A COMPARATIVE STUDY OF DIFFERENT FORMS OF ASSESSMENT IN LABORATORY SETTINGS

OVERVIEW OF THE PROBLEM: Laboratory courses are unique learning environments. Compared to lecture courses, they typically involve more resources per student in terms of expense, equipment, space, contact hours with instructors, and low student/instructor ratios. They are also learning environments that emphasize a broad range of learning goals, going beyond content learning goals to include a range of scientific practices, including written and oral communication, experimental design, data analysis, and others. Despite the abundance of resources and goals that often closely align with scientific practice, laboratory courses often produce unsatisfying or uncertain outcomes of student learning. In addition, national calls have been made for lab courses that engage students in more disciplinarily-relevant activities as a means to improve recruitment and retention of students in STEM. For decades, efforts have been made to transform laboratory environments across the sciences, with “inquiry-based” being one of the more popular approaches. However, even now, it is difficult to compare the efficacy of these innovations, and it is equally difficult for instructors to implement meaningful assessments in their laboratory courses. In spite of the need, the STEM education community has few assessment tools for laboratory teaching environments. Doing robust assessment in these environments has remained a long-standing challenge in laboratory instruction and physics education research.

In order to respond to the national calls and our local needs for laboratory transformation, the senior-level CU Advanced Optics and Modern Physics lab has been transformed through support from the Physics Department and the National Science Foundation. Much of the initial transformation of the course environment, lab equipment, lab guides, and course structure was guided by establishing detailed learning goals developed with significant input from physics faculty and from the STEM education community. Despite these significant accomplishments, one outstanding challenge has remained: rigorous assessment of students’ proficiency at meeting our learning goals. Such assessment is desired both internally, for the ongoing refinement of our laboratory courses, and externally, to provide tools and evidence for instructors at other institutions to guide changes to their own courses.

SPECIFIC CHALLENGES OF LAB ASSESSMENT: Assessment in lab courses is challenging for a variety of reasons. The learning goals of lab courses, while often spanning a wide range of disciplinary ideas and scientific practices, are often vague or undefined. In addition, historically, assessment in labs has primarily been limited to written lab reports, which represent a thoroughly digested synthesis of many hours of effort, but may not capture the kinds of minute-to-minute sense-making and decision-making processes that are needed to successfully execute the experiment. Further, because lab reports are completed after doing the experiment, students do not receive feedback at a time that could have aided them in doing the experiment. Assessment has also been difficult because course structure and pedagogy can vary widely between lab courses, including: students’ hours per experiment, the type and content of instructor/student interactions, and the kinds of prompts in the lab guide. Finally, lab courses are complicated to assess because they often involve sophisticated concepts and complex measurement tools and apparatus (e.g., magneto-optical trapping of rubidium), which makes the courses challenging for students, instructors, and education researchers.

Existing research-based assessments in laboratory courses have been limited to areas such as conceptual gains, a narrow subset of scientific practices (e.g., data analysis), attitudes and beliefs (e.g., our own
Colorado Learning Attitudes about Science Survey for Experimental Physics\textsuperscript{7}, or they are not widely applicable because the assessments are tied very closely to particular curricula.\textsuperscript{8} Very few have addressed students’ understanding of specific laboratory experiments in a way that would be helpful in addressing particular student difficulties or could guide refinement of course materials.

Because assessment is such a challenge, we want to start with the most commonly obtained forms of assessment: written lab reports, lab notebooks, and oral presentations, and ask the following research questions: Do these commonly obtained course artifacts serve as a reliable proxy for assessing students’ learning during the lab?\textsuperscript{9} To what degree can we tell if students’ really did meet our learning goals? How can the standard course artifacts be modified to more reliably measure students’ achievement of learning goals?

**Methodology and Evaluation:** Broadly, we propose to answer the primary research questions by collecting standard forms of laboratory assessment (e.g., written reports, lab notebooks, and oral presentations), and comparing those assessments with post-lab interviews about the recently completed labs.

**Step 1:** Establish experiment-specific learning goals for two commonly completed labs. We propose evaluating two widely conducted labs, a polarization of light lab and a nuclear magnetic resonance lab, in depth. For these two labs, prior to the start of the semester, we will establish detailed learning goals for understanding the physics content, understanding the experiment, and the key scientific practices.

