IBI* SERIES WINNER

Personal Plants: Making Botany Meaningful by Experimentation

Personal Plants, an IBI Prize–winning module, offers students connections to taxonomy and systematics, plant chemistry, water relations, and pollination biology.

Laura A. Hyatt

The use of scientific inquiry in studying plant growth is perhaps as old as agriculture itself. Our ability to feed our current population is the result of the historical application of the scientific method to basic questions about the response of plants to their environment. However, most of today's students have likely never pondered basic questions about plant growth and may not even know general rules of thumb about growing their own food.

The importance of understanding plant life is increasing. Plants play critical roles in maintaining the carbon balance in the atmosphere, and they form the base of food pyramids throughout the world (*1*, *2*). Food, water, and energy shortages can also be linked to plants (or a lack thereof). Low botanical diversity in diets is a major contributor to the decreasing quality of human nutrition, linked to the proliferation of a multitude of health problems (*3*). It is essential that students learn to perceive plants as partners in the continued functioning of a healthy planet and society.

The Personal Plant Project at Rider University addresses these needs using an inquiry-based approach that guides students to an understanding of the rationale behind a variety of basic principles of plant culture while simultaneously teaching them about the scientific method through application. This semester-long curriculum provides multiple avenues to meet a variety of introductory college science objectives and has dramatically increased student understanding of the scientific method, botany, and plant science at our institution (see the first photo).

In the second week of the 13-week semester of The Personal Plant Project, groups of four students are provided with a different general observation and question connected to plants (see the table). Attached to these questions is a bit of background and a short collection of relevant citations to primary literature (see supplementary materials, part 1). The groups are asked to design an experiment to investigate these questions, meeting criteria discussed in class, including independent and dependent variables, controls, and replication (avoiding pseudoreplication). Together, the students compose a proposal. In the third week, with the advisement and approval of the instructor, students devise protocols and implement the experiment, planting seeds and applying initial treatments in our greenhouses. Subsequently, students are expected to collaboratively maintain their group's plants, apply further treatments, and take measurements as laid out in the initial research plan. Infrequently, students' plants fail to grow, but this multisection course ensures that there are multiple approaches to the same question within the class and that students can use one another's data.

Harvesting chives.

Because the outcomes of these experiments take 8+ weeks to manifest, interim assignments throughout the semester are designed to keep the students engaged with their central question and to connect their project to lecture material (see supplementary materials, part 2). These assignments are designed to provide students with information they will eventually incorporate into their final paper. Other shorter inquiry-based and observational labs are conducted to address other plant science topics throughout the term and to supplement the lecture, ranging from designing experiments to explain variation in transpiration rates to manipulating photosynthetic rates in *Elodea*. They also gain experience in writing and rewriting drafts of sections of a scientific paper, based on their experiments and modeled on published literature. By the end of the term, students have amassed a substantial amount of data. They use these data to evaluate the answer to their

Collaboration. Students work together to answer questions about plant growth and productivity.

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Sample prompts for Personal Plant investigations

Gardeners are often told not to plant carrots and dill next to each other. Why?

Should I invest in bone meal for fertilizing plants at my organic cucumber farm?

My seed packet recommends sowing basil seeds at least 4 to 6 inches apart, but I can get more plants into the garden by planting them closer. Should I ignore the directions?

Farmers often rotate legume and grain plants on the same farmland in successive years. Why?

Is it worth paying extra for potting soil with mycorrhizal fungal spores in it?

initial prompt, which they share with the rest of the class through informal presentations and write a complete scientific paper. This exercise is embedded in a required course in our introductory sequence. The first semester focuses on animals, this term focuses on plants, and the third term on microbes and cells. Students often come to the class with several deep prejudices about plants. They are of the opinion that plants are barely alive, that they are dull and uninteresting, and that they are really not all that important (*4*, *5*). However, the engagement this personal plant project offers substantially changes student attitudes. Students develop personal connections with their plants as they watch them grow from seed to flowering adult—some even get upset when they realize that at least some of their plants must die to allow measurements of final dry biomass.

