will get through a single semester of teaching in a laboratory without facing at least one of the problems listed here.

Failed Experiments

For one reason or another, you will have a lab group whose experiment fails to achieve any semblance of the desired results. When this happens, remind your students that they can still do well on their lab reports. Instruct them to explain carefully why their experiment failed to achieve the expected results, to be frank about the shortcomings in their methods, and to take their experimental difficulties into account when interpreting any results they did achieve. Be sure to use failed experiments as a learning opportunity: ask students to generate hypotheses for their odd results and then describe how they would test these hypotheses to see what really went wrong. In this way a “failed” lab becomes another way to learn about the scientific method.

Students Who Miss Lab

Establish your policy on missed labs at the beginning of the semester and write it on the syllabus. Because it is nearly impossible to “make up” a missed lab, you need to be clear with your students about how you plan to handle such absences.
Inattentive Students

While very inattentive students only hurt themselves in most classrooms, they can be a serious detriment to a laboratory group. While you can expect an inattentive student’s classmates to exert some pressure on the student to do their share, you should not place the burden of motivating an unmotivated student entirely upon the other students in their group. You should address this kind of situation as early in the semester as possible.

Watch for students who are often (or always) reading the newspaper or chatting while the rest of their lab group is hard at work. During class, encourage the inattentive student to become involved in the work of the group.

Example  “Maria, the rest of your group looks busy; find out from them what you should be doing.”

You need to catch this kind of behavior as early as you can. Once a group of students identifies a member as “dead weight” they will often respond by isolating that student and figuring out how to work efficiently without them. At that point, it is more difficult for the student to be reintegrated into the group. If this behavior persists, schedule a meeting with the student outside of class to remind them of how their performance in the lab will affect their grade.

Lab Reports

Once the lab is over, your students face the challenge of summarizing and explaining their results in a lab report. While students will learn to write better lab reports from trial and error, you can speed the learning process by offering some important information at the beginning of the term.

Explain the Purpose of Lab Reports

Students will often assume that you want them to mold their lab results—and their lab report—to what they think should have happened during the lab. Explain to students that experiments are as much about process as results. Tell students that it is possible to receive an A on a lab report summarizing a “failed” experiment and that students can also receive an F for a report on an experiment that went very well.
What matters in the lab report is that students demonstrate their understanding of what was supposed to have happened in the lab, why it was supposed to have happened, and how their own results were achieved (even if their results are wrong!). Again, stress to your students that labs are designed to familiarize them with the scientific methods and principles of their field; the lab reports should be used to demonstrate their understanding of both.

**Clarify Your Expectations**

Tell your students in detail what format you prefer for lab reports: the necessary sections to include; how formal the writing should be; if reports may be handwritten; how many decimal places should be allowed for numerical results; if they may write their entire reports on graph paper; approximately how long a report should be; and so on. Describe explicitly what goes in each section; it is a somewhat artificial way of organizing things, so students need a lot of guidance. Lab reports present a significant challenge to many students; take out as much of the “guesswork” about what you expect as you possibly can.

Also, be very clear with students (preferably on your course syllabus) about the penalties for late lab reports.

*See chapter 2, “Syllabus: Setting the Agenda,” for more information on establishing policies for the class.*

**Teach from Old Lab Reports**

At the beginning of the term, make copies of old lab reports that students can use as models for their own reports (make sure they describe experiments your students will not be doing!). Review these reports with students and highlight the strengths and weaknesses of each report. Again, help your students to see the “big picture” behind lab experimentation and to appreciate how they can use their lab reports to communicate their understanding of how their results are related to the goals of the lab. Talk with students about why lab reports are set up according to a particular format—why all the included information is important for them as scientists.

**Group Lab Reports**

There are benefits and drawbacks to asking students to write group lab reports.
Pros  Students learn more about working in groups.
       It involves less grading for you.
       Students can pool their knowledge.

Cons  It may be difficult to ascertain the understanding of individual group members.
       It may discourage active lab participation by all members of the group.
       Some students may do almost no work, while others will do the lion’s share.

See chapter 8, “Grading Group Work,” for more information on how to grade group assignments.

You may want to alternate assignments, asking students to write some lab reports individually and some in groups.

Teach from New Lab Reports

Each week, you can ask one group to prepare a presentation for the next lab in which they give an oral lab report (with a much reduced Methods section). This allows the class as a whole to sum up the previous lab and discuss problems or theoretical issues. It also keeps students from forgetting (quite so immediately!) what they did last week.

Further Reading


