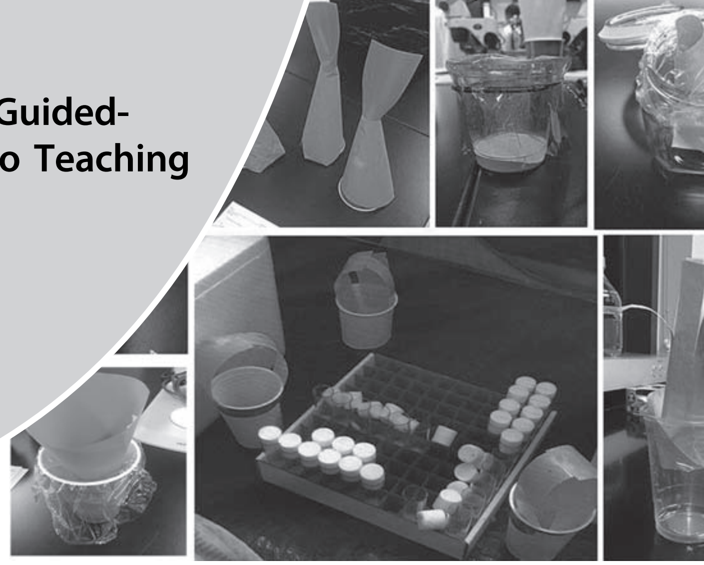
Trapping Fruit Flies: A Guided-Inquiry Lab Approach to Teaching Biology to Nonmajors



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Abstract

Current trends in education include offering students authentic experiences that generate broad interest, develop their cognitive flexibility, and prepare them to be scientifically literate members of society. We present a three-part guided-inquiry lab that gives students practice applying the scientific method to control fruit fly outbreaks and reinforces concepts related to behavioral and sensory biology. This activity was designed and tested at a four-year university but can be modified for high school courses. Students are "employed" by the fictional Fruit Fly Trap Company to design a device to maximize capture of female fruit flies using environmentally friendly lures. During this lab, students collaborate to conduct literature searches, ask research questions, develop hypotheses, design experiments, collect and analyze data, and present findings in a short oral presentation. In our implementation of this module in a biology class for nonmajors in fall 2017, over 50% of students reported that the literature research, scent experiments, trap construction, trap testing, and PowerPoint presentation were extremely effective in teaching science process and biological problem-solving skills. Over 70% of our students rated the practical, hands-on elements of the activity as enjoyable. Overall, students generally enjoyed the lab and reported positive impacts on their learning.

Key Words: *sensory biology; fruit fly; nonmajors biology; inquiry laboratory.*

○ Introduction

Students seeking four-year college degrees are usually required to complete a science laboratory course as part of their general education requirement (Warner & Koeppel, 2009). These types of courses pose motivational challenges to non–science majors (Glynn & Koballa, 2006). Stereotype threat and disdain for a topic far outside the major requirements has been shown to lead to poor academic performance, attributed to lack of self-efficacy (e.g., Luzzo et al., 1999) or lack of interest (e.g., Shell & Soh, 2013). These issues can be addressed in part by course structures and formats designed to motivate students. Student motivation engenders better learning (Schwinger et al., 2012).

Science instructors who teach nonmajors are tasked not only with teaching the basic science content and process skills but also with helping students engage in the process of science through hypothesis testing, experimental design, and data analysis (Brewer & Smith, 2011). A guided-inquiry laboratory curriculum exposes students to science process skills and provides guidance and structured support, thus enabling meaningful learning of the course content (Rutherford, 1964; Welch et al., 1981; Wilson et al., 2010; AAAS, 2011; NGSS Lead States, 2013). Specifically, the *Next Generation Science Standards* (NGSS) focus on scientific practices such as asking questions, using evidence, making and defending claims, and applying statistical methods to help students communicate scientific information and evaluate evidence (NGSS Lead States, 2013). Previous studies have shown that students are better able to think like scientists and appreciate the value of scientific results when given the responsibility of designing experiments to solve problems (Wilson et al., 2010; AAAS, 2011; NGSS Lead States, 2013).

