Redesign of the lab component of PHSC 111 and PHSC 112
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Principal investigators
The leaders for this proposal are the three members of the Department of Physics Instructional Laboratories staff listed below. All three PIs will be equally involved in the project.

- **Van D. Bistrow**, MS Physics, MS Physics Education; *Director of Physics Instructional Laboratories and Lecture Demonstrations.*
  Van Bistrow has 40+ years of experience working in the Physics Department Instructional Laboratories, and is intimately familiar with all aspects of the lab components of all PHYS courses, as well as PHSC 111 and PHSC 112.

- **Dr. Mark Chantell**, PhD Physics; *Physics Instructional Laboratories staff*
  Mark Chantell has been a member of the Department of Physics Instructional Laboratories staff since 1998, and has been involved with research and development of experiments and lab curriculum for Physical Sciences (PHSC) and Physics (PHYS) courses from the elementary to advanced undergraduate level, as well as at the graduate level.

- **Dr. David McCowan**, PhD Physics; *Physics Instructional Laboratories staff*
  David McCowan has been a member of the Department of Physics Instructional Laboratories staff since 2015, and has been involved with research and development of experiments and lab curriculum for Physics (PHYS) courses at the advanced undergraduate and graduate level. Dr. McCowan also served as a graduate student teaching assistant in lab and lecture courses from 2007-2014.

Proposed scope of work
We propose redesigning the laboratory component of PHSC 111 and PHSC 112 (the two Physical Science courses taught by the Department of Physics) to shift the emphasis away from a survey of elementary physics concepts (the current model) and towards an experience that teaches experiment design, critical thinking, and experimental iteration in a more structured way.

The money would be spent both on development (creation of a new curriculum and teaching approach, as well as changes to the ways we train and use teaching assistants) and on equipment (new experimental apparatus). The proposal would have both long-term impact (improvement of the laboratory experience for students taking the courses in future years) and short-term impact (engagement of both physics undergraduate and graduate students in the development process, thereby providing hands-on pedagogy experience).

The total budget requested is $54,125, with $20,000 for equipment and $34,125 for student support (2 undergraduates and 1 graduate student research assistant).
Motivation
Traditionally, the laboratory experiments in PHSC 111 and PHSC 112 have been designed to teach and reinforce physics concepts which are covered in the lecture portion of the course. This style presents several problems for the following reasons:

- In recent years, the Physics Department has opened up the content of PHSC 111 and PHSC 112 – which used to cover Classical Mechanics and Modern Physics, respectively – to be more inclusive of current and popular interest topics such as climate change, energy, and cosmology at the discretion of the instructor. With such shifting content, it is impractical to develop a new set of content-related labs each time the course is taught.
- Recent studies in physics education research have called into question the effectiveness of concept-focused labs in regards to enhancing students understanding of physics concepts covered in lecture.\(^{(1)}\)
- Other studies\(^{(2)}\) indicate that concept-focused labs are not effective in developing student understanding of the role of direct observation and experimentation in the practice of physical science. Indeed, it has been shown that concept-focused labs can even reinforce misconceptions of the nature of experimental science.\(^{(3)}\)

Conversely, the physics education research literature\(^{(1,2,4)}\) has shown that labs designed around the goal of teaching students about the nature of how experimental science is performed are effective in achieving that goal. Moreover, this goal has been endorsed by the American Association of Physics Teachers\(^{(5)}\) as an important contribution which physics labs can make in the development of a scientifically literate citizenry. This is particularly relevant in a physical science course, which are geared toward students in non-physical science majors who may not receive any other formal science training during their college careers.

Format for the new labs
Currently, the lab component of PHSC 111 and PHSC 112 is structured as follows:

- For each course, there are three laboratory experiments, typically scheduled during weeks 3, 5 and 7 of the quarter.
- Each lab is a stand-alone experiment, with a focus on a specific physics concept. Topics covered in the labs may or may not appear on homework or tests, depending on the instructor.
- Students perform the experiment over a 3-hour period, and hand in a short document at the end of the period that includes notes on procedure, data, conclusions, and answers to questions posed by the lab manual.
- Students typically spend very little time outside of lab preparing for the experiments or reflecting on the work done.

