Building Creative Scientists in the Classroom Laboratory: Applications for Animal Behavior Experiments

JUSTIN R. LAMANNA, PERRI K. EASON

Abstract

In this animal behavior laboratory, designed to promote a discovery-based approach to laboratory teaching, students first observe the study organism, which gives them the opportunity to decide what behaviors interest them. They work collaboratively to develop their own hypotheses, which can range from simple to complex depending on the course's level. Student groups then design and run experiments to test their hypotheses. At the end of the exercise, the groups present their results to their peers, who are given time to ask questions. This kind of flexible, student-led exercise develops students' reasoning skills and ability to think creatively.

Key Words: *Animal behavior; teaching; discovery-based; collaboration; crickets.*

Biology students often miss the excitement of discovery because they are assigned highly structured, "cookbook" laboratories, which tend to appeal to teachers and students because they are simple and usually "work" (i.e., the expected result is indeed the outcome). But often this kind of lab only verifies facts that are already known and, thus, results in no discovery, dulling students' innate curiosity and giving them little opportunity to learn how science works. By contrast, an inquiry-based approach allows students to act as scientists. By devising their own hypotheses, designing and conducting their own experiments, and analyzing and presenting their results, students can improve their reasoning skills and ability to think innovatively. Practicing similar activities as scientists also helps students gain a deeper understanding of scientific inquiry (Weaver et al., 2008). Students can learn, for example, that a "failed" experiment (i.e., one that did not give the results they expected) can be more instructive than one that yielded the expected results. Such realizations may make them less afraid to devise and attempt new experiments.

Practicing similar activities as scientists also helps students gain a deeper understanding of scientific inquiry.

Animal behavior is a field that lends itself to student-led work. It is intrinsically interesting to students, in part because they have had direct experiences with animals and have wondered why animals exhibit certain behaviors. Students can thus use their own experiences as a basis for developing hypotheses. The relative lack of jargon in animal behavior is also an advantage (Bednekoff, 2005). Finally, recently published work in animal behavior can be accessible and interesting to more advanced students; they can read about active scientists investigating topics similar to theirs and gain an appreciation of how their work fits into the scientific literature.

Recently, we designed a laboratory using house crickets (*Acheta domesticus*), a common subject in behavioral laboratories. We wanted to design this exercise to be as student-led as possible and to appeal to diverse students. Women, African Americans, and Latinos have for decades been underrepresented in scientific fields (Johnson, 2007; Madsen & Tessema, 2009). By adopting pedagogical strategies that encourage these students' interest in the sciences, we can help to increase their numbers in the workforce, thus addressing problems caused by a sometimes exclusionary climate and a lack of role models (Halpern et al., 2007). Traditionally, crickets have been used in teaching labs to study male aggression, and students are told exactly what to test (e.g., see Animal Behavior Society, 2009). In our new, highly adaptable lab exercise, students choose the topic of their investigations, which gives them a stronger sense of independence. We also designed the laboratory so that it is collaborative and encourages active participation by all students, two attributes known to appeal to diverse students and improve their enthusiasm and learning (Johnson et al., 2007; Chung & Behan, 2010). Such collaboration also mimics the working habits of most scientists, who often work in groups, solving problems and exchanging information among and within these groups. The laboratory can be completed in a 2-hour period, or, more ideally, it can be used as the basis for longer-term projects that extend across several periods.

○ The Study Animal

House crickets are inexpensive, are easy to acquire and care for, and behave fairly normally in captivity. The winged adults are also easily sexed; a female has a single, long, thin ovipositor at the end of her abdomen, and a male does not. The other striking structures at the end of crickets' abdomens are abdominal cerci; these are paired, present in both males and females, and shorter than ovipositors. Anatomical diagrams of house crickets are readily available on the Internet (e.g.,

The American Biology Teacher, Vol. 73, No. 4, pages 228–231. ISSN 0002-7685, electronic ISSN 1938–4211. ©2011 by National Association of Biology Teachers. All rights reserved. Request permission to photocopy or reproduce article content at the University of California Press's Rights and Permissions Web site at *www.ucpressjournals.com/reprintinfo.asp.*
DOI: 10.1525/abt.2011.73.4.8

Downloaded from http://online.ucpress.edu/abt/article-pdf/73/4/228/378821/abt_2011_73_4_8.pdf by guest on 20 January 2021

http://www.flukerfarms.com). To provide context and demonstrate the currency of behavioral studies on crickets, teachers can direct students to recent primary literature (e.g., Martin et al., 2000; Nosil, 2002; Brown et al., 2006; Delago & Aonuma, 2006; Brown et al., 2007).

