A Remote Introductory Biology Lab Using Backyard Birdwatching to Teach Data Analysis and Communication

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Abstract

Asking questions, designing experiments, collecting data and interpreting those data, and communicating the results are some of the most important concepts an undergraduate biology lab can teach students. When the SARS-CoV2 pandemic forced our institution to transition to online learning in the middle of the spring 2020 semester, I was faced with the dilemma of converting a large laboratory course normally structured around active and guided inquiry labs, into an online course, while still covering the planned subject material. To that end, I developed this multi-week lab exercise featuring birdwatching to give students a chance to collect real-world data and use that large, complex dataset to answer an ecological question of their choosing. For this exercise, students were instructed to watch birds at their homes or where they were quarantining, and record a number of different parameters and observations twice a week for three weeks. All records were compiled across the entire class of 347 students. Students were then asked to pick an ecological question that could be addressed with these data, and use the full dataset and a PivotTable to generate a chart summarizing the data relevant to their question. The final project consisted of developing an infographic summarizing the key question and findings of their study in language geared toward the birdwatching public. This exercise gave students the opportunity to explore the scientific process including hypothesis development, data collection, analysis and summarization while still feeling connected to a larger class project.

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Learning Goal(s)

Students will:

- understand how to use complex datasets to address specific questions.
- understand the scientific process in the context of this assignment.

Learning Objective(s)

Students will:

- develop a prediction and a testable hypothesis based on class-collected data.
- use a PivotTable to summarize a complex dataset to address the specific question.
- interpret results of the experiment and summarize the findings in an engaging way.

INTRODUCTION

Introductory biology labs provide the perfect environment to introduce students to the scientific process and cultivate an interest in biology as a whole. The importance of teaching the process of science to students has been widely recognized (1-3) and the idea of using active teaching and learning strategies has gained widespread attention (4). Recent studies have highlighted the importance of using inquiry-based lab exercises to enhance student learning (5-7) and the use of real-world data can help students conceptualize the scientific process in an engaging way (1,3,8).

When the SARS-CoV-2 pandemic swept the nation in the spring of 2020, William & Mary, like many colleges and universities around the world, made a quick pivot to online teaching. This was difficult for lecture-based courses, but even more difficult for labs designed to be hands-on. Virtual labs are becoming more popular as colleges and universities struggle with budget shortfalls, and while these can help enhance student learning (8-9), they cannot completely replace the range of experiences of being in the lab (8). My Introductory Biology Lab course is a hands-on, lab course employing interactive, inquiry-based labs to emphasize principles of biology and scientific writing. In a typical semester, students in my spring course would cover concepts of evolutionary biology and ecology. We were in the midst of a transition to phylogeny, speciation, diversity and ecology when we were forced online by the pandemic. With around 350 students spread all over the world, working in different time zones and in different home

environments, online, asynchronous content delivery seemed to be the best option. My goal with the second half of the remote-learning semester was to develop labs that continued to highlight important concepts like the importance of diversity and human impacts on the local environment, emphasizing and using skills of data analysis and not relying on canned, fill-in-the-blank type lab exercises. I wanted students to still get the experience of collecting data themselves and collaborating together to pool their data into a large dataset where ecological questions could be addressed.

I chose to use backyard birdwatching as the subject of this lab because of the widespread appeal of this activity and the accessibility of birdwatching to the vast majority of students, regardless of their quarantine or stay-at-home restrictions. While not aware of any similar college-level lesson, I have participated personally with citizen science aspects of Cornell Lab of Ornithology's FeederWatch program, which served as the inspiration for this project. In this exercise, each student was tasked with watching birds from their current location. Importantly, neither specialized equipment (binoculars, spotting scopes, etc.) nor bird identification skills were required for this exercise. Students collected and reported basic information about their viewing location including broad geographic location (east of Mississippi River, west of Mississippi River, Canada, South America, etc.), location classification (urban, suburban, rural), vegetation category (many tall trees, few tall trees, shrubs only, etc.), and resource availability (presence of bird feeders, bird baths, or natural water sources). On two consecutive days each week for three weeks, students observed birds for 15 minutes and recorded time of day (early morning, late morning, early afternoon or late afternoon), temperature, weather (sunny, cloudy, rainy, etc.) as well as the total number of birds observed, the number of species of birds observed (species identification was not required), the most common bird observed (identified as best as possible using provided guidance) and the most common behavior observed (classified into broad categories like preening, feeding, soaring, etc.). Data were pooled for the entire class of over 350 students into an impressively large dataset. Students were asked to think about the data they collected and choose a question to address using the dataset with some instructor-provided guidance. Questions were centered on the relationship between time of day, weather, local resources, provided resource or geographic location and the number of birds or the number of species of birds, specific species or common behaviors of birds observed. For example, students might decide to ask if the location classification of the birdwatching site affected the number of birds observed. The size of this dataset provided a perfect opportunity for students to use Microsoft Excel's PivotTable feature to summarize particular aspects of these data.

