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Knowing your own: A classroom case study using the scientific method to investigate how birds learn to recognize their offspring

Joanna K. Hubbard
University of Nebraska - Lincoln

Daizaburo Shizuka
University of Nebraska-Lincoln, dshizuka2@unl.edu

Brian A. Couch
University of Nebraska - Lincoln, bcouch2@unl.edu

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Lesson

Knowing your own: A classroom case study using the scientific method to investigate how birds learn to recognize their offspring

Joanna K. Hubbard[1], Daizaburo Shizuka[1], Brian A. Couch[1]*

[1]School of Biological Sciences, University of Nebraska-Lincoln, Lincoln, NE

Abstract

Understanding the scientific method provides students with a necessary foundation for careers in science-related fields. Moreover, students can apply scientific inquiry skills in many aspects of their daily lives and decision making. Thus, the ability to apply the scientific method represents an essential skill that students should learn during undergraduate science education. We designed an interrupted case study in which students learn about and apply the scientific method to investigate and recapitulate the findings of a published research article. This research article addresses the question of how parents recognize their own young in a system where birds of the same species lay eggs in each other's nests. The researchers approach the question through three experiments in which the bird's own offspring and unrelated offspring hatch in different orders. This experiment specifically tests for the effect of hatching order on the bird's ability to recognize its own offspring. In the case study, students form hypotheses based on behavioral observations made while watching a video clip, together with background information provided by the instructor. With additional information about the experimental design, students make graphical predictions for the three related experiments, compare their predictions to the results, and draw conclusions based on evidence. This lesson is designed for introductory undergraduate students, and we provide suggestions on how to adjust the lesson for more advanced students. This case study helps students differentiate between hypotheses and predictions, introduces them to constructing and interpreting graphs, and provides a clear example of the scientific method in action.

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Supporting Materials: S1. Knowing your own: Lecture presentation slides, S2. Knowing your own: In-class handout for students, S3. Knowing your own: Video of Dr. Shizuka, and S4. Knowing your own: Follow up homework/exam questions.

***Correspondence to:** School of Biological Sciences, University of Nebraska-Lincoln, 204 Manter, Lincoln, NE 68588-0118 E-mail: bcouch2@unl.edu

Learning Goal(s)

- Students will be introduced to and apply components of the scientific method.
- Students will recognize the cyclical nature of the scientific method.
- Students will see an example of research in which undergraduate students made key contributions.

Learning Objective(s)

- Students will be able to identify and describe the steps of the scientific method.
- Students will be able to develop hypotheses and predictions.
- Students will be able to construct and interpret bar graphs based on data and predictions.
- Students will be able to draw conclusions from data presented in graphical form.

INTRODUCTION

Recent national reports have emphasized the importance of the scientific method and scientific reasoning within undergraduate biology courses (e.g., 1, 2). Building on their previous educational experiences, students should address problems scientifically from the very beginning of their first undergraduate science course (3). Accordingly, we wanted to create an interactive and straightforward way to introduce students to the scientific method at the start of the fall term. We taught this lesson at the end of the first week in an introductory biology course on molecular and cellular biology, although the lesson is appropriate for any introductory biology course. We also used this lesson to introduce students to how clickers would be used throughout the course, as a means for promoting peer-learning through discussion and identifying misconceptions or points of confusion (4,5). A final goal of this lesson was to inform students, many of whom are in their first semester of college, that undergraduates can make critical contributions to the research being conducted by faculty at their institution. We therefore chose to focus this lesson around research that involved undergraduate student researchers.

The lesson consists of an interrupted case study, where students are guided through an experimental investigation, interspersed with clicker questions and worksheet prompts. We chose this format because it mimics the process of real scientists working through a problem, thus reinforcing the steps of the scientific method (6,7). The case study approach has been used previously to enable students to apply the scientific method in a manner similar to published studies (e.g., 8, 9). By using clickers, or another personal response system, with peer discussion, students in a large class can be actively engaged as the case progresses (10). This format is popular among science faculty (7), and many examples of interrupted "clicker" case studies can be found in case study repositories, such as the National Center for Case Study Teaching in Science (http://sciencecases.lib.buffalo.edu/cs/).