To motivate and engage nonmajors in their first college-level exposure to the process of science, we employed a well-studied model organism, the fruit fly *Drosophila melanogaster*, in an unconventional, inquiry-based experimental approach to building a better fly trap. *Drosophila* is a versatile, inexpensive, and easy-to-care-for model organism that can be used by scientists and students to learn Mendelian genetic crosses, molecular and genetic evolution, development, drug discovery, and, in our case, aspects of behavioral and sensory biology (Jenning, 2011). Here, we describe our use of *Drosophila* in a three-part guided-inquiry lab activity designed to engage students in the process of science (Figure 1) and reinforce concepts related to behavioral and sensory biology. Students research possible color and odor attractants of fruit flies, design a fruit fly trap, and test the trap's efficacy against traps designed by their peers and well-rated commercially available fly traps. Even for nonmajors, *Drosophila* are easy to relate to, are easy to visualize, and provide an opportunity to practice manipulating and measuring variables (Beck & Blumer, 2007) while keeping the focus narrowed to the topic of sensory biology. The goal of this three-part lab at the

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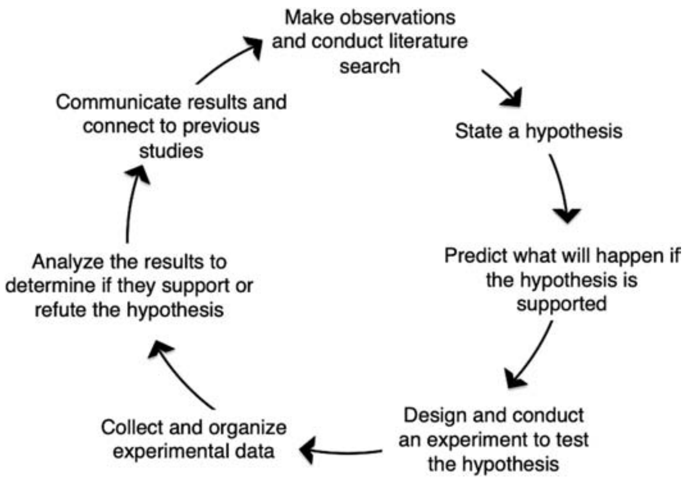

Figure 1. The scientific methodology taught to students in this multipart lab activity.

Figure 2. Lure-testing apparatus, consisting of a horizontal plastic culture tube divided into three zones, with zone 1 being the farthest from the lure and zone 3 being the closest to the lure (Vang et al., 2012). Students added flightless flies and placed a lure soaked into a cotton ball at one end. Flies assort by proximity to the lure, which students categorized into three zones for ease of rating each lure's attractiveness. At the conclusion of the trial, students placed the tube on ice to immobilize the flies, counted the number in each zone, and then used a small paintbrush to transfer the immobilized flies into ethanol to determine their sex under a microscope. Photo credit: Alison Onstine.

college level is to introduce the practice of the scientific method to nonmajors, lay a foundation for future applications of scientific methodology in the remaining lab sessions in the course, and help students interpret scientific data they will encounter in future educational and societal settings.

○ Materials

For more detailed information, pictures, and ordering instructions, please see the Supplemental Material available with the online version of this article. The needed materials can be summarized as follows:

- Wild-type, flightless (vestigial) *D. melanogaster* strains available from Carolina Biological Supply (cat. nos. 172100 and 172460, https://www.carolina.com/).
- Fly media and culturing supplies: instant fly media, vials, plugs, and incubator. Four vials of flightless flies were provided to each group of four students for lure testing, and 20–40 vials of wild-type flies were used for trap testing. Fly cultures mature in two weeks at 25°C.
- Fly observation materials: dissecting microscope with overhead lighting and 30–40× total magnification, paintbrushes for fly manipulation, and 70% ethanol to euthanize flies before observation.
- Lure testing supplies: plastic tube or empty fly vial to allow for the testing of different lures (Figure 2). Each testing chamber was divided into several equally sized sections with the lure placed at one end. At the end of each trial the number of flies occupying each section was quantified and compared. Organic lures included acetic acid, fruit juice, fruit, corn syrup, and baker's yeast.
- Fruit fly trap supplies: plastic drinking cups of various types, cellophane and construction paper in different colors, sticky insect paper, aluminum foil, cling wrap, tape, and scissors.
- Commercial fruit fly traps and bait were used for comparison during trap testing.
- Insect-proof tent (Figure 3), modified to prevent fly releases as traps are being moved in and out (for instructions, see Supplemental Material).

○ Overview of Multipart Laboratory Exercise

This lab activity was designed and tested in fall 2017 with 42 undergraduates – including business, computing, engineering, humanities, and social science majors – at a large southeastern university rated R1 (very high research activity). Over three consecutive lab sessions, students learned about the biology of fruit flies, posed research questions and hypotheses, consulted the primary literature to inform the design and choices of color and lure for their fly traps, designed experiments, collected data on numbers of flies trapped, constructed graphs, performed statistical analysis, and presented findings in a short group oral presentation. Because this lab was designed for non–science majors who had minimal experience in a wet-lab setting, we structured class time around lab components to provide students with appropriate guidance to meet the learning objectives of this lab exercise, and noted how these aligned with NGSS (Table 1).

○ Part 1: Introduction to *Drosophila*, Scent Lure Experiments & Initial Trap Design

The first part of this lab includes a brief introductory lecture on *Drosophila* morphology and life cycle, including time for students to examine flies under a dissecting scope (30 minutes), organize their thoughts in a worksheet (75 minutes), and conduct lure preference testing (75 minutes). The learning objectives of Part 1 are to utilize knowledge to design and conduct experiments to trap fruit flies, quantify the fruit flies' sex and phenotypes and match them to the lure scent, perform data analysis and communicate findings with the class, and appreciate the real-life nature of this lab and its applicability to everyday situations.

While many students know what fruit flies are, most have never examined them up close or under a dissecting scope. During the morphological examination of *Drosophila* under the dissecting scope, the instructors emphasized differences in body structure

Table 1. Components of the fruit fly trap lab (class time in parentheses) with *Next Generation Science Standards* and learning objectives.

Lab Component	*Next Generation Science Standards*	Learning Objectives
Planning the experiment: conducting primary literature search, formulating a research question, hypothesis, prediction, experimental design (75 minutes)	Ask questions that arise from examining models or a theory to clarify relationships. *(HS-LS3–1)*	• Hypothesize a fly trap design and fly lure based on background knowledge from the behavioral and sensory biology primary literature. • Design an experiment with testable fly lures.
Scent lure experiments (105 minutes)	• Use a model based on evidence to illustrate the relationships between systems or between components of a system. *(HS-LS1–4)* • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. *(HS-LS3–3)* • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *(Secondary to HS-LS2–7 and HS-LS4–6)*	• Design an experiment to test the attractiveness of different scent lures to fruit flies. • Collect data on fly attraction to different scent lures. • Statistically compare treatments and interpret the results. • Use experimental output to inform final fruit fly trap design, including uncertainty surrounding statistical results.
Designing and constructing the fly trap (outside of class, or 30–60 minutes in class)	Use a model based on evidence to illustrate the relationships between systems or between components of a system. *(HS-LS1–4)*	Use previous experimental results and evidence from the literature to design and build fly traps.
Competition to assess trap efficacy (105 minutes)	Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. *(HS-LS4–5)*	• Design an experiment to test the attractiveness of different scent lures to fruit flies. • Collect data on how well traps function to catch *Drosophila*. • Statistically compare the groups and interpret the results.
Short group presentation and communication of findings (recommended 10 minutes, including ~7 minutes for each group to present and ~3 minutes for follow-up questions)	Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated evidence. *(HS-LS3–2)* Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). *(HS-LS4–1)*	• Make and defend a claim based on scientific knowledge of behavioral and sensory biology of the fruit fly and student-generated evidence. • Communicate scientific information in an oral slide presentation.

between male and female flies. We recommend using flightless flies, such as the *vestigial* mutant, to reduce the chances of escapees into the lab spaces. Morphological examination at the beginning of the lab teaches students how to sex flies, which will be necessary after they collect data from the lure-choice experiments (Part 1) and fly traps (Part 2).

