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Back to basics: The plant research CURE

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Abstract

This low budget Course-based Undergraduate Research Experiences (CURE) Course gives students the tools and opportunity to design, perform and present their own research experiment on factors affecting the physiology or phenology of beans, Phaseolus vulgaris L. over one semester of three-hour weekly labs. The course is Plant Biology, an elective class after two semesters of Majors Biology. Students discuss environmental factors that may affect the growth, seed production or photosynthesis such as temperature, light intensity, soil nutrition, heavy metal contamination, salinity etc. Then, the class divides into groups of 3-4 according to topic of interest, gets instructed on how to perform a literature search, and is reminded of what is needed for a research experiment. The whole class uses the same control plants, followed in turns by all groups. All that is needed except for the photosynthetic equipment is cheap: soil, pots, beans, rulers, and regular lab scales. Measuring photosynthesis is not strictly necessary. In all treatments height, number of leaves, color of the last fully expanded leaf, photosynthesis, fresh and dry masses, and pigment content are measured. The number of stomata may also be measured. Results are collected in pre-designed spreadsheets and uploaded during lab to the class Discussion board on Blackboard and become available to all. Students are lightly guided through collaborative data analysis. The semester ends with group research posters. Peer feedback is used to edit and later present at the College student research symposium and other venues. During this workshop participants will go through measurements with the tools and the spreadsheets students use. The most challenging part of this project is the balance between guidance and encouragement of independence.

Keywords: CURE, Plant research, environmental stress, STEM retention

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INTRODUCTION

Having an opportunity to do mentored hands-on undergraduate research is known to have real benefits on the retention, independence, and motivation to stick with science in students, especially for minorities in science and first-generation students both science majors (O'Donnell *et al.* 2015; Meyer *et al.* 2023) and non-majors (Feinstein et al. 3013). For both majors and non-majors, involvement in research may be a great tool to improve pro-science views and possibly even entice some non-majors to switch to a science field (Osborne *et al.* 2003). There are many obstacles to providing this opportunity to students, particularly early in their undergraduate career where it may have the most benefit to satisfaction and thus retention. Research experience later in students' academic careers although certainly beneficial, is undertaken only by students that already have self-selected, while increased engagement early (Bowman & Holmes 2018) may increase retention particularly in minority and first-generation students that will have an opportunity to see themselves as scientists (Russell *et al.* 2007) and be motivated to stay in science. Limitations such as mentor availability (most faculty gain nothing from mentoring undergraduate research and have limited time), cost, infrastructure, how to make it "count" for credit in pre-established programs, student time availability out of class etc. The Course-based Undergraduate Research (CURE) can solve some of these issues as they are inserted in existing credit bearing classes that students need to complete to graduate. This CURE doubles as an opportunity for students to do original research, and to view the role of plants in society. In an urban setting despite hearing about the dangers of climate change to our environment, many students have never grown plants and observed them throughout their whole life cycle, so this is a concrete way for them to investigate first-hand possible effects of climate change stressors and/or man-made conditions on food production.

Back to the basics Plant Research CURE

This Back to the Basics Plant Research CURE offers a low budget, customizable tested plan that will have students do original research in a small space, using common controls and (almost) exclusively during class lab time, labs meet for three hours weekly in a fifteen-week semester. Students will be introduced to environmental issues facing common crops they find on their table, they will be trained on the whole process of scientific research, from observation to result presentation as a poster to the class, college community and often external student conferences. In this case the plant of choice is the humble bean *Phaseolus vulgaris* L. We have run this lab with 12 to 18 students, but more students can be accommodated. Students divide in groups, choose an environmental factor to test, such light availability, salt tolerance, temperature, nutrition, (safe to humans) toxins and then proceed to do guided literature research on the topic collaboratively in lab before planning their experiment. Students start germination tests early on after choosing their topic, while working on an introduction draft and planning their experiment. Parameters to be measured are the same for all groups and there is a common control that groups take turns measuring, this saves space, time, and resources. All data is collected in excel file templates (ready to fill) that are shared before students leave lab. Since this is a commuter school and our students have jobs and other obligations, very little is expected from students out of the lab session other than signing up to water and check on plants as their class schedule allows.