Brood Parasitism in Birds: The case of the American Coots

This lesson takes students through a published study of American coots (*Fulicula americana*), a common bird in North America. Female coots lay eggs in each other's nests, a phenomenon known as conspecific brood parasitism. This study specifically asks how parents recognize their own young so they can preferentially allocate resources to their genetic offspring. Here, we provide some relevant information that will help the instructor gain a better understanding of the experimental system and related evolutionary questions.

Natural history of American coots

American coots are dark-gray waterbirds with white beaks that breed in many ponds and lakes throughout the Central to Western United States and Canada. Although coots can superficially resemble ducks, they are actually members of the rail family, and thus are more closely related to cranes. During the breeding season, male and female coots form pairs and together defend territories, build nests, and care for young. Nests are typically constructed on the water from dried or fresh vegetation from the previous year (e.g., bulrushes, cattails; 11). Females lay 4-15 eggs (median = 9 eggs), and these eggs hatch over 2-11 days (median = 6 days; 12). Coot chicks can begin to move in and out of the nest within six hours after hatching but are fed by their parents for 10-40 days before becoming independent. During this time, parental care is not distributed equally across the brood. For example, in a brood with no parasitic chicks, parents tend to favor the youngest chicks once the oldest chicks have begun to forage for themselves (12). Parents also favor chicks that have bright orange ornamental plumage over those chicks whose ornamental plumage has been artificially removed (13; and see 14 for a case study related to this research). Without adequate parental provisioning during the first couple of weeks, chicks will die of starvation, and nearly half of all chicks die before reaching independence (12).

Evidence of brood parasitism in coots

The considerable loss of offspring due to starvation suggests that parental care is a limiting factor in the reproductive success of American coots. Laying eggs in the nests of other birds (i.e. brood parasitism) represents a potential mechanism to increase fitness by outsourcing the high costs of parental care (15). Some brood parasites lay eggs in the nests of other species, called interspecific brood parasitism, and never make their own nests (e.g., European cuckoos, *Cuculus canorus*, and brown-headed cowbirds, *Molothrus ater*). American coots are among the many species that practice conspecific brood parasitism, in which females lay eggs in nests of members of their own species, often in addition to laying eggs in their own nest (15,16). American coots exhibit high rates of conspecific brood parasitism, with about 40% of nests containing at least one parasitic egg (17).

An evolutionary puzzle: Why care for parasitic chicks?

The costs of interspecific brood parasitism on hosts are clear: host birds that accept parasitic chicks of other species pay the cost of caring for unrelated offspring. Furthermore, parasitic chicks can either actively kill off host offspring or outcompete them for access to parental resources. In contrast, it may seem that raising conspecific brood parasites would be less costly than raising interspecific brood parasites; however, parasitic chicks of the same species are unlikely to be related to either of the host parents (18). Thus, hosts of conspecific brood parasites pay similar fitness costs as hosts of interspecific brood parasites (19). Consequently, selection has favored various forms of anti-parasitism defense mechanisms. For example, many hosts of interspecific brood parasites have evolved to recognize and reject parasitic eggs laid in their nests (20). This egg rejection behavior has also been documented in hosts of conspecific brood parasites, including American coots (19). While egg recognition and rejection are widespread among hosts of brood parasites, very few hosts have evolved the ability to recognize and reject parasitic chicks. In the case of interspecific brood parasitism, this lack of ability to recognize and reject parasitic chicks can produce surprising scenarios in which a smaller host unwittingly provides food to a much larger parasitic chick. To date, there are three hosts of interspecific brood parasites that have been shown to recognize parasitic chicks and reject them by either abandoning the nest or removing the suspected parasite chick (21-23). In the research article that is the subject of our case study, Shizuka and Lyon showed that American coots have evolved the capability to reject parasitic chicks of their own species, which is, currently, the only example of this behavior in hosts of conspecific brood parasites (24).