The PivotTable allows users to quickly generate averages, sums, counts, and other basic statistical information like standard deviation and variation from data with categorical attributes. For example, in this project, one of the categorical variables students reported was location: urban, suburban or rural. Quantitative counts of number of birds observed and number of species observed were reported for each of six observation periods for each student. Using the PivotTable, users could select "location classification" as a field, and the PivotTable will group all data into those three categories,

displaying the summarized values (such as average) for the quantitative fields in each category, vastly reducing the amount of time required to generate these data by sorting fields and computing summary values manually. In this manner, students could quickly compare the average number of birds observed in each observation period for each location category (urban, suburban and rural). Data from the PivotTable were used to generate a chart which, with a figure legend, was the central feature of the final project. This final project was an infographic where students presented their question and results as an informative poster designed to be viewed by a lay audience in a home improvement or bird enthusiast shop. Prior to this point, students had been tasked with generating multiple charts in Excel and had received feedback on writing figure legends. All student work could be conducted remotely and submitted to our learning management system (LMS, Blackboard, in our case) for evaluation. While not ideal, this solution did provide a way for students to be engaged in a class-scale project, collect real-world data, and analyze the resulting dataset using easily accessible tools.

Intended Audience

At William & Mary, the Introductory Biology course operates as a lecture and an independent lab course over two semesters. Students in this course cover topics of molecular, cellular and developmental biology in the fall semester, while the spring semester is devoted to topics of evolutionary biology and ecology. Students enrolled in this course are primarily (~75%) freshman and are both majors and non-majors. Typical enrollment in the spring semester of the lab course is 325-350 students organized into 16-17 sections of 20-24 students each. This experiment was developed as part of the ecology content block in the second semester of the lab course after the abrupt transition to online instruction due to the SARS-CoV2 pandemic.

Required Learning Time

Normally, this lab course meets once a week for 2 hours 50 minutes with an additional 50 minute discussion section. After the transition to online delivery, the discussion was converted to a 20-30 minute recorded lecture and the lab material designed to be completed in under 3 hours. For this assignment, students observed birds for 15 minutes on two consecutive days per week for three weeks (total of 6 observation sessions) while completing other weekly assignments. Students submitted data sheets weekly and entered summarized information into a shared class Google Sheet. This required <10 minutes per week. One week into the three week project, students submitted an outline with their selected question, a suitable hypothesis and a sketch of what they thought their chart would look like if their hypothesis was correct. Feedback was given to every student. The last week of the semester, the weekly lab assignment was devoted to using the class-generated data to generate a chart and an infographic summarizing the findings. Each student's infographic was graded by one of 9 graduate teaching assistants.

Prerequisite Student Knowledge

In this course, I placed emphasis on scientific writing skills and particularly emphasized hypothesis development, experimental design, data collection and summarization as well as interpretation. Prior to the lab described here, students had been given multiple assignments involving the crafting

of charts in Excel and writing succinct and accurate figure legends. In the weeks leading up to this lab, students carried out two assignments involving the use of Microsoft Excel PivotTables to distill large datasets and create charts intended to present those summarized results. Students received feedback on these charts as well as the accompanying figure legends. For the assignment described here, no prior knowledge of or experience with songbird identification is required.

Prerequisite Teacher Knowledge

The instructor should be well-versed in Microsoft Excel and Google Sheets, if those platforms are used as described here. The instructor needs to have a solid, working knowledge of Microsoft Excel PivotTables including common problems that arise on both Windows and Apple computer systems. Experience with common songbird identification is useful but not required to handle student questions about bird identification.

