Argument-Driven Inquiry in Biology

Lab Investigations for Grades 9–12
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Victor Sampson, Patrick Enderle, Leeanne Gleim, Jonathon Grooms, Melanie Hester, Sherry Southerland, and Kristin Wilson

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The Next Generation Science Standards (NGSS Lead States 2013) outline a new set of expectations for what students should know and be able to do in science. The overarching goal of the NGSS, as defined by the National Research Council (NRC) in A Framework for K–12 Science Education (NRC 2012), is

to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)

To accomplish this goal, teachers will need to help students become proficient in science by the time they graduate from high school. The NRC suggests that students need to understand four core ideas in the life sciences, be aware of seven crosscutting concepts that span the various disciplines of science, and learn how to participate in eight fundamental scientific practices in order to be considered proficient in science (NRC 2012). The three dimensions of the Framework, which form the basis for the NGSS, are summarized in Figure 1.

FIGURE 1
The three dimensions of the framework for the NGSS

<table>
<thead>
<tr>
<th>Life Sciences Core Ideas</th>
<th>Crosscutting Concepts</th>
<th>Scientific Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>From molecules to organisms: Structures and processes</td>
<td>Patterns</td>
<td>Asking questions</td>
</tr>
<tr>
<td>Ecosystems: Interactions, energy, and dynamics</td>
<td>Cause and effect: Mechanism and explanation</td>
<td>Developing and using models</td>
</tr>
<tr>
<td>Heredity: Inheritance and variation of traits</td>
<td>Scale, proportion, and quantity</td>
<td>Planning and carrying out investigations</td>
</tr>
<tr>
<td>Biological evolution: Unity and diversity</td>
<td>Systems and system models</td>
<td>Analyzing and interpreting data</td>
</tr>
<tr>
<td></td>
<td>Energy and matter: Flows, cycles, and conservation</td>
<td>Using mathematics and computational thinking</td>
</tr>
<tr>
<td></td>
<td>Structure and function</td>
<td>Constructing explanations</td>
</tr>
<tr>
<td></td>
<td>Stability and change</td>
<td>Engaging in argument from evidence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Obtaining, evaluating, and communicating information</td>
</tr>
</tbody>
</table>
The NRC also calls for teachers to use new instructional approaches that are designed to foster the development of science proficiency. This book will help teachers accomplish this task by providing a set of 27 lab investigations that were designed using an innovative approach to laboratory instruction called argument-driven inquiry (ADI). The lab investigations are aligned with the content, crosscutting concepts, and scientific practices outlined in the NRC Framework. These lab investigations allow students to develop the disciplinary-based literacy skills outlined in the Common Core State Standards, for English language arts (NGAC and CCSSO 2010), because the ADI instructional model calls for students to give presentations to their peers; respond to questions; and then write, evaluate, and revise reports as part of each lab. Thus, this book can help teachers make lab instruction more meaningful for students and enable students to learn more inside the school science laboratory.

References


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Kristin Wilson attended Florida State University and earned a BS in secondary science teaching with an emphasis in biology and Earth-space science. Kristin teaches biology at FSU School. She helped develop the ADI instructional model and was responsible for writing and piloting many of the lab investigations found in this book.
INTRODUCTION

The Importance of Helping Students Become Proficient in Science

The new aim of science education in the United States is for all students to become proficient in science by the time they finish high school. Science proficiency, as defined by Duschl, Schweingruber, and Shouse (2007), consists of four interrelated aspects. First, it requires individuals to know important scientific explanations about the natural world, to be able to use these explanations to solve problems, and to be able to understand new explanations when they are introduced. Second, it requires individuals to be able to generate and evaluate scientific explanations and scientific arguments. Third, it requires that individuals understand the nature of scientific knowledge and how scientific knowledge develops over time. Finally, and perhaps most important, it requires that individuals be able to participate in scientific practices (such as designing and carrying out investigations, constructing explanations, and arguing from evidence) and communicate in a scientific manner. Science proficiency, in other words, involves more than an understanding of important concepts; it also involves being able to do science.

In the past decade, however, the importance of learning how to participate in scientific practices has not been acknowledged in state standards. In addition, many states have attempted to make their science standards “more rigorous” by adding more content to them rather than designing them so they emphasize the core ideas and crosscutting concepts described by the National Research Council (NRC) in A Framework for K–12 Science Education (NRC 2012). The increasing number of science standards, along with the pressure to “cover” them that results from the use of high-stakes tests targeting facts and definition, has unfortunately forced teachers “to alter their methods of instruction to conform to the assessment” (Owens 2009, p. 50). Teachers, as a result, tend to focus on content and neglect the practices of science inside the classroom. Teachers also tend to move through the science curriculum quickly to ensure that they cover all the standards before the students are required to take the high-stakes assessment.

