Evaluation of the Effectiveness and Success of Inquiry-Based Laboratories In IPHY

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Introduction

The purpose of this proposal is to request support to evaluate the effectiveness and success of the revised physiology laboratories in Integrative Physiology (IPHY). Under the direction of a formal Physiology Lab Revision Committee, the physiology laboratories in IPHY have been transformed from an expository ("cookbook") style of instruction to a more inquiry-based approach. These laboratories serve about 500 majors and non-majors each year, and employ a combination of human and animal experimentation to explore basic physiological principles.

Specifically, we are requesting support for Eric Homestead to help conduct student interviews, and to analyze pre-post assessment and student attitude data on the revised physiology laboratories. Eric is currently the lead graduate teacher in IPHY and has been a teaching assistant for the physiology laboratories for several semesters.

Project proposal

The physiology laboratories in IPHY are currently of the expository (or "cookbook") style of instruction in which the instructor defines the topic to be investigated and directs the actions of the students. Students carefully follow the step-by-step procedures outlined in a lab manual to replicate/generate the predicted outcomes. Although very popular among faculty and easy to administer, this type of laboratory instruction is typically viewed by students as uninteresting, boring, and tedious (Ledbetter 1993; Lord & Orkwiszewski 2006; Wilke 2003; Yang 2010).

Besides the negative student attitudes toward these laboratories, a number of criticisms of the expository style of instruction have led the IPHY department to consider revision of its physiology laboratories. The expository style promotes passive learning, as students need only follow directions and verify already-known outcomes (Kolkhorst et al. 2001). In order to write the mandated/prescribed laboratory report, students focus simply on obtaining the expected results (Stewart 1988), and fail to connect physiological concepts from lecture with the laboratory activities (Casotti et al. 2008). Moreover, these labs do not emphasize the scientific approach to problem solving, nor promote an appreciation or understanding of the scientific method. This can lead students to a mistaken impression of the nature of science and research (for example, science is about confirming already known outcomes), and does not prepare students to formulate hypotheses, interpret data, or evaluate the validity of an experiment or its conclusions - important skills that are components of higher orders of thinking and learning (Bloom et al. 1956; Anderson & Krathwohl 2001; National Research Council 2000).

In order to move beyond the "cookbook" style of instruction and improve student attitudes, a formal Physiology Lab Revision Committee was developed, and in Spring 2011 began to revise the physiology laboratories. This committee included Heidi Bustamante (instructor, chair of the committee), Janet Casagrand (instructor), Robert Hermanson (lab coordinator), Francoise Bentley (IPHY science teaching fellow), and Teresa Foley (IPHY science teaching fellow, instructor). A primary purpose of the Physiology Lab Revision Committee was to establish learning goals for the course and to develop a more inquiry-based approach to the laboratories.

Compared to the expository style of instruction, inquiry-based methods provide little direction to the students and require students to develop their own hypothesis and procedures (Leonard, 1989). These types of lab activities more closely model how scientists actually engage in research (Hofstein and Lunetta, 1982), and helps students develop independent, critical and analytical thinking, and scientific reasoning

abilities (Kolkhorst *et al.* 2001; Gerber et al. 2001;Marek & Cavallo 1997; Lawson 1995; Adey & Shayer 1990). A number of studies have shown this style of lab to improve student learning and enhance understanding of lecture concepts and the scientific method (for example, Jensen & Lawson 2001; Rissing and Cogan 2009; Casotti *et al.* 2008; Luckie *et al.* 2004; Myers & Burgess 2003), and overall attitudes and motivation toward learning and science (for example, Henige 2011; Berg *et al.* 2003; Gibson & Chase 2002; Kolkhorst *et al.* 2001).

In Spring 2011, the Physiology Lab Revision Committee developed learning goals and revised the existing physiology laboratories towards an inquiry-based approach. As the inquiry-based style of laboratory can be very cognitively challenging for students, the laboratories were designed to start out with a more guided approach to help students develop the necessary skills (formulate hypotheses; design experiments with appropriate controls; and collect, analyze, and interpret data), and then become progressively less guided and more student-directed.

The learning goals for the revised laboratories are that students should be able to:

1. Given different types/sets of background information (i.e., data, scenarios, etc.), be able to properly formulate a hypothesis and a research question.
2. Given a scenario, analyze which experimental design would best answer the question, and/or design an experiment that would best answer the question. Be able to identify proper controls and possible limitations.
3. Predict what data you would see if your hypothesis is correct, and/or analyze whether the given data support or refute the hypothesis.
4. Given a data set and/or scenario, evaluate whether a conclusion is valid.

The revised physiology laboratories are currently being reviewed by IPHY faculty experts and will be incorporated to the curriculum in Fall 2011. To ensure successful implementation of the new format, two members of the Physiology Lab Revision Committee, Drs. Janet Casagrand and Teresa Foley, will teach several sections of the course. In addition, Drs. Casagrand and Foley will be directly involved in training and mentoring the teaching assistants of the remaining sections to help them understand how to successfully guide students in a student-directed lab environment.