This lab allows students to learn hands-on all aspects of experimental design, including literature research, evaluating problems worth studying, creating hypotheses, designing a controlled experiment, analyzing data, working with peers, and presenting research posters. The possibility of engaging with other junior researchers and being recognized for their research was a great motivator to keep working and have more confidence moving to a four-year school.

STUDENT OUTLINE

Objectives

Learn to do scientific research

Evaluate effects of environmental factors on plant growth and development

Make a research poster

Introduction

Plants face a variety of challenges that you may not think of when you look at the beans on your plate. What are a few that you can think of? Think about the challenges of climate change you see on the news for a start, and think how they may impact plants, specifically the plants we depend on for food. During this one semester lab you will choose and test an environmental factor that interests you and that can be controlled in the classroom environment, grow your plants from seed to fruit (unless your applied stress limits that) while comparing your plants with controls grown for the whole class without the tested factor. You and your peers will take turns measuring and maintaining the essential control plants. Before you start you will learn how to do literature research (find out what is known already), how to read a scientific article, learn (or re-learn) lab techniques, and then collect and treat data collaboratively and discuss the meaning of your results. You will participate in peer editing, help others improve their work and they will help you. At the end of the semester, you and your group will be asked to orally present your results as a virtual projected poster to the other members of your class and optionally later to the whole college community on Student Research Day and other student conferences.

In this class you will be a scientist doing original research.

Methods and Data Collection

Part A: Choose your topic

The first part of this project involves selecting a topic that aims to test the impact of an environment plant stressor on beans.

Examples: Salinity, drought, waterlog, nutrient excess or deficiency, light intensity, temperature, herbivory (simulated or real)…

A list will be created from class participation. You will assemble in groups of three or four student according to topic and personal preference.

Part B: Literature research

Librarians will guide you through the library data bases and show the basics of literature research.

You will start your literature research and be given advice on how to select papers and get information from them. Read through Key words, then the abstract, and if relevant read the paper. Collect information for an introduction and, based on what was learned from the literature, draft a proposed treatment.

Part C: Seed Germination

You will germinate bean seeds on paper towels or soil trays exposed to your treatment or water. We will determine rates of germination next lab but start by germinating more seeds with water than you think you will need to assure enough plants to experiment on. Finally, you will present your background information from your literature research and your proposed treatment to the class for feedback.

Part D: Finalize your treatment plan and start preparing 10 4’’ pots of your treatment and 10 controls (for the whole class) in separate trays. Plant germinated seeds and apply your treatment. Discuss and agree on all parameters to measure as a class in the following weeks. For example, you might choose total length, leaf number, leaf color (use chart to attribute number to color), length and width of second leaf, leaf area or stomatal density. Photosynthesis or other physiological parameters may be measured during or at the end of the experiment. Number of flowers and seed pods would be counted during the later weeks of the experiment. Enter all the data on the provided spreadsheet and share with the class on LMS or Google docs each week. Start organizing your data, and graphing and discussing data as it becomes available when there is time available after measurements.

Part E: Harvest

After 4-5 weeks your plants may be ready to harvest, this is the time to make destructive measurements such as fresh mass and dry mass of each plant component separated, chlorophyll content and any other parameters that you decided to study. Stomatal count with varnish peels can be taken for later counting.

Part F: Data analysis and poster preparation and presentation

You will analyze the data in lab with instructor guidance and in collaboration with your peers. You will be given a template to prepare your poster and after the first draft will share with other groups for peer review. Your feedback to your peers will be graded. The discussion of your work should be drafted after the data is analyzed, results are compared to hypothesis and meaning can be extracted out of data. The discussion on your poster should be as clear and concise as possible. Remember that not all conclusions are final, they may encourage further questions. A discussion that raises more questions is a good discussion.