SCIENTIFIC TEACHING THEMES

Active Learning

This lab was designed to be carried out individually and remotely due to the SARS-CoV-2 pandemic. In order to engage students in this experiment, students collected the bird observations themselves and contributed them to the class dataset analyzed by all students. Students were able to see their data contributions in the large dataset and recognized the value of contributing good data. Instructors may wish to emphasize that while not the typical in-class group activity, this type of data pooling is a form of collaboration even though students are not interacting directly with other students. Many students reported sharing their weekly bird observations with family members in their quarantined households, and several were able to convince other household members to be involved in the birdwatching observations even beyond the timeframe of this assignment.

Assessment

Students submitted digital datasheets detailing their observations for each session (two per week). Additionally, students were required to enter their summarized observations into a shared Google Sheet. These weekly contributions were scored on completion. Prior to the final project, students submitted a project outline in which they gave the question they selected for analysis, proposed a hypothesis, and submitted a sketch of a chart representing their expected results if their hypothesis was supported. If desired, it would be easy to modify this to include a drawing of the results if the hypothesis was not supported. These outlines were graded for completion, but extensive feedback was given on hypotheses and data analysis techniques. A final infographic was submitted by each student summarizing their results. The infographic was crafted for a general audience, something like what you might expect to see in an outdoor store or bird enthusiasts supply store. The infographic was graded based on a supplied rubric.

Inclusive Teaching

This lab was designed to be completed by students individually due to the quarantine conditions in place when it was delivered. Content was made available online and video walk-through demonstrations of PivotTable implementation were presented with captions. Students were allowed to complete bird observations and the final project at any time during the weekly window to accommodate students in different time zones and with different living situations. Observations did not require the use of any equipment and it was not necessary for students to fully identify all bird species seen in order to accommodate those without binoculars or with visual impairments. To accommodate those students whose living environment did not include views of natural spaces, YouTube live video channels of bird feeders hosted by the Cornell Lab of Ornithology were recommended. Online bird identification resources were also recommended for those interested in pursuing bird identification further.

LESSON PLAN

Weekly Bird Observations

Week 1

The basic structure of these observations was loosely based on the Cornell Lab of Ornithology's Project FeederWatch. Students were asked to perform weekly bird observations of 15 minutes on two consecutive days for three weeks for a total of six observation sessions, and were given detailed instructions about picking a viewing location, choosing the days and picking a time to watch birds (S1. Backyard birdwatching – Student Instructions). Importantly, for those students without access to a suitable viewing location, we recommended using the Cornell Lab of Ornithology Live FeederCams available on YouTube. In these cases, students reported site location data corresponding to that camera location rather than their physical location. Each observation day, students completed a Datasheet (S2. Backyard birdwatching – Student Datasheet) which included space for basic environmental data (time of day, temperature and weather conditions) and an area for bird tallies. Binoculars and bird identification experience was not required. Birds did not need to be identified, but instead could be described in general terms which allowed students to differentiate different species without full identification. For example, a student might observe two small brown birds with upturned tails and one black bird with a yellow beak. They could make notes about these descriptions and then record "brown bird" and "black bird" tallies with some confidence that the brown bird was the same species each time it was observed. Students were also asked to do their best to label the behaviors each bird did the most during the observation window. A list of behaviors was provided on the datasheet and included soaring/flying, preening/cleaning, feeding, fighting, perching or singing/calling. This is admittedly difficult to do, but I wanted to at least expose students to collecting these types of observations. Finally, students were asked to do their best to identify the most common bird and give the common name. Bird identification resources were provided in the Instruction document and students were encouraged to take pictures if possible and ask for help with tricky identifications. A pre-filled example datasheet was provided as an example (S3. Backyard birdwatching – Example Student datasheet). Completed datasheets were submitted on our learning management system (LMS) platform.

In addition to completing and submitting the filled datasheets electronically, we asked students to also submit the summarized data separately. This was necessary as this

class had 347 students and it was not possible for me or my teaching assistants to manually pull observations from each datasheet and compile it in a spreadsheet. I also felt that data entry was an important part of this experience. For the first week, I created a Google Form (W&M students have access to the full complement of G-Suite Apps) intended to collect basic information from each student about her/his viewing location (S4. Backyard birdwatching – Initial Google Form) such as general geographic location, location classification as rural, suburban or urban, local environment, bird resource availability, and day of the week chosen for observations. This form also included a section for the first week's bird observation summary. We asked students to report the time, weather information, temperature, total number of different types (species) of birds observed, total birds observed (all types/species combined), the most common bird observed, and the most common behavior observed. These summarized observations were reported for each observation day in that first week. A link to this form was emailed to all students. The responses from this Google Form were used to create the shared Google Sheet used in subsequent weeks (see section below).