A key to the successful implementation of inquiry-based laboratories is to design experiments that are demanding for students, but within their capabilities (for example, see Kolkhorst *et al.* 2001). To assess how the students are responding to the revised laboratories, we require additional assistance from Eric Homestead who will perform ~400 student interviews, and will help analyze pre-post assessment and CLASS-BIO data (see below). Eric will be trained and supervised by members of the Physiology Lab Revision Committee.

Benefits

The outcomes of this project will have a number of useful benefits for us, Eric Homestead, IPHY faculty, IPHY students, and the CU-STEM community.

(1) Heidi Bustamante, Janet Casagrand, and Teresa Foley are full-time instructors in the IPHY department, with no contractual research component. This project allows us to further our professional development by learning and implementing a new style of instruction. Furthermore, once we obtain data on student learning and attitudes towards the revised laboratories, we plan to present our findings at science education conferences (such as the Human Anatomy & Physiology Society (HAPS) and Applied Physiology Society (APS) meetings). These meetings will be an excellent opportunity for us to network and dialog with instructors from other institutions interested in science education.

(2) This project will also further the professional development of Eric Homestead, who has a growing interest in science education research. Eric has taken several graduate-level classes on science education at CU and is actively involved in the Graduate Teaching Program. This project will give Eric more "hands-on" experience with designing, implementing, and disseminating science education research.

(3) The addition of a new style of laboratory instruction will be useful for IPHY faculty for several reasons. Not only will this new style of instruction better prepare IPHY students for the upper division core courses, but also for undergraduate research in the laboratories of our faculty. We anticipate that the revised laboratory format may result in more IPHY students becoming interested in research, which could lead to more and better trained students entering the graduate program. Furthermore, the data collected from the study will be useful in further establishing the efficacy of active learning approaches to the faculty.

(4) This lab redesign will also better serve our IPHY students by helping them develop their critical thinking and problem solving skills. These skills will better prepare them for their future careers, and will promote their appreciation and understanding of the scientific method and interest in science (something which is often negatively impacted by expository style laboratories).

(5) What we learn about implementing a transition to inquiry-based laboratories may also be of interest to others in the CU-STEM community who wish to redesign existing expository laboratories. Such a transition can be challenging, and what we learn from our students' experiences may be useful to others and help provide support for making such changes. To reach the CU-STEM community we plan to present our findings at the annual Symposium on STEM Education and the weekly DBER Seminar Series.

Timeline

Spring 2011: Physiology Lab Revision Committee established learning goals and formal drafts of the 10 revised laboratories.
Summer 2011 (current): IPHY faculty experts are currently reviewing the revised laboratories. Assessment tools are being developed (see below) and will be administered to IPHY students enrolled in the laboratory course being offered for the last time in its current expository form.
Fall 2011: Implementation of revised laboratories. Administration of assessment tools. First round of student interviews by Eric Homestead (doctoral student). Revision of laboratories by the committee (if necessary). TA training.
Spring 2011: Implementation of revised laboratories. Administration of assessment tools. Second round of student interviews by Eric Homestead. Revision of laboratories by the committee (if necessary). This cycle will continue until we are satisfied with the outcomes of the student interviews and assessments.

Evaluation of progress

Evaluation of the effectiveness and success of the revised physiology laboratories will be accomplished using three different methods:

(1) To evaluate whether student attitudes towards biology have shifted with the revised laboratories, we will administer the Colorado Learning Attitudes about Science Survey for Biology (CLASS-Bio; http://www.colorado.edu/sei/class/CLASS-Bio.html). The CLASS-Bio is composed of 31 Likert-scale statements that probe various perceptions about biology including enjoyment of the discipline, real world connections, and problem-solving strategies.

(2) To assess potential learning gains in scientific reasoning or critical thinking skills in the goals outlined above, we will administer a revised version of Anton Lawson's classroom test of formal reasoning. Lawson's test "provides a solid starting point for assessing scientific reasoning skills" (Lawson 1978,

2000) and examines the ability of students to analyze a situation, make a prediction, or solve a problem. Both the CLASS-Bio and the revised Lawson's test will be given to IPHY students before (Summer 2011) and after (Fall 2011, Spring 2012) the lab transformation.

(3) To determine student reactions to the new format of instruction, student interviews will be conducted at the beginning and end of the Fall 2011 and Spring 2012 semesters. These interviews will help us determine whether the guided transition to inquiry-based laboratories occurs at a reasonable pace for students, or whether further revisions are needed to help students successfully make the transition.

Budget

25% Teaching Assistant appointment for Eric Homestead (Fall 2011-Spring 2012) $8000

- To perform student interviews and analyze assessment data; training
- 150 hours per semester; 300 hours total

Student interviews ($10/hour for 30 minute interviews) $2000

- Fall 2011: 100 students at 30 minute interviews = 50 hours
- Spring 2012: 300 students at 30 minute interviews = 150 hours
- Total = 200 hours x $10/hour = $2000

Current and pending funding

We do not have any current or pending funding towards this project.

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