Think first, act later - A course structure for improving student designed experiments

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Introduction

The lab courses at Brigham Young University seek to prepare students to complete a thesis project and to become capable experimentalists. To accomplish these goals, we have recently refocused our lab courses on teaching experimental skills and habits, such as those outlined by Carl Wieman [1] and by the AAPT Committee on Laboratories [2], which go beyond a prescribed set of technologies, concepts, and/or techniques. In particular, the structure of our final lab course is designed to prepare students to establish research goals, define criteria, and assess feasibility by providing multiple instructor and peer feedback loops.

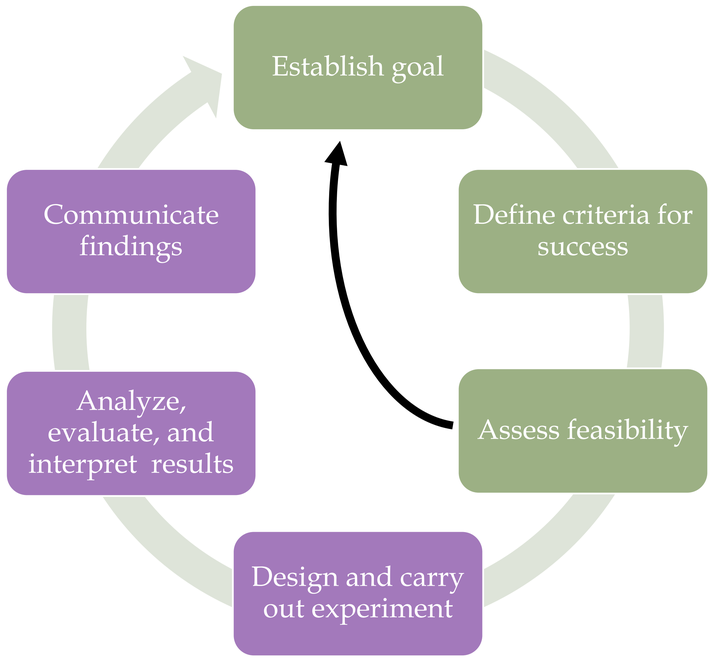

Figure 1 – Cognitive tasks involved in experimentation adapted from [1]. Students need experience developing ideas by going through feedback loops prior to conducting an experiment.

Course Structure and Rubrics

The course has three main elements: Subject-area rotations, experimental cycles, and a student-designed final project. The elements are interleaved (See Fig. 2) to allow students to learn and practice their ability to develop ideas. This also helps students manage their time and provides multiple opportunities for feedback on their final project.

