An Investigative Laboratory for Integrated Plant and Animal Physiology at the Sophomore-level

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ABSTRACT

Physiological Dynamics in Animals and Plants (http://www.willamette.edu/cla/biology/ biol244/) is an integrated, sophomore-level course required of all biology majors at Willamette University. Early course lectures emphasize differences in macro-physiological mechanisms used by plants and animals for internal transport and gas exchange, energy transduction, and nutrient and food processing. Subsequent lectures emphasize commonalities in cellular physiological mechanisms such as regulation of membrane electric potential and signal transduction. The laboratory for the course begins with six weeks of standard exercises that introduce students to basic techniques of plant and animal physiology. Over the final eight weeks, teams of students carry out research investigations of their own design. Each team must develop a testable hypothesis; design experiments to test the hypothesis; collect and analyze data; present the results of the project in a symposium at the end of the course; and write a paper summarizing the study. The assessment plan for the laboratory includes pre- and post-course student self-assessment, student assessment of lab team members, and assessment of students by professors. Desired student learning outcomes are development of an ability to acquire data with a computer; overcome technical problems in the lab; correct flawed experimental designs; solve scientific problems; recognize and analyze patterns among data; critically evaluate experiments; draw reasoned conclusions from data; interpret physiological studies; and draw appropriate parallels between plant and animal physiology. By May, 2007,nearly 150 students will have completed the assessment program; preliminary results of the assessment will be presented. The use of course equipment in various K-12 outreach programs will also be discussed. The laboratory is funded by grant 0309545 from the Course, Curriculum and Laboratory Improvement Program of the National Science Foundation.

BACKGROUND

Physiological Dynamics in Animals and Plants (PDAP) is a sophomore-level introductory core biology course at Willamette University, required of all biology majors. Lectures are used to transmit the basic content of animal and plant physiology. The PDAP laboratory is the first in a three-year sequence of graded experiences aimed at developing students' scientific process skills. It is also designed to introduce majors to a set of data acquisition and communication technologies that they will use over the rest of their undergraduate years. The educational goals of the laboratory program to be described are to:

1) expose students majoring in biology *early* in their college careers to the investigative, inquiry-based, self-directed learning that characterizes scientific research; 2) provide students with practice in formulating testable hypotheses that are grounded in their own experiences and observations; 3) increase students' ability to solve problems with experimental design and/or with technical aspects of experimental protocols; 4) enhance students' capacity to recognize and analyze patterns among data collected in the laboratory; 5) develop students' capacity to critically evaluate experiments, recognize limitations inherent in experimental designs and methods, and draw reasoned conclusions from experimental results; 6) familiarize students with computerized methods of data acquisition and web-based methods for dissemination, peer-review, and publication of experimental results.

Two major educational outcomes were expected.

1) It is expected that students' ability to interpret physiological studies and appreciate parallels between animal and plant physiology will be increased;
2) It is expected that the laboratory program and equipment, and its availability for use in other courses, will increase student interest in and enthusiasm for physiology.

LABORATORY ACTIVITIES

Students are organized into two sections, and they alternate labs on a weekly basis.

WEEK	ACTIVITY	EDUCATIONAL OBJECTIVE
Weeks 1 & 2:	Plant Movement and Yeast Respiration	Hypothesis Formulation; Experimental Design;
Weeks 3 & 4:	Electromyography and Photosynthesis – light reactions	Computer-aided Data Acquisition; Computation; Graphical Analysis.
Weeks 5 & 6:	Cardiac Cycling and Photosynthesis – dark reactions	Team-developed Research Proposal.
Week 7:	Draft Research Proposal	Data collection, reduction, and analysis.
Weeks 8 – 14:	Investigative, independent research	Oral Presentation by the Team; Scientific Paper
Week 15:	Symposium, oral presentations.	

STUDENT LEARNING OBJECTIVES (SLO)

We evaluate students on the degree to which they have mastered the following skills:

	Evaluation area	Level 1	Level 2	Level 3	Level 4
SLO 1	Overcome technical problems	Does not recognize the need to question the accuracy of the instruments; makes no attempt to solve instrumentation problems or attempts are random and unsuccessful.	Tries multiple solutions, asks clear questions related to the technical problem, and is able to partially resolve the technical issues.	Resolves the technical problems through use of the technical manual or instructors, collaboration with others, or systematic experimentation.	Resolves the technical problems without assistance. Works well with others to assist them with their technical problems.
SLO1	Correct flawed experimental designs	No systematic effort made to correct limitations in experimental design.	Makes effort to eliminate design flaws, but is only partially successful.	Achieves an improved design by reading the literature and honoring suggestions of peers and faculty.	Works independently to improve experimental design and anticipates potential limitations.
SLO1	Solve scientific problems	Not able to devise a plan to address a problem or lacks the necessary background or critical thinking skills.	Able to answer basic questions about a problem, but lacks a deep understanding of the topic; not able to devise concrete investigative strategy to address the problem.	Understands and articulates the problem; can devise at least one complete solution to the problem.	Understands and articulates a question that addresses the problem; can speculate as to outcome of the problem; can select from a multitude of solutions and has an appreciation for the implications of each solution.
SLO2	Recognize & analyze patterns among data.	Failure to understand statistical analyses and their outcomes; inability to identify patterns.	Partially succeeds at making connections, but fails to develop an integrated view between the theory and the results.	Recognizes patterns in the data and can successfully derive conclusions regarding the outcomes of an experiment.	Understands the processes of data collection and analysis; clearly identifies all possible interpretations; proposes ways to improve the quality of the experiment.
SLO3	Critically evaluate experiments.	Does not connect classroom content or literature; has no understanding of the fundamental components of the experimental process and the dissemination of results.	Understands the basic argument, but lacks the ability to relate it to material presented in class.	Clearly incorporates class material and independent readings to an understanding of material in the literature; identifies good and flawed arguments.	Has masterful command of the topic, easily incorporates previous research into problem solving, and provides several alternatives.
SLO3	Recognize limitations in experimental designs & methods.	Accepts all published literature as truth, and does not question accuracy of measurement or suitability of instrument.	Understands the major problems associated with a study, but has no concrete plan to address them.	Able to identify strengths and weaknesses in a study design and use of data collection equipment; can propose alternative tests to answer the question.	Understands the inherent limitations in every study and their implications with regard to the reported outcome of the study; expresses opinions about the ideal experimental approach to the problem.
SLO3	Draw reasoned conclusions.	Does not account for confounding variables or failure to incorporate appropriate controls.	Recognizes the variables in the experiment, but does little to minimize their impact.	Constructs an experimental design to address many of the major variables that impact the outcome.	Thoroughly understands the nature of variability and constructs a design to address those variations.
SLO4	Computerized data acquisition skills.	Cannot follow instructions or understand the basic concepts and functions of the transducer, amplifier, and recorder.	Has the ability to follow instructions and collect data without knowledge of how the instruments work; cannot troubleshoot, and cannot create custom settings unless assisted by the instructor.	Has the ability to understand how digital data collection equipment work; can create custom settings for specific measurements; is capable of calibrating the instruments and extracting and interpreting the data.	Can interface several equipment for multiple measurements, understands advantages and disadvantages of each instrument, and can assist others at the use of data collection systems.
SLO4	Web-based dissemination skills.	Able to understand the functions of the internet, not capable of generating material for use on the web.	Can use the internet to access the course web page and download significant material; can use the internet for academic searches; able to only generate a simple web page using the appropriate option in a word processing software.	Capable of creating a laboratory report in a web page format, using acceptable standards of scientific writing and actual data and images from the experiments.	Able to create attractive web pages displaying the steps of the experiment, the equipment and the techniques used and the final conclusions; can create links to other significant online resources; can generate visual and audio enhancements; can upload documents in a format easy to be used by others (PDF documents, online PowerPoint presentations, etc.).
SLO5	Interpret physiological studies.	Draws conclusions not logically linked to data set.	Makes little effort to provide interpretation and virtually ignores the anomalies in the data.	Provides an adequate interpretation of the data in the context what is know or not know about the area of inquiry.	Arrives at conclusions that do not overstate or understate the limitations in the data.
SLO5	Draw parallels between animal & plant physiology.	Failure to understand that DNA is conserved and hence expressed in the connections between animals and plants.	Limited ability to demonstrate how animals and plants are similar at the physiological level of organization.	Adequate understanding of the commonalities and differences in animal and plant physiology.	Recognize the extent to which animals and plants share physiological characteristics and how differences are peculiar to their separate adaptations for survival.

ASSESSMENT PROTOCOL

We developed a comprehensive assessment plan, outlined below:
Week 1 – Student pre-term self evaluation.
Week 14 – Student end-of-term self evaluation; Student evaluation of team members; Faculty evaluation of each student.
Week 15 – Student evaluation of Biopac equipment.

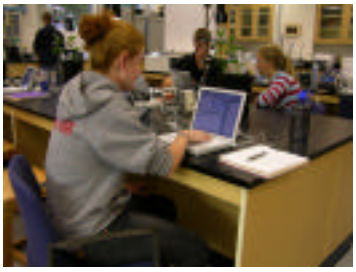
For all details please visit our website at ***http://www.willamette.edu/cla/biology/biol244/nsfcclib.htm***

OUTCOMES

We are in the process of compiling all the assessment information for dissemination. Interim NSF reports can be downloaded from the course website.

BROADER IMPACT AND OUTREACH

In addition to serving over 150 PDAP students to date, the equipment has greatly facilitated the teaching of a number of additional courses, such as Human Physiology, Fundamentals, of Neuroscience, and a multitude of independent student projects. We have also established a series of successful avenues to make our equipment available to promote NSF-targeted activities, such as diversity (D), K-12 education (K12), and Teacher Preparation (TP). We have established strong partnerships with the Willamette Academy (D, K12), Willamette Saturday Explorations Program (D, K12), and the Community Outreach Program (K12, TP). In addition, we have facilitated countless visits from local middle- and high schools. Our outreach efforts have served over 650 students from the local and extended areas.



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