The research questions framing this personal plant assignment are generally connected to common observations that do not require much special knowledge, although students' lack of exposure to agriculture and gardening make many of these simple descriptive patterns qualify as "revelations."

Because the prompts are fairly simple and investigations of causes for patterns come to mind readily, students are able to focus on applying their understanding of experimental design and the scientific method without having to understand a lot of jargon or terminology. They have opportunities later in the semester to build their own framework for understanding the behavior of individual plant species and to explain the patterns they see. Student findings from the interim assignments are often reintegrated into the final project.

Over the 10 years we have used this project at Rider, we have made many modifications. Although Personal Plants was initially designed for individual projects, we have found that students prefer to work in groups (see the second photo). Students learn a great deal about the importance of keeping records in the process of keeping a lab notebook, an experience they prefer to using our online learning management system (LMS) for recordkeeping. In two iterations of the course in 2002 and 2003, students were asked to use our LMS to keep blogs about their experiments, but at that point, students were not prepared to apply the technology. Most recently, upper-level bioinformatics students served as statistical consultants for the personal plant student groups. This experience required the Personal Plant Investigators to organize their data in preparation for the consultant visit and offered upper-level students the opportunity to share what they had learned and solve a real problem using real data.

Although most students design experiments that are straightforward, some build complex multifactorial designs and obtain findings that bear repeating or expansion in other courses. For instance, freshmen found that a native plant (evening primrose) grew poorly in soils enriched with activated carbon, a compound often used in experimental settings to absorb allelochemicals produced by plants. In response, students in an advanced botany course constructed an experiment to examine competitive outcomes between evening primrose and a variety of exotic, invasive species in the presence or absence of activated carbon.

Students have independently sought out information on the resources for which plants compete, rhizobia symbioses, allelopathy, or the need for mineral nutrients. Throughout the semester, students share their progress across groups in their lab in informal conversation—devising approaches to reduce insect infestations, teaching each other about the uses of various measurement tools, and ending the semester with both formal written and informal oral summaries of their work and findings.

To assess the extent to which this experience helps students with experimental design, a final exam question asks students to describe a pattern observed during their last lab on a nature walk and to design an experiment to test a hypothetical explanation for that pattern. Students are told during the lab that they should use the time to prepare their answers to this upcoming final exam question. Their responses are graded on the basis of the testability of their hypotheses, the graphs they construct illustrating supportive and refuting results they might find, and the quality of their experimental design. All the criteria for this exam question are embedded in the personal plant assignments throughout the semester. Students have constructed extremely imaginative (and sometimes fantastical) hypotheses and experiments to explain patterns of the distribution of skunk cabbage, mayapples and pussy willows.

Although most students in this class do not go on to a career in the plant sciences, they complete this project with a deeper understanding of plant life, an exposure to basic primary literature, and experience with the methods scientists use in their work. Most of them can also correctly pronounce the Latin binomial of their personal plant 3 years later, at graduation.

About the author

Laura A. Hyatt is associate professor of Biology at Rider University where she studies the population biology and chemical ecology of exotic, invasive plant species. She is the founding director of Rider's Sustainability Studies program and currently serves as associate dean in Rider's College of Liberal Arts, Education, and Sciences.

PHOTO CREDIT: PETER BORG

References and Notes

1. R. A. Houghton, E. A. Davidson, G. M. Woodwell, *Global Biogeochem. Cycles* **12**, 25 (1998).
2. T. Garnett, *Food Policy* **36**, (suppl. 1), S23 (2011).
3. World Health Organization, Diet, nutrition and the prevention of chronic diseases, Report of a joint WHO/FAO expert consultation. *WHO Tech. Rep. Ser.* no. 916 (2003).
4. D. Senchina, *Plant Sci. Bull.* **54**, 50 (2008).
5. G. E. Uno, *Am. Biol. Teach.* **56**, 263 (1994).

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Supplementary Materials

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