○ Housing & Feeding Crickets

House crickets can be ordered in large quantities from cricket farms and biological supply companies or bought at pet and bait shops. Colonies can be maintained in small aquaria approximately 51 × 26 × 30 cm in size, with roughly 150 crickets per aquarium. The sides of the aquaria should be covered with dark paper to reduce disturbance. Cardboard tubes (such as cores from rolls of paper towels) or cardboard egg cartons should be placed in the aquaria to provide hiding places and greater spatial structure; these items also make it easy to remove the crickets when needed. The tops of the aquaria can be covered with a screen, although crickets rarely escape if tubes and cartons are kept low.

Crickets can be sustained on ad libitum chick starter, dry cat food, or special cricket diet. To provide water, fill test tubes (18 × 150 mm or smaller) with tap water and push a cotton ball into each test tube until flush with the opening. Lay test tubes on the aquarium's floor, making sure that the cotton does not touch the cardboard. The crickets will use these tubes for drinking and oviposition.

If it is not feasible to alter the light cycle where the crickets are housed, this lab can be run by reducing light levels in the classroom during the experiment. If the light cycle can be controlled, a 12:12 hour light:dark cycle works well, with lights going out 3 hours before each experiment (Brown et al., 2006). Crickets acclimate to a new light cycle in 3–4 days.

Early Preparation for the Lab

If the students will run mate-choice or courtship experiments, the crickets should be moved into single-sex aquaria two and a half weeks before the laboratory. Females can store sperm for two weeks after mating (Fluker Farms, 2009), and early separation ensures that they will be receptive to mating during the laboratory exercise.

○ Setting up Trials

For the trials, the students can use aquaria measuring 51 × 26 × 30 cm or other similarly sized containers. Smaller aquaria can be used but will increase interactions between crickets; this may be desirable, especially if students are observing only two crickets, but may result in students having to record data quickly. Aquaria should have 1.0 cm of brown sand or soil as a substrate; crickets will not behave normally on white sand or bare glass. The sides of aquaria should be covered with dark paper to reduce the crickets' attempts to go through the glass, and aquaria should be set on some sort of padding (we used bubble wrap) to dampen vibrations that disturb crickets. To enable the students to record the crickets' locations, we used a computer to draw a grid of 2.5 × 2.5 cm squares and labeled each square with a letter (for row) and number (for column). We photocopied this grid onto transparencies that we taped atop the aquaria.

The students or their teacher can capture crickets, use toothpicks to mark them with small dots of paint on their thoraxes so they can be identified as individuals, and place them gently in aquaria for observation. Care should be taken to avoid getting paint on their wings. The students should allow the crickets to acclimate for 5 minutes in aquaria before collecting data. During all observations, lighting should be reduced as much as possible because crickets avoid bright lights. We turn off overhead room lights and use small desk lamps to provide just enough light to see the crickets' behaviors.

The students can work in groups of two to four, with one student watching one cricket and recording its behavior. Five or more groups are ideal if the class is testing one hypothesis. Students may need time-keeping devices that show seconds for recording data.

○ Observational Period: Learning to Watch Crickets & Developing Hypotheses

Most students will be unfamiliar with cricket behavior, and providing time dedicated to watching crickets will give them a better foundation for developing suitable hypotheses. We typically allot 20–30 minutes for observation. During this time, student groups can look for anatomical and behavioral differences between the sexes.

