Facilitating Laboratory Activities Series

PART 1: Best Practices for Planning and Facilitating a STEM Laboratory Class

Laboratory sections can play an important role in increasing the persistence of STEM majors by providing students with opportunities for practical, relevant learning in science and engineering, and pushing them to identify professionally as a scientists and engineers (Graham et al., 2013). Graduates with STEM degrees are in increasing demand across the world; however, as of 2013, less than half of the three million students entering US colleges as intended STEM majors persisted to graduation in a STEM degree (Graham et al., 2013). Laboratory sections provide important spaces where students can gain a better understanding of key course and STEM concepts by applying those concepts in practical activities. This resource will offer a number of specific strategies and suggestions for effectively planning and facilitating a laboratory section.

Basic principles for planning an effective undergraduate laboratory section

Actively creating connections between lecture material and laboratory activities can help build meaning and relevance for your students. Nilson (2010) emphasizes the importance of placing lab activities in context with course concepts and the bigger scientific picture before moving on to the actual activity. This can help students create connections between the more theoretical concepts they learn in lecture, and the practical application of those concepts in their lab section. Here are a few basic principles to keep in mind when planning your lab section:

Strategies	Teaching Suggestions
Design and assess projects that align with your learning outcomes.	Appropriate goals for a laboratory section could include helping students understand theory by observing and verifying concepts, having them go through a research and design processes, helping them improve their powers of reasoning by manipulating cause/effect relationships, and acquainting them with essential lab equipment. If possible, assess these learning outcomes on exams in ways that reference or depend on some of the learning from lab. This sends a clear message to students that the lab learning is integrated, relevant, and worth studying and really learning.
Use inquiry-guided problem- or case-based learning principles.	These types of assignments are often more “authentic,” in that they model the actual process scientists use in professional laboratories to solve problems. Students are pushed to use their own critical thinking skills and inductive reasoning to develop their own strategies for meeting the challenge, which helps to build relevance to lab activities for students. For more on inquiry-based projects, see Part 3 of this resource, and Part 2 of our “Strategies for Covering Content Series.”
Design activities that develop transferrable skills.	Transferrable skills can include collaboration and group work, oral and written communication skills, organization and project planning, and more (Dunne & Ryan, 2010). By participating in activities designed to develop skills that can be transferred into future lab classes or into the workplace can help students understand the relevance of lab activities beyond the immediate concerns of your class.
Create opportunities for collaboration and teamwork between classmates.	Most scientific and technical projects today are cooperative. By creating collaborative activities, your students will not only gain the opportunity to learn from each other, but will also participate in a more genuine laboratory experience. However, it is important to also scaffold these group activities in ways that help your students develop collaborative skills. For example, you could have students practice working in pairs or small groups on simple tasks, then gradually build up the complexity of the collaborative assignments.

Consider equipment you want to expose your students to.	Ideally, students should be exposed to equipment, materials, and procedures they may need to use again in the future. Whichever equipment you use, make sure it is in working order prior to the lab.

Planning and facilitating an effective lab activity
Given that laboratory activities can often be complex, time-intensive learning tasks for students, it is important that each lab class session be designed to run smoothly. Here are a few suggestions on how to plan and facilitate an effective lab activity:

Strategies	Teaching Suggestions
Plan ahead.	Lab activities should be planned at least a week in advance if possible, and the professor and lab assistants or TAs should rehearse the procedure before the lab sections and review the results afterwards. Make sure that the requirements are feasible for students to complete in the amount of time allotted, and that the productive constraints (recommended ranges or limited quantities of materials to work with) chosen for the activity produce the desired results. Have a TA or lab assistant review the assignment sheet to ensure that the instructions are clear for students.
Make sure to train students in lab safety.	Whenever adapting or developing new labs, it is important to also go over safety and have a clear plan for the necessary safety training for students. It can be productive to include TAs in the brainstorming of hazards and safety concerns, since they bring such valuable experience in this area. The safety office for your department may also wish to be involved in reviewing the lab plans and approving the safety education materials that are planned for TAs and students. One way to train students in lab safety is to have your TAs spend some time discussing hazards and safety concerns before beginning any lab activities, followed by a pre-lab quiz to assess students' understanding.
Have students begin each lab by reviewing the previous week's material.	This can help students see how this lab activity fits into the bigger picture of the course, which can build relevance. For example, you could have students free write about what they remember from last week's lab, and then share responses in small groups. Or, you could create a short quiz on the material from the week before, for students to complete at the beginning of their lab section. These short, low-stakes assessments can also be used to encourage attendance or to assess students' understanding of safety instructions for the lab.
Have TAs go over the main objectives with students prior to starting the lab activity.	Having TAs explain and/or demonstrate the objectives, major procedures, and learning outcomes for the lab can help to ensure that the lab runs smoothly for everyone. Consider having your TAs write "Lab Tips" on the board that outline suggestions for completing the lab successfully, safety instructions, and typical pitfalls and mistakes students can run into. For consistency between sections, you can provide your own suggestions for lab tips and safety during TA meetings, then have your TAs use those suggestions to discuss and generate their own lists as a group. Also, during lab, have your TAs demonstrate new lab procedures, equipment, and handling for special materials for students.
Encourage TAs to take an active role in the lab.	Encourage TAs to play an active role in the lab by observing groups and checking in regularly with students. Students may feel uncomfortable asking questions, especially in the first few weeks of the term; therefore, suggest that TAs to avoid waiting for students to approach them, and encourage them to learn students names.
Leave time for review at the end of the lab.	Make sure to leave time to go over the expected results, and to review the activity as a class. This step helps ensure that students understood and learned from the activity, while also identifying students who may be struggling with laboratory or lecture concepts.