The current focus on covering all the standards, however, does not seem to be working. For example, The Nation’s Report Card: Science 2009 (National Center for Education Statistics 2011) indicates that only 21% of all 12th-grade students who took the National Assessment of Educational Progress in science scored at the proficient level. The performance of U.S. students on international assessments is even bleaker, as indicated by their scores on the science portion of the Programme for International Student Assessment (PISA). PISA is an international study that was launched by the Organisation for Economic Co-operation and Development (OECD) in 1997, with the goal of assessing education systems worldwide; more than 70 countries have participated in the study. The test is designed to assess reading, math, and science achievement and is given every three years. The mean score for students in
the United States on the science portion of the PISA in 2012 is below the international mean, and there has been no significant change in the U.S. mean score since 2000 (OECD 2012; see Table 1). Students in countries such as China, Korea, Japan, and Finland score significantly higher than students in the United States. These results suggest that U.S. students are not learning what they need to learn to become proficient in science, even though teachers are covering a great deal of material.

### TABLE 1

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S. mean score*</th>
<th>U.S. rank/Number of OECD countries assessed</th>
<th>Top three performers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>499</td>
<td>14/27</td>
<td>Korea (552)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Japan (550)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Finland (538)</td>
</tr>
<tr>
<td>2003</td>
<td>491</td>
<td>22/41</td>
<td>Finland (548)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Japan (548)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hong Kong-China (539)</td>
</tr>
<tr>
<td>2006</td>
<td>489</td>
<td>29/57</td>
<td>Finland (563)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hong Kong-China (542)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Canada (534)</td>
</tr>
<tr>
<td>2009</td>
<td>499</td>
<td>15/43</td>
<td>Japan (552)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Korea (550)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hong Kong-China (541)</td>
</tr>
<tr>
<td>2012</td>
<td>497</td>
<td>36/65</td>
<td>Shanghai-China (580)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hong Kong-China (555)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Singapore (551)</td>
</tr>
</tbody>
</table>

*The mean score of the PISA is 500 across all years.

Source: OECD 2012

In addition to the poor performance of U.S. students on national and international assessments, empirical research in science education indicates that a curriculum that emphasizes breadth over depth and neglects the practices of science can actually hinder the development of science proficiency (Duschl, Schweingruber, and Shouse 2007; NRC 2005, 2008). As noted in the Framework (NRC 2012),
INTRODUCTION

K–12 science education in the United States fails to [promote the development of science proficiency], in part because it is not organized systematically across multiple years of school, emphasizes discrete facts with a focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is actually done. (p. 1)

The NRC goes on to recommend that science teachers spend more time focusing on key ideas to help students develop a more enduring understanding of biology content. They also call for science teachers to start using instructional strategies that give students more opportunities to learn how to participate in the practices of science. Without this knowledge and these abilities, students will not be able to engage in public discussions about scientific issues related to their everyday lives, to be consumers of scientific information, or to have the skills needed to enter a science or science-related career. We think the school science laboratory is the perfect place to focus on key ideas and engage students in the practices of science and thus to help them develop the knowledge and abilities needed to be proficient in science.

How School Science Laboratories Can Help Foster the Development of Science Proficiency

Laboratory activities look rather similar in most high school classrooms (we define a school science laboratory activity as “an opportunity for students to interact directly with the material world using the tools, data collection techniques, models, and theories of science” [NRC 2005, p. 3]) (Hofstein and Lunetta 2004; NRC 2005). The teacher usually begins a laboratory activity by first introducing his or her students to a concept through a lecture or some other form of direct instruction. The teacher then gives the students a hands-on task to complete. To support students as they complete the task, teachers often provide students with a worksheet that includes a procedure explaining how to collect data, a data table to fill out, and a set of analysis questions. The hope is that the experience gained through completion of the hands-on task and worksheet will illustrate, confirm, or otherwise verify the concept that was introduced to the students at the beginning of the activity. This type of approach, however, is an ineffective way to help students understand the content under investigation, learn how to engage in important scientific practices, improve communication skills, or develop scientific habits of mind (Duschl, Schweingruber, and Shouse 2007; NRC 2005). Most laboratory activities therefore do little to promote the development of science proficiency.

One way to address this problem is to change the focus of laboratory instruction. A change in focus will require teachers to place more emphasis on “how we know” (i.e., how new knowledge is generated and validated) in addition to “what we know” about life on Earth (i.e., the theories, laws, and unifying concepts). Science teachers will also need to focus more on the abilities and habits of mind that students
need to have in order to construct and support scientific knowledge claims through argument and to evaluate the claims or arguments made by others (NRC 2012). As explained in the *Framework* (NRC 2012), argumentation (i.e., the process of proposing, supporting, and evaluating claims) is essential practice in science:

> Scientists and engineers use evidence-based argumentation to make the case for their ideas, whether involving new theories or designs, novel ways of collecting data, or interpretations of evidence. They and their peers then attempt to identify weaknesses and limitations in the argument, with the ultimate goal of refining and improving the explanation or design (p. 46).