Cricket Behaviors Your Students Are Likely to Observe

Cricket behaviors have been well described (e.g., Alexander, 1961; Adamo & Hoy, 1995). Females and males have similar behaviors during aggressive interactions, which typically occur over resources. The most commonly observed aggressive behaviors in the laboratory include the following:

- *Antennal jousting.* Two individuals touch one another with their antennae. Individuals may touch the opponent's antennae or hit its body.
- *Chase.* One individual pursues the other by walking.
- *Head butt.* One individual rams the other with its head and tries to push its opponent away.
- *Kick.* An individual kicks its opponent with walking or jumping legs.
- *Wrestle.* A highly aggressive interaction in which individuals grapple with one another, using legs, mandibles, or both.
- *Supplant.* A subtle, low-intensity interaction in which a dominant individual approaches a subordinate, which leaves without physical contact. Crickets generally supplant one another after dominance is established, by previous interaction or obvious differences in size.
- *Body stand.* Typically, only females show this behavior, in which one individual walks onto her opponent's back and stands there. Generally, the female who stood on the other is dominant in later interactions, and her opponent will avoid her if she approaches.
- *Chirp.* Only male crickets chirp, and the nocturnal song of males calling to advertise their presence and attract females is one of the hallmarks of summer in many parts of America. Males chirp by rubbing their forewings together so that a smooth scraper on one moves across a serrated file on the other. They chirp differently to court females that visit and use a third kind of chirp in aggressive interactions with males.

Common solitary behaviors include walk, stand, drink, eat, dig, antennal wave, and, for males, chirp. Depending on the hypotheses of interest, students may also want to record crickets' locations and whether they are in "burrows"; if suitable, small, opaque cylinders (approximately 3.0 × 5.0 cm) are provided. Males typically occupy and defend such cylinders, providing a possible topic to explore.

○ Developing Hypotheses & Collecting Data

Students can be given different degrees of liberty to create their own hypotheses. For beginning students, teachers should give more explicit examples of hypotheses; advanced students can develop their own. To test a hypothesis, the students need a sample size of at least 10 paired trials. Depending on the time available, the groups can work independently or the students can reach consensus on one hypothesis all groups will test.

Downloaded from http://online.ucpress.edu/abt/article-pdf/73/4/228/378821/abt_2011_73_4_8.pdf by guest on 20 January 2021

To foster the tendency to collect narrative data, the students should create data sheets (examples given below), which the teacher should approve. The groups should clarify each person's role before beginning trials.

Examples of Hypotheses Students May Generate

For advanced students, we included appropriate statistical tests in this section.

Female crickets are more likely than males to use the edges of the aquarium. The students might test this by observing single crickets, or same-sex groups of 3 or 4 crickets, with a student recording each cricket's location every 15 seconds. For these data, the students might use data sheets with two columns, titled "edge" and "not edge," and put a mark in the appropriate column at each time interval. If they use single crickets, they can use a Mann-Whitney U-test to compare the number of times that males and females are located in grid squares along edges (online test: http://elegans.swmed.edu/~leon/stats/utest.html). If they use groups, they should use the mean number of occurrences in edge squares in each trial as the basis for analysis.

The presence of a female cricket changes males' space use. To test this, the students can observe males alone and males with a female present. They can then assess, for example, the numbers of times that males were located near edges, or near burrows, or within a short distance of other males, using a Mann-Whitney U-test to compare males with and without females.

The presence of a female changes aggression among males. The students should record aggressive behaviors among males in groups of 3 or 4, and among males in groups of the same size with a female present. They can assess aggression by counting aggressive interactions between males, recording the amount of time that males spend in aggressive interactions, and comparing the intensity of males' acts. High-intensity behaviors include wrestling, kicking, and head butting; supplanting is a low-intensity behavior. Chasing, antennal jousting, chirping, and body stands are of intermediate intensity. Data sheets for testing differences in aggression levels and time spent in aggression are given in Figures 1 and 2. Numbers of interactions can be compared with Mann-Whitney U-tests (e.g., the number of high-intensity acts in the presence or absence of a female) or chi-square tests (to compare the distribution of acts across the three intensity levels in the presence and absence of a female). The mean time that males spent in aggression can be compared with a t-test.