Students were given a worksheet containing a series of prompts that isolated each element of the scientific method (background information, research question, hypothesis, etc.) and were asked to fill out each element over the course of the lab period. Each student group completed and submitted this worksheet before leaving lab and received instructor feedback at the start of the next lab period.

In the activity, students are "employed" by the fictional Fruit Fly Trap Company to design a device to maximize capture of female fruit flies using environmentally friendly lures. Each student group designed an experiment to determine an effective lure to attract flies to their trap. We asked students to conduct a literature search on organic attractants for *Drosophila* and then summarize and cite two primary literature sources about odor attractants on their worksheet. Students were provided several sets of lure-testing apparatus, lures, and flies, a dissecting microscope, ice, and 70% ethanol to immobilize flies. They received instruction on constructing a lure-testing apparatus (Figure 2) and how to handle and transfer fruit flies into the test tubes in order to test their preference for different scent attractants. In the course of their design, students produced a research question, a hypothesis or prediction, and an experimental design to test the efficacy of different odor attractants. The instructors prompted students to control for potential confounding variables such as light and temperature that might influence or bias lure choice. Over 60 minutes, students concocted their lures with various scent combinations, added fruit flies, and observed the attractiveness of the different treatments under the microscope to determine the sex of flies attracted to the lure. Students repeated this procedure for different scents. For homework, the instructors provided a variety of materials so that each student could construct a fruit fly trap at home and bring it to lab the following week (see Supplemental Material).

○ Part 2: Test Initial Trap Designs, Build Replicates of the Final Designs & Assess

In Part 2, students justified and piloted their initial fly trap designs, selected a final trap design and produced three replicates, and entered their replicate traps in a fly-trapping competition. Students arrived in class with their completed fruit fly traps for the first experimental trial, with rationales for their choices of color and design. The instructors returned the worksheets and asked students to revise their research question and their hypothesis or prediction about the lure and color of the trap, based on their homework.

To test the individually designed traps, students added the lure they had identified in their trials in Part 1, then placed the baited traps for 60 minutes inside an insect containment tent that contained approximately 1500 wild-type fruit flies. We made the tent by modifying a commercial insect-proof tent (Figure 3). The insect-proof tent was supplied with boxes of various sizes to allow students to place their trap at a preferred height in the tent. After the 60-minute pilot, students counted and sexed the flies in their traps to collect data on which trap designs were most efficacious. Over the following 45 minutes, each student group then used the data to select a fly trap design and created three replicate traps of their favored design (Figure 4).

The final hour of the lab period was reserved for the fruit fly trap competition, in which each group placed its three traps inside the tent to compete for flies against the other groups' traps (Figure 4) and against the commercial fly traps, which served as experimental controls. The trap design that caught the greatest number of fruit flies during this final round of competition was declared the overall winner.

Throughout the experimentation process, while students were awaiting the results of their experiments, they were asked to use information they had written in their experimental design worksheets to start building their PowerPoint slide presentations for their group oral presentations.

Students tallied the flies captured in their three replicates and entered their data into Google Sheets, followed by appropriate descriptive or inferential statistics. For homework, they were asked

Figure 3. The insect-proof tent is a collapsible one-person tent modified with two mesh-lined sleeves for controlled access. Students add and remove traps through the sleeves without releasing flies. Photo credit: Alison Onstine.