<u>Weeks 2 and 3</u>

Observations were performed in subsequent weeks as described above. Students were still required to submit the Word datasheets on our LMS system. But rather than have students submit a Google Form each week that would then need to be compiled into a spreadsheet, I opted to require students to enter their summarized bird observations directly into the full Google Sheet spreadsheet (the Excel version of the final full spreadsheet is provided in S5. Backyard birdwatching – Final full dataset). Students were sent a link to the editable Google Sheet. Each student was randomly assigned a unique identifying number (UID). This was used to anonymize the data but still allow us to trace back observations to specific students. The basic site classification information did not change each week. To make it easier for students to find where they should enter data each week, I highlighted the appropriate columns in a different color for each week. We did occasionally have issues with students accidentally entering data in the wrong place or overwriting other student data, so I made copies of the Google Sheet periodically to give us a backup copy should something go wrong.

Outline

During the last week of bird observations, students were tasked with completing an outline of their final project (S6. Backyard birdwatching – Outline Instructions). Since at that point students had some experience with the types of data collected each week, they were given the flexibility to choose their own research question about backyard birds. I have found that when given complete flexibility, students in my course often struggle to find appropriate questions. So to assist in this process, I gave students a list of the variables they had collected and some example questions they might consider. There was still a good amount of flexibility in the example questions, and I found that while most students used the examples provided, some students took the initiative to craft creative questions using these examples. From the question they selected, students were asked to craft a hypothesis that explained the biology behind the question they selected, and a prediction if their hypothesis were true. Finally, students were

asked to sketch what their chart might look like if the data supported their hypothesis. This was intended to get students thinking about what kind of chart would be most appropriate and how they would structure the data. An example outline was provided. This outline was graded for completion and was mainly used as a mechanism for the students to receive detailed feedback from me or my teaching assistants.

Final Infographic Project

The final deliverable from this experiment was a digital infographic. The infographic was intended to be a very visual representation of the experiment, and was geared towards the general public. Students were instructed to use free platforms online to create the infographic and were given a rubric that would be used for scoring (S7. Backyard birdwatching – Infographic Instructions). Emphasis was placed on creativity and accurate interpretation of the scientific question asked. Up to this point, students had been given weekly practice on creating charts in Excel and writing figure legends. The previous two weeks of lab exercises involved using Microsoft Excel PivotTables to summarize large datasets. The data collected from the entire class was used by each student to generate a PivotTable and a final chart. Students were given the option to use one observation session or all six. A video walk-through was provided to help students use the PivotTable with this particular dataset (S8. Backyard birdwatching – Video walk-through). An example infographic I created with Piktochart was provided for reference (S9. Backyard birdwatching – Example Infographic). Open source images are available from within the Piktochart platform or images captured by students can easily be added. Please note that the infographic example was intended to be a template and as such uses a simple question that cannot be addressed using these data. This was intentional in order to avoid students copying the example or choosing the example question for analysis. The simplistic nature of this example was also intentional to push students to think hard about their own question. Extensive feedback given on the outline helped students develop an appropriately rigorous hypothesis. However, this example could easily be modified to provide more parallel guidance.

TEACHING DISCUSSION

Overall, I felt this lab experience achieved a number of goals. First, it gave students the experience of collecting data relevant to an ecological experiment while still honoring stay-at-home quarantine orders. Secondly, it introduced birdwatching as a hobby to students who may not have ever considered it. It had an added benefit of providing students with a stress-free activity and gave them a chance to relax while observing nature. Finally, I feel this lesson encapsulated the scientific process well while still giving students a chance to be creative and have ownership of the data and the question they decided to investigate. The final project infographic was well received and the submissions were very creative. Students commented that they enjoyed the process of creating the infographic and felt good about what they created. Many students commented that they enjoyed birdwatching so much that they involved parents, relatives and siblings in the weekly observations. Some have continued to watch birds and update me on interesting observations even after the semester ended.