Cricket size determines dominance. The students can measure crickets' body lengths and then put pairs of differently sized, same-sexed crickets in aquaria and record their interactions to determine dominance. In interactions, the lower-ranked cricket is the one that walks away first. The students can determine which cricket is dominant by which won more interactions (Figure 3). Typically, dominance in crickets is settled with few interactions, with losers quickly avoiding winners. The simplest way to analyze data from all trials is to perform a chi-square test on the numbers of trials in which larger and smaller crickets are dominant versus the numbers expected by chance (i.e., larger and smaller crickets would each be expected to win 50% of the trials). More advanced students might want to test the hypothesis that establishing a dominance relationship takes longer or involves more highly aggressive behaviors when crickets are similarly sized.

The presence of a burrow changes crickets' aggression levels. The students can record and compare numbers, intensity, and/or lengths of interactions between crickets that have been provided a burrow and control crickets that have not. The students can also evaluate whether more interactions than expected by chance occur near burrows.

This lab exercise is highly flexible, and numerous other straightforward hypotheses can be tested with the set-up described here, which gives students an opportunity to be creative. For example, students might assess crickets' substrate preferences by comparing the amount of time crickets spend on light versus dark sand, or investigate whether crickets prefer areas with higher habitat complexity. They might test whether a higher risk of predation affects crickets' use of space or aggressive behaviors; to do so, they could bump aquaria regularly to simulate a disturbance by a potential predator. They could also examine whether females prefer larger (or smaller, or more or less aggressive) males as mates, whether temperature affects interactions, whether crickets prefer

Trial Number ____________

Female Present (Yes/No) __________

Male 1	Male 2	Time Interaction Began	Time Interaction Ended	Duration of Interaction (seconds)
↓	↓	↓	↓	↓

Figure 1. In the first two columns, students can record the color marking of the two males involved in the interaction. During trials, they record the time the interaction starts and ends in the third and fourth columns. The final column can be calculated after the trial; giving duration in seconds makes addition easier when students calculate total interaction time, which they do by summing all interactions' durations.

Trial Number ____________

Female Present (Yes/No) __________

Counts of Acts

Low Intensity	Medium Intensity	High Intensity

Figure 2. Data sheets for recording interaction types should include three columns, which should be headed low-, medium-, and high-intensity. Until students become familiar with the acts, those in each category can be listed beside the appropriate heading to make recording simpler. During trials, students simply enter a hatch mark for each interaction in the correct column.

Downloaded from http://online.ucpress.edu/abt/article-pdf/73/4/228/378821/abt_2011_73_4_8.pdf by guest on 20 January 2021

Trial Number _______

Cricket 1

Color _______ Body length (mm) _______

Cricket 2

Color _______ Body length (mm) _______

Cricket 3

Color _______ Body length (mm) _______

Cricket 4

Color _______ Body length (mm) _______

Interactions

Winning cricket	Losing cricket	Winner larger? (Y/N)
↓	↓	↓

Figure 3. Students can write the color of the winning and losing individual in the appropriate columns. Each interaction should be recorded on a separate row. At the end of the trial, students can determine whether the larger individual won by counting how many interactions each individual won. For students interested in looking at more complex dominance hierarchies, more crickets can be added to the data sheet and observed together.

burrows near those of other crickets, or whether males' courtship is affected by the presence of other males, other females, or female size.

○ Data Analysis & Presentation

Data analysis and presentation will depend on the level of the course. For younger students, calculating descriptive statistics, such as averages, and creating suitable graphs may be adequate analysis. More advanced students should additionally use simple inferential statistics.

For all students, presenting results to peers is invaluable, although this practice of a typical scientific activity is too often omitted from the classroom (Osborne, 2010). Through explaining their work, defending their conclusions, and questioning others, students will gain an appreciation of the benefits of collaboration, improve critical-thinking skills, and learn how to assess others' work (Krajcik & Sutherland, 2010; Osborne, 2010). Ideally, students should present their work in the standard format of scientific meetings, with a presentation of 10–15 minutes, in which all group members should participate, followed by a 5-minute period for questions.