**Step 2a:** Collect course artifacts such as written lab reports, lab notebooks, and oral presentations. A video recording of oral presentations will be done for all oral reports. Electronic copies of lab reports, presentations, and lab notebooks will also be obtained. In addition, we will collect copies of instructor feedback provided to students.

**Step 2b:** Perform post-lab interviews with students. First, we will establish an interview protocol with questions and tasks that query students’ proficiency in the learning goals determined in Step 1. The follow-up interviews will be conducted with all students within 1 to 2 days of completing the two-week lab. We expect 10 to 20 students will be interviewed for each of the two experiments. The interviews will be video recorded for later analysis.

**Step 3:** Code the course artifacts and interviews for each learning goal along two dimensions: (1) thoroughness of the assessment and (2) student proficiency. Thoroughness of the assessment reveals how extensively the particular source (e.g., lab notebook) assessed each of the learning goals, and in what forms that assessment was revealed (e.g., an explanation written in text, a diagram, etc.). Student proficiency will code for the extent to which the assessment demonstrated the students’ proficiency in meeting the learning goal. The coding will be conducted using NVivo, a standard qualitative data analysis package.

**Step 4:** Analyze coding results to answer the following questions: For the different assessment types, how thoroughly is each learning goal assessed? What are the strengths and limitations of the assessment formats? For which goals do students demonstrate the least proficiency? Do the different assessment types ever give conflicting assessments of students’ proficiency? Do the standard course artifacts (i.e., reports and lab notebooks) serve as a good proxy for the richer set of information we get in the interview? Do the assessments provide sufficient information to students and instructors to make actionable changes?
And, finally, how can the assessments be modified to more accurately measure the students’ achievement of the learning goals?

**The Development Team.** The research design, data collection, analysis, and reporting will be led by myself (Benjamin Zwickl) and supervised by Heather Lewandowski (Assoc. Professor of Physics and JILA Fellow) and Noah Finkelstein (Professor of Physics). Our team has gained experience doing lab-related physics education research over the last 2.5 years as we have transformed and taught the advanced lab. This project extends our previous attempts at assessment in laboratory environments using student attitude surveys, and short 45 minute lab practical activities where we are assessing students’ conceptual and quantitative reasoning while conducting experiments. The team will also include an undergraduate physics education researcher who will assist in coding the interviews and lab reports.

**PROJECT IMPACT:** This project is one of a handful of physics education research attempts that responds to the national need for assessment of student learning in lab courses. By comparing different forms of assessments in laboratory courses, we hope to gain insight into the limitations of each and propose new forms of assessment that target our learning goals more specifically. Improving our understanding of how to develop useful assessments in lab courses will allow us to transform courses so that students receive more actionable feedback to focus their efforts on learning goals they haven’t met. Similarly, providing faculty with actionable feedback will help improve their teaching methods and course materials. All of these impacts have relevance across all levels of laboratory instruction in the sciences. The work will also provide our research team with data about common student difficulties that can be used to further refine course materials in the Advanced Physics lab.

**TIMEFRAME AND BUDGET:** The learning goals for the polarization of light and nuclear magnetic resonance labs will be established during the Summer of 2013. We will coordinate with instructors of the Physics Advanced Lab course for Fall 2013 and Spring 2014 to conduct our research and have access to students. The data will be collected in Fall 2013 and Spring of 2014. Coding and analysis can begin after students complete the first round of laboratories and will be finished by Summer of 2014. The work will be presented at two national conferences on physics education (Summer Meeting of the American Association of Physics Teachers and the Physics Education Research Conference) and also submitted for publication in a peer-reviewed journal on physics education research.

Two months of postdoc salary are requested in the budget to support me during the Fall of 2013, the period when data collection, interviews, coding, and analysis require the most dedicated focus. The support will be integral to initiating these new directions for our lab-focused education research. The participation incentives, transcription services, and undergrad research assistant will aid in data collection and analysis.

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<th>Cost Description</th>
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<tr>
<td>Two months postdoc salary</td>
<td>$3825/month x 2 month = $7650</td>
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<tr>
<td>Study participation incentives</td>
<td>$20 per interview x 15 students/lab x 2 labs = $600</td>
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<tr>
<td>Transcription services</td>
<td>$1/min of audio * 30 interviews * 30 minutes = $900</td>
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<tr>
<td>Undergrad research assistant salary for coding interviews and artifacts</td>
<td>$12/hour * 70 hours (15+ hours of video to be coded) = $840</td>
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