Figure 4. Sample fruit fly traps constructed by students using various types of plastic cups, colored construction paper, sticky insect paper, aluminum foil, and cellophane. Photo credit: students from the course.

to build a graphical representation of their data. Because students often struggle to choose an appropriate graph type and construct a relevant graph, a pedagogical scaffold was provided (the "step-by-step guide" tool; Angra & Gardner, 2016) to give students the opportunity to plan, construct, and reflect on their graph choice and construction.

○ Part 3: Short Group Research Presentations & Self-Reflections

After the short PowerPoint presentations, the instructors engaged students in a discussion about the various components of the fly trap (chemical lure, color, etc.) and how those components influenced the numbers of flies trapped. Students were guided to discuss the experimental controls and potential confounding variables in the experiment and then were asked to reflect on how these elements should be incorporated into student work on future lab experiments in the course. We administered a post-activity survey on a three-point Likert scale to each student to assess student perceptions of their learning and enjoyment of the activity (Figures 5 and 6). Although we did not have students write a formal lab report for this activity, instructors could easily replace the oral presentation component with a written component.

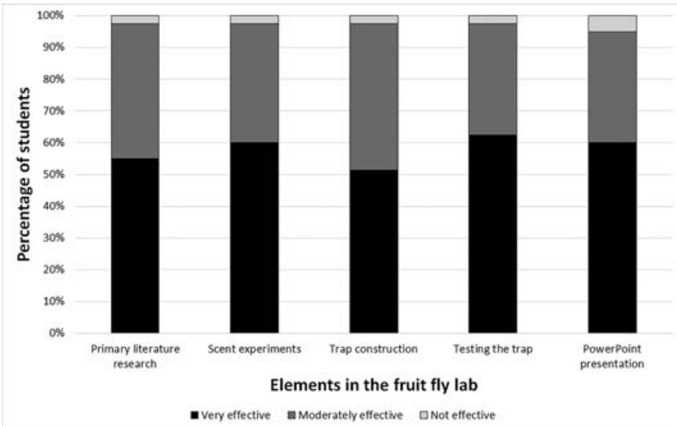

Figure 5. Students were asked to reflect on the elements of the fruit fly lab they had learned the most from. Over 50% of students (N = 42) indicated that all aspects, from starting with primary literature to the PowerPoint presentation, were effective in teaching them about the science process and the biological problem they were presented with. Fewer than 5% of students felt that this lab was ineffective overall.

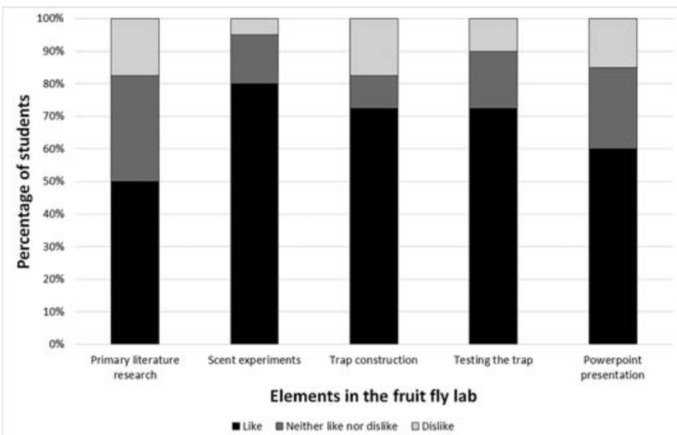

Figure 6. Students were asked to rate their enjoyment in learning each aspect of the fruit fly lab. Over 50% of students (N = 42) reported enjoyment of various elements of the activity, with a strong emphasis on the scent experiments, trap construction, and trap testing. Fewer than 20% of students disliked any given element.

○ From the Classroom

Students produced diverse and engaging research questions when given the scope provided in a guided-inquiry course. Here, we share two examples of the most popular types of experiments.