American Coots Learn to Recognize Their Own Young

Long-term monitoring suggests that parasitic young have significantly lower survival compared to the genetic young of the host parents, suggesting that host parents are able to distinguish between their own chicks and parasitic chicks (24). The goal of the study by Shizuka and Lyon was to determine how coot parents differentiate between their own young and parasitic young (24). Previous studies revealed the key finding that, since parasitic females only lay eggs in nests that already have at least one egg, host eggs will tend to hatch before parasite eggs because the first eggs will be more developed than those laid on subsequent days. Building on these field

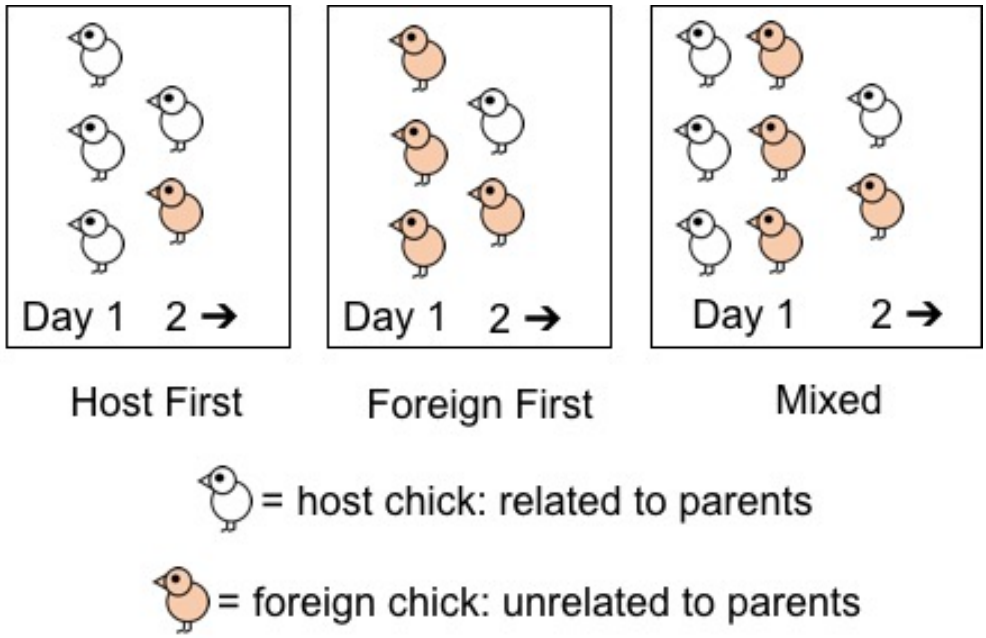

Figure 1. Diagram of the experimental design used in the focal study for the lesson (figure adapted from Shizuka and Lyon; 24).

observations and conversations that included undergraduate field assistants (see Supporting Video S1), Shizuka and his research team hypothesized that parents consider the first-born chick to be their own and use certain traits of these chicks (e.g., visual, auditory, or olfactory cues) as a reference to identify their genetic offspring. This strategy would provide parents with a reliable mechanism to prevent the rejection of their own young.

To test their hypothesis, the research team conducted three experiments in which they simulated brood parasitism, by adding foreign chicks to a brood and manipulating the order that 'host' and 'foreign' chicks hatched (Fig. 1). In the first condition, all the chicks that hatched on the first day belonged to the host parents. In the second condition, all the chicks that hatched on the first day were foreign. In the third condition, a mix of host and foreign chicks hatched on the first day. In all conditions, a mix of host and foreign chicks hatched on subsequent days. A detailed description of these experiments can be found in the original manuscript (24).

For each condition, the researchers compared the survival of host and foreign chicks. In the first condition, host chicks had higher survival than foreign chicks confirming that parents can recognize their own chicks. In the second condition, foreign chicks had higher survival than host chicks, providing strong evidence that parents use the first chicks as a reference, even when these chicks are not their own. There was no difference in survival in the third condition demonstrating that the parents cannot recognize their own chicks when the reference information provided on the first day is unclear.

Given that a brief introduction to American coots can provide students with sufficient background knowledge to develop testable hypotheses, this study serves as an accessible and interesting example of the scientific method in action. The case study described here uses this study as a context for students to distinguish between hypotheses and predictions and make graphical predictions that can be visually compared to study results. Students interpret and draw conclusions from the experimental data, and consistent with the experiences of most scientists, this study yields as many questions as it does answers (e.g., what characters do parents use to recognize their chicks?). This case study captures the iterative nature of science and emphasizes how new research changes our understanding of the natural world.