While this project was originally created with my large class size in mind, it could easily be adapted to smaller class sizes. If a smaller class size were possible, instructors could choose to incorporate student feedback in the outline or final project evaluations or could choose to use a presentation-style final project rather than an infographic. Involving members of the community in the presentations would also be a nice addition, if quarantine conditions allow. This lab could also be easily adapted to in-person instruction and bird observations could be conducted as a class on-site rather than remotely, if conditions allow. One could also assign specific environments to student groups to change the types of questions asked of the data. If performed in a more advanced class, statistical analysis could be included and data could be analyzed in more advanced software packages like R or Python. Adding more observation sessions can be easily accomplished and could address broader questions of seasonality or migration. It would also be trivial to reduce the number of observation weeks if time was short.

While this exercise did not require expert-level bird identification skills, this novice-level expertise could generate some potentially confounding identifications. For example, some students might identify sexually dimorphic birds (like cardinals) as two different species. Additionally, students might misidentify similar birds as the same species (like grackles and starlings). Instructors may choose to highlight these limitations at the beginning of the project and provide some identification tips for common bird species. Alternatively, instructors may ask students to think about how potential identification issues might impact interpretation after the data are collected. Students could propose alterative experimental approaches or suggest additional experiments to further the conclusions draw from their analysis.

This exercise also highlighted the importance of proper data entry. For example, there were a few instances of students reporting temperature observations in Fahrenheit instead of Celsius. I chose to leave these instances in place and instruct students who chose to ask temperature-related questions to describe how they would deal with these instances either by making assumptions that student really meant to enter Celsius values and converting the numbers after the fact, or by omitting those entries which appeared erroneous. Data entry issues are common and I felt that leaving those errors in place could serve as an important teachable moment. If instructors chose, a quick quality control step could easily be added where students with mistakes in reporting data were contacted and asked to fix their entries.

SUPPORTING MATERIALS

- S1. Backyard birdwatching – Student Instructions
- S2. Backyard birdwatching – Student Datasheet
- S3. Backyard birdwatching – Example Student Datasheet
- S4. Backyard birdwatching – Initial Google Form
- S5. Backyard birdwatching – Final full dataset
- S6. Backyard birdwatching – Outline Instructions
- S7. Backyard birdwatching – Infographic Instructions
- S8. Backyard birdwatching – Video walk-through (includes link)
- S9. Backyard birdwatching – Example Infographic

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Table 1. Recommended teaching timeline for this lab project.

Activity	Description	Time	Notes
Weekly bird observations	1. Students watch birds for 15 minutes on two consecutive days for three weeks. 2. Students complete a Word Datasheet for each observation day (two per week) and submit to LMS. 3. Students summarize data from each bird observation session and report it on Google Form (Week 1) or Google Sheet directly (Weeks 2 and 3). 4. Instructor grades each week's submissions for completion only.	For the student: About 20 minutes per week. For the instructor: A few minutes per student.	• Weekly bird observations were assigned in addition to other weekly lab assignments. • Supporting File S1. Backyard birdwatching – Student Instructions. • Supporting File S2. Backyard birdwatching – Student Datasheet • Supporting File S4. Backyard birdwatching – Initial Google Form • Supporting File S5. Backyard birdwatching – Final full dataset
Outline	1. Students decide on a research question using provided examples. 2. Students write a hypothesis and prediction. 3. Students think about what the chart representing these data should look like and sketch it on the outline. 4. Instructor grades for completion but provides detailed feedback on hypothesis and data analysis technique.	For the student: Less than 1 hour. For the instructor: About 15 minutes per student.	• Supporting File S6. Backyard birdwatching – Outline Instructions
Data preparation	1. Instructor converts the Google Sheet data into an Excel file and makes it available to the class.	3-4 hours	• This involves looking for data entry mis-coding and typos as well as reorganizing the data into rows rather than columns to facilitate smooth PivotTable use.
Final Infographic Project	1. Students use the full dataset and Microsoft Excel PivotTables to analyze their chosen question. 2. Students use online platforms to design and create an infographic describing the research question and resulting data in an engaging way appropriate for a general audience.	For the student: Less than 3 hours. For the instructor: About 10 minutes per student.	• Students were given this assignment on the last week of class and were not assigned additional lab work. • Supporting File S7. Backyard birdwatching – Infographic Instructions. • Supporting File S8. Backyard birdwatching – Video walk-through of using a PivotTable. • Supporting File S9. Backyard birdwatching – Example Infographic.