Present your poster to the rest of the class. You will have a rubric to grade your peers' posters. If space allows invite guests to your poster presentation.

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MATERIALS

Pots, soil, indoor area with lights or by window or sun exposure outdoors. Trays, scales, string, measuring sticks or measuring tape, ruler, calipers (optional), nail polish, clear tape, slides, green color gradient cards. Optional: photosynthesis equipment and spectrophotometer. Cell phones for photos and possible apps for measuring leaf area and leaf color.
Computers in lab (in my lab laptops were booked from the media center and brought in), projector.

NOTES FOR THE INSTRUCTOR

The hardest part of this lab is to balance independence versus guidance, give freedom (within reason) of topic choice, give some choice of what to measure, group choice and poster design, give guidance on how to read a paper, set spreadsheet for data, data share in class and peer review with rubric. Giving topic choice is essential so students have ownership, but so is having affordable, easy to apply and safe-for-student treatments. Asking for possible environmental stresses and listing them on the board as they are suggested works. Going through those you have the means to administer and why should still leave some topics to choose from. Add to the student suggested list if needed.

Literature search training by library staff is very useful if available, but be sure to limit their time and be specific about what you want. Guidance on how to look at a paper will likely be needed, including looking at keywords, reading an abstract, how to read figures, discussions and introductions. Students may also need instruction on how to take notes on papers.

Getting student work done out of lab time may be hard at commuter colleges, so it is best to plan to have it all or mostly done in lab. Make sure students log and share all the data collected in prepared to fill spreadsheets and do most of the search and data treatment in lab where they have support. Encourage students to help each other, that will create community. Graded peer review with a simple rubric increases quality of participation. Short lab tutorials on “how to” make graphs, make calculations etc. are recommended, as is going around lab seeking those who could use help or encouragement. Give deadlines, and adjust them as needed, make clear that in real life research may not go as planned and that we learn from that too. Having enough groups to distribute students should one group accidentally kill their plants early is a good plan. Students may then join another ongoing group with their research. Controls are measured by all groups in turns. Check that the controls were measured early on and define what group/groups are doing them each time. Or have the first group to finish their measurements start with the controls.

Keep the class posters virtual, have them projected as a PowerPoint slide, this will reduce costs, extent time for corrections, and allow for correction based on presentation feedback for those who will present the poster elsewhere.

This class went through various iterations with balancing independence and guidance. Freedom of topic choice with guidance on procedure and data treatment as needed, worked well, particularly the student cooperation part. A final paper previously required turned out to be too demanding, leading to frustration and subpar work, a poster was just right and proved adequate in building confidence. Poster templates did help, as did guided and graded peer review.

This CURE was tested on Community College Science Majors, but it is equally feasible for non-majors, the plant choice and level of complexity can be easily geared to the student population.
This semester of research will not always be easy, and providing help before frustration sets in is sometimes a hard to calibrate art, but it will be worth it when students have posters to take to a student conference and when some are motivated to stay in science or to value science and reasoning if non-majors.

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About the Authors

Catarina Mata is an Associate Professor at the Borough of Manhattan Community College, City University of New York where she has taught since 2007, she teaches Majors and Non-Majors Biology, Plant Biology and Microbiology. She does plant research with students, and is the Secretary of the College Council, a College governance body.

APPENDIX A
Data collection tables

Date
: Week:

Treatment:

Plant n	Height cm	shoot mm	2nd l length cm	2nd leaf with cm	leaf #	flower/pod #	leaf color #	Comments

Harvest Date:

Treatment:				
Plant n	leaf DWg	shoot DWg	pod DWg	Comments

Rubric introduction review
Reviewer: Reviewed:
Is the text sufficiently informative Y N
Are there citations to back-up claims? Y N
Are the citations inserted in the text? Y N
Is the text clear and well written? Y N
Please make three suggestions for improvement:

1. ____________________________________
2. ____________________________________
3. ____________________________________

Poster rubric from American Society of Cell biology was used.

Example of green scale for leaves.

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