Intended Audience

This lesson is intended for students in an introductory biology course at the beginning of the term. It assumes little to no background in biology and could be implemented in majors and non-majors courses as well as high school biology classes. We also provide recommendations for how it could be adapted for upper-division courses. This case study was piloted in two large sections (>200 students each) of introductory molecular and cellular biology at the University of Nebraska-Lincoln. This course is the first in a two-semester series that serves as the foundation for biology-related programs. Most students in this course are in their first or second year of college and have declared a major in a life sciences field (Table 1).

Table 1. Breakdown of student level and major, aggregated across the two sections in which this lesson was taught; both sections had enrollments of more than 200 students.

Level	**# of Students**
First-Year	229
Sophomore	134
Junior	72
Senior	29
Post-Baccalaureate	4
Major	**# of Students**
Life Science	307
STEM, Non-Life Science	45

Table 2. Overview of the lesson plan with suggested timing for each step.

Activity	Description	Time	Notes
Preparation for Class			
Instructor reads original paper on which the lesson is based		30 minutes	Shizuka & Lyon. 2010. Coots use hatch order to learn to recognize and reject conspecific brood parasitic chicks. Nature 463: 223-226
Instructor prepares in-class handout	Make one copy of handout for each student * Instructor may decide to remove axes provided for graphical predictions	10-30 minutes to review and modify, if needed	Handout is provided in Supporting File S2
Class Session			
Instructor introduces the scientific method	• Go over learning objectives • Pass out handout • Introduce scientific method	10 minutes	• Lecture slides with notes are in Supporting File S1 • Student handout is in Supporting File S2
Students watch video of coot chick being harassed by parents	• Introduce video • Watch video • Discuss observations	3 minutes	• Link provided in lecture slides • After the video, ask students to explain what happened
Instructor provides background information	• Natural history of American coots • Parasitism and brood parasitism • Provide pertinent background knowledge	7 minutes	• During the lecture, instructor should pose questions to students and allow volunteers to share their answers
Students form hypotheses		3 minutes	• Students should work in groups to come up with hypotheses • Students volunteer their groups' hypothesis
Instructor explains experiment by Shizuka & Lyon	• Provide hypothesis tested in Shizuka & Lyon • Experimental design	5 minutes	• In a higher level course, students could come up with experimental design on their own
Students make graphical predictions	• Host first condition • Foreign first condition	2 minutes	• Students should work in pairs or groups to come up with their graphical predictions
Students report back with clickers and discuss graph interpretations	• Host first condition • Foreign first condition	5 minutes	• Show the actual results and explain the graph • Discuss other possible interpretations • Discuss interpretations of other options
Instructor provides additional details and students make graphical predictions for 'mixed' condition	• Explain the mixed condition • Have students draw graphical prediction • Report back with clickers	5 minutes	• The mixed condition supports that parents are using the chicks that hatch on the first day to learn what their chicks look like
Students draw conclusions from the evidence and the instructor wraps up the lesson	• Prove vs. Support • Review scientific method • Place study in broader context	10 minutes	• Emphasize that the scientific method is iterative • This study has implications in many fields and the broader context can be tailored to the specific course
After Class			
Students watch video of Dr. Shizuka	In this video, Dr. Shizuka discusses this study and the research team, which included undergraduates	11 minutes	• Can be shown at the end of class, or provided to students outside of class • Video is provided in Supporting File S3

Level	# of Students
Non-STEM	67
Undeclared	49
Total # of Students	468

Required Learning Time

We taught this lesson during a 50-minute class period and provide a timeline of lesson presentation in Table 2 (on page 4). During the final 5-10 minutes, one of the authors of this lesson (D.S.), who was also involved in the original research on which the lesson is based, spoke to the students about his personal experience with this research project. In the supplement, we have included a 10-minute video of Dr. Daizaburo Shizuka sharing his experiences, which can be shown in class or provided to the students to watch outside of class. If provided outside of class, we suggest it be made available to the students after the lesson, since the lesson assumes the students are naive to the hypotheses and results discussed in the video (Supporting File S3).

Pre-requisite Student Knowledge

We taught this lesson on the third day of the term to introduce students to the scientific method and skills that they would use throughout the course as well as in other life sciences courses. Students will benefit from some basic knowledge of how to draw and interpret bar graphs.