For the new laboratory component, we envision a structure along the following lines:
• For each course, students would have 3-5 in-laboratory experiments, held every-other week. On weeks between experiments, students would meet for discussion sections with TAs and with their classmates.
• Rather than independent experiments, each quarter’s labs would be connected by a theme, with the goal of each subsequent lab building in a meaningful way on the work of the previous lab.
  o Since the focus is on the process rather than specific concepts, the underlying physics covered would likely not be taught in lecture, but would be discovered and explored through work in the lab. Like the research questions that professional scientists ask, the students would not necessarily know what outcomes to expect in the labs, nor what physics topics will ultimately be relevant for understanding the results.
• Students would typically spend 3 hours in the lab for experiment sessions, and 2 hours in the lab for discussion sessions. Students would again submit short lab notes at the end of each experiment, but would also be expected to do work between sessions, including reading, writing, or preparation of discussion or oral presentation questions.
• In lab, students would be guided through the process of observing a phenomenon, developing hypotheses and models based on their observations, making predictions and testing their models with further experimentation in order to plan and execute a final experiment.
• In discussion, students would reflect on the work of the previous lab session, and formulate their own plans for the next experiment. There would also be considerable emphasis on interpreting and reporting on the results, and on how students should approach the task of experimental design and scientific inquiry. TAs would guide students through directed activities, and keep the discussions on point.

Use of students in the development
Currently, the Department of Physics does not offer any official courses in pedagogy at the undergraduate level and only one course at the graduate level (PHYS 300). In addition, no faculty are actively engaged in physics education research. Many students within the department, however, plan to go on to teach, and therefore have an interest in course development and curriculum building.

For this reason, we think that recruiting undergraduate physics majors and PhD candidate graduate students to help with the development portion of this project would provide a unique opportunity to those who want a hands-on experience. There would be opportunities for these students to learn about current physics education research, to test and prototype ideas, and to get feedback not just from the proposal leaders, but from their peers, faculty and ultimately the students in the course.
Budget and timeline
The total budget requested is $54,125, as detailed below.

Fiscal Year 2017-2018
- $6,000 -- Support for two (2) undergraduate positions (10 hours per week, $15/hr) to run 20 weeks during Winter Quarter 2017 and Spring Quarter 2018. Undergraduates will work with PIs on research and development of new experiments, with the goal of having several potential modules (2-3 lab periods and associated discussion sessions) outlined and prototyped by the end of Spring Quarter 2018.
- $9,375 -- Full support for one (1) type A research assistant (RA) during Summer Quarter 2018. The RA will assist the PIs with fleshing-out the modules into fully-developed experiences, including creating instruction material for both students and teaching assistants.
- $20,000 -- Equipment to support up to 10 lab stations.

Fiscal Year 2018-2019
- $18,750 -- Full time support for one type A research assistant for both Fall Quarter (PHYSCI 111) and Winter Quarter (PHYSCI 112). The RA will be responsible for assisting with implementing and evaluating the new lab format. In particular, the RA will be present in the lab for at least portions of all lab sections, working with both the students and regularly assigned TAs. This function cannot be performed solely by staff due to the requirements of running the rest of the Physics Department Instructional Laboratories program.

Assessment
To assess how well the proposed changes to the lab structure impact student learning, we will use the Colorado Learning Attitudes about Science Survey for Experimental Physics (E-CLASS). The E-CLASS is a survey-based tool designed to assess students pre- and post-course perceptions of how experimental physics is performed. E-CLASS will be used to evaluate both lab courses beginning in the 2017-2018 academic year, and will be used into the future whether or not further changes to the courses.

A summary of the progress of the project will be made available to PSCD/PSD and the Provost's offices at the end of Summer 2018 (after development, but before implementation), and again at the end of Spring Quarter 2019 (after the first year of implementation). An additional report will be prepared at the end of Spring 2020 to assess the long-term impacts one year after the completion of the program.
References