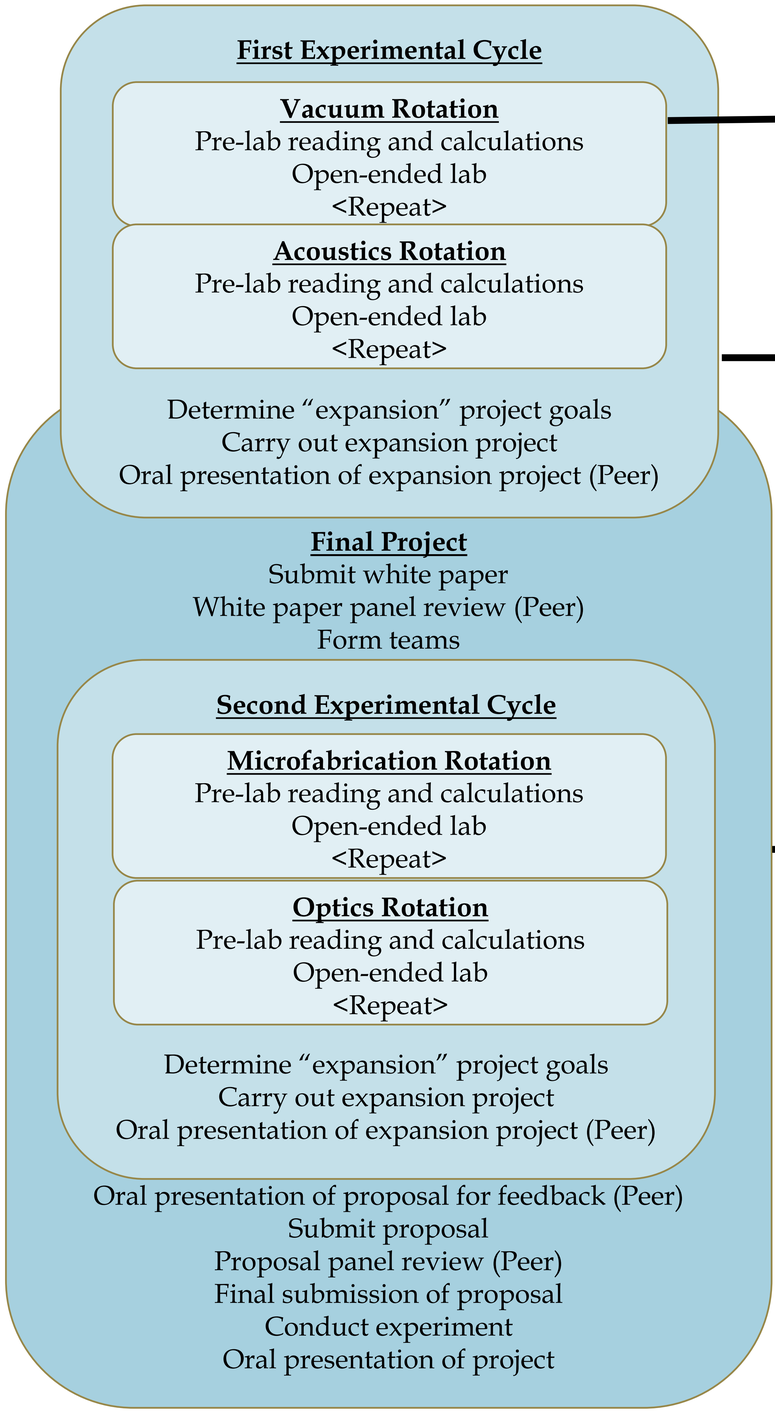

Figure 2 – Course structure helps students develop ideas.

Rotations include a series of experiments in a given subject area. Most of the projects are open-ended. Students are required to determine information they should look up and calculations they should perform before beginning the experiments.

Each e**xperimental cycle** includes two rotations. At the end of a cycle, students conduct a self-designed experiment ("expansion" project) using skills and concepts from a rotation. They deliver an ungraded oral presentation of their work. Peers, TAs, and the professor give feedback using the rubric for the final project presentation. These mini projects provide students a low-risk opportunity to practice implementing a project from conception to completion.

Final project milestones are interspersed throughout the semester. Each student submits a "white paper" describing a topic they wish to investigate. A peer review panel assesses whether the topic is interesting, relevant, and feasible. To show feasibility students must: 1) Include calculated predictions 2) Indicate availability of equipment 3) Having a clear and complete report with appropriate references included.

Half the projects are "funded" (chosen to move forward). Unfunded students join a funded student to develop a full proposal. The unfunded student takes the lead on delivering a presentation and fielding questions before submission of a proposal. The proposals are again peer reviewed. Students must address all feedback before they begin the project.

Finally, teams execute the plan and present their results. The presentation rubric includes understanding of the material, organization of the presentation, and quality of the delivery and slides.

Results

While no quantitative measure was made, there were several positive impacts of the new course structure. First, were highly motivated and displayed ownership for the final project. Second, the scope, quality, and success rate of final projects was improved from previous semesters. Third, students indicated they learned more about scientific writing in this course than they had in other courses.

In conclusion, we have developed an intermediate lab course that promotes effective experimental habits and behaviors. In the course, students get a small taste of what it takes to develop and implement scientific research projects. Both implementing student-designed projects and participating in the peer review process seem to help students improve their ability to develop and communicate their ideas.

References: [1] Carl Wieman, The Physics Teacher 53, 349-351 (2015). [2] AAPT Committee on Laboratories, AAPT Recommendations for the Undergraduate Laboratory Curriculum (AAPT, College Park, MD, 2014).