Adapted from: Nilson, 2010 & Stanford Teaching Commons, "Laboratory Teaching Guidelines." Includes contributions from Julia Chamberlain, UC Davis Department of Chemistry.

Additional Resources
For information on designing an effective lecture class to pair with your laboratory section, please refer to our series on "Activating Your Lecture."

Citation
Center for Educational Effectiveness [CEE]. (2018). Facilitating Laboratory Activities Series. *Just-in-Time Teaching Resources.* Retrieved from https://cee.ucdavis.edu/JITT

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PART 2: Supporting Graduate Teaching Assistants in Lab Settings

TAs for laboratory section can range in terms of their experience with teaching and/or lab facilitation. Therefore, it is important to develop coherent instructions for lab activities for TAs, and to outline clear expectations for their behavior while facilitating lab sections. Additionally, you can help your TAs develop a culture of support by encouraging collaboration between graduate instructors. Below are a few suggestions for how to support your TAs:

Strategies	Teaching Suggestions
Encourage TAs to prepare in advance for facilitating each lab activity	Encourage your TAs to familiarize themselves with the laboratory manuals, assignments, and materials in advance of facilitating a lab activity, and suggest that they create a plan beforehand. This can help ensure that the laboratory session runs smoothly, and that both the students and TAs feel comfortable with the procedures and expectations of the lab activity.
Foster collaboration between TAs from different sections and	Provide a space (such as a discussion forum or an email list) for TAs to share materials, suggestions, and problem-solving strategies with each other, especially between sections of the same class. For example, if a TA in an early section noticed students had trouble with a particular task, they could send out a group email to you and the other TAs, so that students in the next sections can be better supported in that portion of the task.
Encourage more experienced TAs to help mentor those with less experience	Work with your more experienced TAs (including those who have TAed that class before, and those who have more experience teaching in general) to help mentor new or less experienced graduate instructors. This can help limit the amount of stress and anxiety new TAs experience, and can help ensure that each lab section runs as smoothly as possible.
Remind TAs that you're available to help if needed	Make sure your TAs know that you are available to answer questions or provide support if needed.

Adapted from: Stanford Teaching Commons, "Facilitating Labs" & the "TA's Guide to Effective Teaching at UC Davis," 2017

Additional Resources
CEE provides a variety of teaching development resources on campus for graduate instructors:

- CEE Workshops for Graduate Instructors
- Teaching Assistant Consultants
- Graduate Teaching Community
- TA's Guide to Effective Teaching at UC Davis

In addition to the TA Guide, both the Stanford Teaching Commons and the Center for Research on Learning and Teaching at the University of Michigan have articles aimed at graduate instructors on facilitating a lab section that could be helpful for your TAs.

Citation
Center for Educational Effectiveness [CEE]. (2018). Facilitating Laboratory Activities Series. *Just-in-Time Teaching Resources.* Retrieved from https://cee.ucdavis.edu/JITT

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PART 3: Implementing Inquiry-Based Learning in Lab Settings

Much of the research in the last few decades on inquiry- or problem-based learning in science and engineering education has been favorable (Ciocanel & Elahinia, 2008; French & Russell, 2002; Minner, Levy, & Century, 2010). By presenting students with a realistic problem or challenge that they must solve, inquiry-based projects allow students to be more involved in their own learning process, and helps them develop a more transferrable understanding of foundational concepts and theories (Nilson, 2010). In addition to the benefits for undergraduate students, research has shown that teaching inquiry-based laboratory activities can also help graduate students internalize important concepts (French & Russell, 2002). Below are a few suggestions on how to implement inquiry-based projects in your own laboratory sections:

Strategies	Teaching Suggestions
Consider the learning outcomes of your class	Consider how an inquiry-based project might help your students achieve the learning outcomes of your course. For example, if one of the goals of your course is to introduce students with a particular scientific process, an inquiry-based project could allow students to actively experience that process through an investigative task.
Consider the level of guidance you want to provide your students	According to Lantz & Fairfield, there are four main levels for guided-inquiry in laboratory classes: **controlled**, where students are given a problem, procedure, and outcome (i.e., traditional "cookbook" labs); **structured**, where students are given a problem and procedure, but not the outcome; **guided**, where students are given a problem, but not the procedure nor the outcome; and finally, **open**, where students determine their own problem, procedure, and outcome. It is important to note that each of the levels above demands increasing amount of preparation by TAs and instructors, as well as increasing support for students completing the task.
Include opportunities for collaboration	While laboratory activities are generally well-suited for group work between students, the increased conceptual demands of inquiry-based projects make collaboration an important aspect of these types of projects. Through group work, students learn how to effectively collaborate with colleagues in both lab activities and in the resulting writing/reporting tasks. An important consideration to make is whether you want to establish permanent groups or have students vary partners throughout the term.
Have students practice "authentic" science writing, rather than just reporting	While many students are familiar with the traditional the "lab report," the structured nature of this genre can make it difficult for students to learn how to compose in more the realistic science writing genres they may experience in the future. An example of an "authentic" science writing task could be learning to write an effective "results" section for an article on empirical research. Hood-DeGrenier (2015) provides a step-by-step explanation on how to teach students to write a results section: see her article here. Additionally, consider having your students practice peer review by exchanging written projects with colleagues from other groups.

Adapted from: Lantz & Fairfield, 2016 & Nilson, 2010

Additional Resources

Here are a few additional resources, including virtual labs, inquiry-guided labs, simulations, and problem scenarios:

- PhET Interactive Simulations Project
- The ChemCollective
- Biointeractive
- Virtual Courseware for Earth and Environmental Sciences
- Johns Hopkins University Virtual Laboratory

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