○ Conclusions

This laboratory gives students the freedom to investigate varied behavioral concepts. Students first spend time observing crickets, which allows them to develop hypotheses on their own, and then work collaboratively to design experiments, analyze data, and present results to their peers. This kind of design can be applied to other biology labs. With a more open, discovery-based approach to laboratories, students can pursue avenues of interest to them and are more likely to improve their critical-thinking skills, developing abilities that can help them become lifelong learners.

References

Adamo, S.A. & Hoy, R.R. (1995). Agonistic behaviour in male and female field crickets, *Gryllus bimaculatus*, and how behavioural context influences its expression. *Animal Behaviour*, *49*, 1491–1501.

Alexander, F.D. (1961). Aggressiveness, territoriality and sexual behaviour in field crickets (Orthoptera: Gryllidae). *Behaviour*, *17*, 130–223.

Animal Behavior Society. (2009). Laboratory exercises in animal behavior – crickets and territory defense. Available online at http://www.animalbehavior.org/ABSEducation/laboratory-exercises-in-animal-behavior/laboratory-exercises-in-animal-behavior-crickets-and-territory-defense.

Brown, W.D., Chimenti, A.J. & Siebert, J.R. (2007). The payoff of fighting in house crickets: motivational asymmetry increases male aggression and mating success. *Ethology*, *113*, 457–465.

Brown, W.D., Smith, A.T., Moskalik, B. & Gabriel, J. (2006). Aggressive contests in house crickets: size, motivation and the information content of aggressive songs. *Animal Behaviour*, *72*, 225–233.

Chung, H. & Behan, K.J. (2010). Peer sharing facilitates the effect of inquiry-based projects on science learning. *American Biology Teacher*, *72*, 24–29.

Delago, A. & Aonuma, H. (2006). Experience-based agonistic behavior in female crickets, *Gryllus bimaculatus*. *Zoological Science*, *23*, 775–783.

Fluker Farms. (2009). *Fluker's Cricket Biology Guide*. Available online at http://www.flukerfarms.com/PDFs/Cricket.pdf.

Halpern, D.F., Aronson, J., Reimer, N., Simpkins, S., Star, J.R. & Wentzel, K. (2007). *Encouraging Girls in Math and Science* (NCER 2007-2003). Washington, D.C.: National Center for Education Research, Institute of Education Sciences, U.S. Department of Education.

Johnson, C.C., Kahle, J.B. & Fargo, J.D. (2007). Effective teaching results in increased science achievement for all students. *Science Education*, *91*, 371–383.

Krajcik, J.S. & Sutherland, L.M. (2010). Supporting students in developing literacy in science. *Science*, *328*, 456–459.

Madsen, L.D. & Tessema, G.X. (2009). The next generation: education and broadening participation in science and engineering. *Journal of Electroceramics*, *2*, 8–12.

Martin, S.D., Gray, D.A. & Cade, W.H. (2000). Fine-scale temperature effects on cricket calling song. *Canadian Journal of Zoology*, *78*, 706–712.

Nosil, P. (2002). Food fights in house crickets, *Acheta domesticus*, and the effects of body size and hunger. *Canadian Journal of Zoology*, *80*, 409–417.

Osborne, J. (2010). Arguing to learn in science: the role of collaborative, critical discourse. *Science*, *328*, 463–466.

Weaver, G.C., Russell, C.B. & Wink, D.J. (2008). Inquiry-based and research-based laboratory pedagogies in undergraduate science. *Nature Chemical Biology*, *4*, 577–580.

JUSTIN R. LAMANNA is Assistant Professor of Biology at Alverno College, Milwaukee, WI 53234; e-mail: justin.lamanna@alverno.edu. PERRI K. EASON is Professor of Biology at the University of Louisville, Louisville, KY 40292; e-mail: perri.eason@louisville.edu.

Downloaded from http://online.ucpress.edu/abt/article-pdf/73/4/228/378821/abt_2011_73_4_8.pdf by guest on 20 January 2021