Pre-requisite Teacher Knowledge

Instructors should read Shizuka and Lyon's short article so that they are familiar with the experiment presented in the lesson (24). The description provided with the case study, the original research article, and the PowerPoint notes should provide sufficient background information and experimental details for an introductory biology instructor to implement the case study and field related questions.

SCIENTIFIC TEACHING THEMES

Active learning

Throughout the lesson, students discuss answers and ideas in small groups. These discussions focus on key steps of the scientific method. After watching a video of coot behavior, the students describe what they saw to each other and some groups share their observations with the whole class. Similarly, groups discuss and share hypotheses and conclusions based on the evidence as students move through the case study. As a result, students interact with the material in a way that reflects the process of a team of scientists conducting collaborative research. Students also work in groups to come up with graphical predictions that would support the tested hypothesis. After drawing these predictions on their worksheets, students use handheld "clicker" devices to indicate which figure, from four provided options, most closely matches what their group's answer.

Assessment

Students answer clicker questions during the lesson and receive immediate feedback on their answers. In our pilot implementations, we did not score these questions for points, since it was the first week of the semester and not all students had acquired a clicker. On the first exam, we asked students to apply the skills they learned in this lesson to a new scenario; specifically, a multiple-choice question asked the students to select the correct graphical prediction that supports a given hypothesis. We provide this exam question and two additional questions we did not use on the exam due to time and space (Supporting File S4). The first question asks students to differentiate between hypotheses and predictions asked in a multiple-true/false (T/F) format, and the second is a short-answer question that asks students to form a hypothesis, design an experiment, and make predictions based on a given observation. These questions could be given to students either as homework or on an exam.

Inclusive teaching

This lesson allows students to discuss and share their ideas with their peers prior to answering clicker questions and incorporates multiple ways for students to interact with the scientific method, including participating in discussions, drawing graphs, and watching videos. By sharing stories from the field, Dr. Shizuka highlights the collaborative nature of scientific research and emphasizes how undergraduate students can make key contributions to the formation of research questions, hypotheses, and experimental design. Moreover, this narrative contradicts the misconception that scientific research follows a predetermined path. In fact, Dr. Shizuka and his research team began with a set of expectations, but allowed their research and hypotheses to be guided by unexpected observations and outcomes.

LESSON PLAN

During class, students follow along with a PowerPoint presentation (Supporting File S1) using a handout (Supporting File S2) that can be collected and graded, if desired. The lesson starts with a brief overview of the scientific method that walks students through an everyday example and highlights that scientific studies are motivated by observations and questions. Students watch a short video of a coot chick being harassed by an adult and record their observations on the handout. Students share their observations with the class, and the point is made that this behavior is more aggressive than typical interactions between parents and their apparent offspring. The instructor then provides background information on coot natural history and brood parasitism (see Supporting File S1). This discussion is followed by further exploration of parasitism and familiar parasites, including ticks, lice, and 'zombie ants' (see 25). These examples are used to introduce the defining feature of parasitism (i.e., exploitation of a host for resources), and this concept is then related to brood parasitism in which the parasite exploits its host specifically for parental care.

At this point, the students recognize that adult coots can be overly aggressive with chicks and that not all the chicks in their nest belong to them. These observations lead to the research question, "How do the parents know which chicks belong to them?" The next step in the scientific method is to gather background knowledge, so students receive some key information and use this information to form a hypothesis that answers the research question. After students share their diverse hypotheses, the instructor reveals that a group of researchers has investigated this exact question and tells the students what these researchers hypothesized. Here, the instructor can emphasize that this research is published in one of the most prestigious biology journals and that it was performed by a team that included undergraduate researchers.

Students then separately consider the first two experimental conditions and construct bar graphs predicting results that would support the researchers' hypothesis. Students report their predictions via clicker questions in which they match their graph to one of several potential graphs. Students then see the actual experimental results, which have been redrawn as bar graphs from the original research article. The instructor describes key features of the graph and prompts students to draw conclusions based on the results, after which, the instructor summarizes how the results support the original hypothesis.