> *Student Research Question 1:* Do fruit flies have a color preference for the fruit fly trap design?
>
> *Student Prediction:* Flies will be more attracted to the yellow colored trap as compared to other colors.
>
> *Instructor Notes:* Although students were asked in Part 1 to design and test experiments on the chemical lure that attracted the most flies, in this case the final research question and prediction ended up being about the color of the fruit fly trap. While many student groups used both chemical scent and color to form a single research question and prediction, some chose a single factor to test. To clarify the preferred goal of combining the two factors in a single prediction, instructors should emphasize that Parts 1 and 2 are connected and continuous, rather than independent, experiments.

> *Student Research Question 2:* Are female *Drosophila melanogaster* more attracted to certain colors and scents?
>
> *Student Prediction:* The fruit flies will be more attracted to and best trapped by apple cider vinegar over other scents, and will prefer the colors red and yellow to any other color.
>
> *Instructor Notes:* Many but not all student groups tested both the scent and color preferences of female fruit flies, specifying the sex because the female lays eggs. Testing of females was in accordance with the instructions of the fictional Fruit Fly Trap Company. Other student groups did not specify the sex of the fruit fly. Although they did not meet the company's requirements, these groups were not penalized as long as their research question, prediction, and data analysis aligned with their explanation, focusing broadly on both the male and female fruit flies.

Overall, most student experiments were successful and yielded quantitative data that the students could spreadsheet in Google Sheets. They then constructed a graph of the data, performed the appropriate statistics, and presented their findings to the class in a group presentation. To help students plan, construct, and reflect on their graph choice, published graphing materials and implementation strategies were used (Angra & Gardner, 2016, 2018).

Regardless of their experimental outcome, each student group was asked to revisit their hypothesis or prediction and explain whether or not the data they collected in their experiment supported their hypothesis or prediction, using statistical support stated in terms of a P-value from the associated statistical analysis, done in Part 3. Student groups were also asked to list limitations of their experimental design, future directions for research, and potential improvements if they were to repeat their experiment. Many student groups wrote that they would like to test their trap in a more realistic setting, such as a kitchen or a farmers' market, and over a longer period, to gain more realistic and authentic data.

Reflecting on their learning (Figure 5), over 50% of students rated the elements (literature research, scent experiments, trap construction, testing the trap, and PowerPoint presentation) as extremely effective in teaching science process and biological problem-solving skills. Over 70% of our students rated the practical, hands-on elements of the activity – scent experiments, trap construction, and trap testing – as enjoyable (Figure 6). Fewer than 20% of students disliked any given element.

○ Conclusion

This guided-inquiry lab activity allows students to implement the process of science by researching fruit flies and lures, designing fruit fly traps, and testing their efficacy in a lively competition. This experiment effectively balanced student learning and student enjoyment, which was equated with engagement. The activity met our goals of preparing and motivating students to do well in the course.

Designed for nonmajors as a vehicle to engage them in authentic inquiry around a common pest species, this lab activity would also benefit science majors. Upon hearing that a course will include *Drosophila*, science majors often comment that they "did that in high school," exposing a misconception that *Drosophila* are useful for teaching or learning only one concept. Modifying this fruit fly trap module for science majors would present an alternative use for a popular model organism, priming students to learn about classical experimental evidence; to read the primary literature in behavior, genetics, and evolutionary biology; and to conduct undergraduate research using this or other model organisms. And while *Drosophila* is indeed commonly used in high school and undergraduate lab exercises, this fruit fly trap module provides a unique alternative to traditional fruit fly labs in which students design and deploy traps to capture fruit flies as household pests.

Although we used the module specifically to teach the process of science, instructors could easily modify it to focus on biochemistry. For example, students might work solely on the chemical scents by extracting the different molecules, using nuclear magnetic resonance or infrared spectroscopy to determine the chemical compounds attractive to fruit flies. Instructors could also present the activity with mainly an engineering or design focus, allowing students to plan and build or print 3D versions of their fruit fly traps, which they could use to test against commercial fly traps. With its many possibilities, this fruit fly trap experiment adds to a growing collection of guided-inquiry labs for science majors and nonmajors alike.

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