In our course, we also use these results as an impetus to discuss natural selection. Given that survival for both host and foreign chicks is less than 100%, we ask students to explain why survival is less than 100% and how these survival rates relate to natural selection. This discussion complements the first chapter of most introductory biology textbooks, which provides an overview of the conditions necessary for natural selection (e.g., 26-28).

Next, students consider the third treatment group in which there is an even mix of host and foreign offspring hatching on the first day. Again, students graphically predict survival for host and foreign chicks, check in with a clicker question, see the experimental results, and draw conclusions. At this point, the instructor brings all the evidence together in a synopsis of the final conclusions.

To relate the experiments to the scientific method, students answer an additional clicker question that addresses the proper language for discussing hypotheses and results, specifically distinguishing between "support" versus "proof." The instructor then returns to the diagram of the scientific method and points out that the conclusions from one study often serve as the observations for subsequent studies. Alternatively, if a hypothesis is refuted, then the investigator would form new hypotheses to test and the cycle continues.

Finally, the case study takes a step back and talks about how this study proceeded from the perspective of the researcher. In our course, we had the privilege of having Dr. Shizuka, the lead author of the original study, share a brief anecdote on how the project originated and how undergraduate researchers were involved in forming the initial question, identifying potential hypotheses, and conducting the cross-fostering experiments in the field. We have included a video with a similar narrative as supplement for instructors to share with their class (Supporting File S3).

TEACHING DISCUSSION

We taught this lesson in two sections of an introductory biology course (LIFE 120) at the University of Nebraska-Lincoln during the fall semester. We used this lesson to introduce students to the scientific method, which they will use throughout the course and in other science courses. We chose to base the lesson on a published scientific study to demonstrate that scientific research can be accessible even without an extensive scientific background.

Overall, students seemed engaged during the lesson based on their willingness to share ideas and the fact that groups distributed around the lecture hall volunteered answers. The video of an adult coot attacking a coot chick helped provide a graphic 'hook' that elicited an audible reaction from students and drew them back in if their attention had waned during the overview of the scientific method. After watching the video, we asked students to share what they observed and several students volunteered. We were also impressed with the hypotheses the students came up with to explain how parents recognize their own offspring. Many of the hypotheses volunteered by students focused on the mechanism of how to distinguish between different birds (e.g., coloration or sound), rather than how to identify which birds are one's own offspring (e.g., hatch order). Several groups came up with the hypothesis tested by Shizuka and Lyon, and one group hypothesized that coots learn from previous parenting experience, a variable that the researchers themselves took great efforts to address in their study.

While students were discussing their graphical predictions, we walked around the classroom to check in with groups. The teaching team for the course consisted of the instructor (B.A.C.), a postdoctoral researcher (J.K.H.), and two to three undergraduate learning assistants per section. During group discussions, the teaching team would circulate among groups, ask probing questions, and answer clarification questions. During this time, we noted that some groups were struggling with drawing the graphs. This difficulty was also evident on the worksheets we collected, but the clicker data indicated that students largely selected the correct answer (>90%). This discrepancy could be due to (1) students effectively explaining their logic to each other and converging on the correct answer or (2) students having difficulty generating graphs *de novo* but being able to interpret pre-made graphs. Thus, we encourage instructors to do a similar informal assessment of their students' ability to draw these graphs before seeing an example.

Several students approached Dr. Shizuka at the end of each class to ask about research opportunities, suggesting the lesson successfully encouraged some students to ask questions or consider getting involved in undergraduate research. Students completed a mid-semester feedback survey regarding the course, and while the focus of this survey was not specific to this lesson, a handful of students commented that they considered this case study to be helpful for their learning. For example, one student said, "The scientific method example was very helpful to me to revisit the scientific method process. I liked that we were able to see examples and explanations that were wrong and explanations that were correct."

Improvements

After teaching this lesson to two introductory biology sections, we suggest the following improvements:

- Walk the students quickly through the steps of the scientific method using the animated diagram in the PowerPoint presentation. The instructor should come up with a relatable example that does not require much explanation. We used the example of getting a headache in a certain environment and trying to figure out the cause through experimentation. While moving through the coot study, be sure to highlight each step of the scientific method and reiterate what happens in that step.
- To assess the first learning objective of applying the steps of the scientific method, instructors could incorporate additional clicker questions to 'check in' with students throughout the lesson regarding which step they just completed or which step comes next.
- A surprising number of students struggled to construct graphs, but most selected the correct graph for the cognate clicker question. This finding underscores that it should not be assumed that students have even a novice understanding of graphs and that it is important to let students produce their own representations before

selecting from pre-made options. Instructors should also prompt students to reflect on whether their constructed graphs match the graphs on the PowerPoint, even if they answered the clicker questions correctly. Furthermore, instructors may wish to collect a small sample of students' hand drawn graphs and display some of the examples to the class by using a document camera, showing a cell phone image, or reproducing graphs on a tablet.

- Instructors should take the time to discuss why each answer is correct and other possible outcomes or interpretations. This need is particularly important for conditions two (foreign first) and three (mixed), since these experiments serve as important controls to support the tested hypothesis by eliminating alternative explanations.

Adaptations

We taught this lesson in the first week of an introductory biology course with the main goal of introducing students to the scientific method. Given this scenario, we purposefully kept the lesson quite simple, but here we provide suggestions to make the lesson better suited for a more advanced course or stage in the term.

Instructors may prefer a more 'flipped' version of this lesson in which background information on the scientific method and parasites is presented outside of class as videos or readings. We suggest the following:

- Cut down the lecture covering the scientific method by using this SciShow video that provides an overview and some history of the scientific method: The Times and Troubles of the Scientific Method https://youtu.be/i8wi0QnYN6s
- Cut down on the lecture covering parasitism by using this BBC wildlife video that provides background on and examples of brood parasites. This video also provides subtle hints regarding the importance of hatch order in recognizing parasitic chicks: https://youtu.be/4Mb0GOITRUU
- On the handout (Supporting File S2), questions 2, 3, and 5 ask students to write down information provided by the instructor. While these are low-level questions, their purpose is to ensure the students have the necessary information to answer subsequent questions. We have provided alternative, more challenging versions of these questions on the last page of the handout. Instructors should note that these will require more class time and may need to be highlighted in the PowerPoint slides (Supporting File S1).
- Rather than providing students with the experimental design used by Shizuka and Lyons (2010), require the students to come up with an experimental design to test their own hypothesis. For example, students may choose to test the hypothesis that coot parents identify their genetic offspring as the chicks that are most numerous in the nest, which could be tested by constructing nests with different proportions of host and foreign offspring. This deviation would likely require more time and lead to a broad diversity of different answers.
- Rather than providing the axes and explicit instructions for drawing graphical predictions, require students to come up with the appropriate graphical representation and how to arrange the axes (independent and dependent variables). The instructor could also modify the clicker answer options to include distractors that show different graph types and outcomes.
- To further assess the fourth learning objective of drawing conclusions from data presented in graphical form, instructors could ask an additional clicker question or have a group discussion regarding the conclusions.
- Instructors could add a question or discussion that asks students how they would proceed if the tested hypothesis had not been supported by the results, which would help emphasize the cyclical nature of the scientific method.
- Rather than ending where the study does, require the students to come up with a follow up question (e.g., what character do they use, does learning persist for subsequent seasons, what is the cost of a mistake) and have them follow the steps of the scientific method to develop and test a hypothesis.
- Instructors may also use this lesson to achieve learning goals related to natural selection and parasitism depending on the scope of their course. For example, instructors could use a follow up lesson to understand coot behavior within a broader evolutionary context by having students consider the costs of raising unrelated offspring.
- More generally, we hope that instructors will use this case study as a template from which to create new cases based on research by faculty in their own department.

SUPPORTING MATERIALS

- S1. Knowing your own: Lecture presentation slides
- S2. Knowing your own: In-class handout for students
- S3. Knowing your own: Video of Dr. Shizuka
  - Introduction - 0:00 to 1:32
  - Observation 1: Parents can recognize parasitic chicks - 1:32 to 3:24
  - Observation 2: Adoption of own offspring - 3:24 to 4:45
  - Experimental Design: Trial & Error - 4:25 to 6:02
  - Observation 3: The 'aha moment' - 6:02 to 7:38
  - Undergraduate assistants are valuable members of a research team - 7:38 to 10:45
  - Credits - 10:45 to 10:58
- S4. Knowing your own: Follow up homework/exam questions

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