The NRC therefore calls for argumentation to play a more central role in the teaching and learning of science.

In addition to changing the focus of instruction, teachers will need to change the nature of laboratory instruction to promote and support the development of science proficiency. To change the nature of instruction, teachers need to make laboratory activities more authentic by giving students an opportunity to engage in scientific practices instead of giving them a worksheet with a procedure to follow and a data table to fill out. These activities, however, also need to be educative for students in order to help students develop the knowledge and abilities associated with science proficiency; students need to receive feedback about how to improve, and teachers need to help students learn from their mistakes.

The argument-driven inquiry (ADI) instructional model (Sampson and Gleim 2009; Sampson, Grooms, and Walker 2009, 2011) was designed as a way to make lab activities more authentic and educative for students and thus help teachers promote and support the development of science proficiency inside the classroom. This instructional model reflects research about how people learn science (NRC 1999) and is also based on what is known about how to engage students in argumentation and other important scientific practices (Berland and Reiser 2009; Erduran and Jimenez-Aleixandre 2008; McNeill and Krajcik 2008; Osborne, Erduran, and Simon 2004; Sampson and Clark 2008).

**Organization of This Book**
The remainder of this book is divided into two parts. Part I begins with two text chapters describing the ADI instructional model and the development and components of the ADI lab investigations. Part II contains the lab investigations, including notes for the teacher, student handouts, additional information for students, and checkout questions. Four appendixes contain standards alignment matrices, timeline and proposal options for the investigations, and a form for assessing the investigation reports.
References


Application Labs


Teacher Notes

Purpose
The purpose of this lab is for students to apply what they know about animal behavior and the interactions among species and their environment to determine if bird migration patterns have been affected by climate change. This lab also gives students an opportunity to use an online database as part of their investigation. Students will also learn about the characteristics of science as a body of knowledge and the difference between data and evidence.

The Content
More than 650 species of birds nest in North America. Some are permanent residents and live in the same area year-round, but most of these species migrate during the year. Birds migrate from areas of low or decreasing resources to areas of high or increasing resources. The two most important resources that birds need are food and a nesting location. Birds that nest in the Northern Hemisphere tend to migrate northward in the spring to feed on insects or budding plants and to take advantage of the abundance of nesting locations. As winter approaches, and the number of insects and the availability of other food resources dwindle, the birds move south again. Escaping the cold of winter is also a motivating factor, but many birds can survive freezing temperatures as long they have enough food. The migration pattern of a bird usually falls into one of three categories:

- Short-distance migration: Moving only a short distance, such as from higher to lower elevations on a mountain, on a seasonal basis.
- Medium-distance migration: Traveling between one or more states.
- Long-distance migration: Traveling from the United States or Canada in the summer to Mexico or farther south in the winter.

The mechanisms that trigger the start of a migration vary from species to species. Some birds migrate in response to a change in day length or a change in temperature. Some species migrate when food becomes scarce or because of a genetic predisposition. There are some birds that migrate in response to a combination of triggers. Some of these triggers, such as temperature or food availability, may be influenced by changes in climate.
Warmer temperatures in the summer and more severe winters could lead to changes in the distances that birds migrate, where birds migrate to, and the timing of these migrations.

Timeline
The instructional time needed to implement this lab investigation is 180–250 minutes. Appendix 2 (p. 391) provides options for implementing this lab investigation over several class periods. Option E or G (250 minutes) should be used if students are unfamiliar with scientific writing because either of these options provides extra instructional time for scaffolding the writing process. You can scaffold the writing process by modeling, providing examples, and providing hints as students write each section of the report. Option F or H (180 minutes) should be used if students are familiar with scientific writing and have the skills needed to write an investigation report on their own. In options F and H, students complete stage 6 (writing the investigation report) and stage 8 (revising the investigation report) as homework.

Materials and Preparation
The materials needed to implement this investigation are listed in Table 13.1. The eBird database, available at http://ebird.org, is free to use and can be accessed using an internet browser; eBird is a real-time, online checklist program that was launched in 2002 by the Cornell Lab of Ornithology and the National Audubon Society. The All About Birds database (Cornell Lab of Ornithology; www.allaboutbirds.org), the National Weather Service database of the National Oceanic and Atmospheric Administration (NOAA; www.weather.gov), and the NOAA National Climatic Data Center database (www.ncdc.noaa.gov) are also free to use. You should access these websites and learn how they work before beginning the lab investigation. In addition, it is important to check if students can access and use the simulation from a school computer because some schools have set up firewalls and other restrictions on web browsing.

<table>
<thead>
<tr>
<th>TABLE 13.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials list</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer with internet access</td>
<td>1 per group</td>
</tr>
<tr>
<td>Student handout</td>
<td>1 per student</td>
</tr>
<tr>
<td>Investigation proposal C (optional)</td>
<td>1 per group</td>
</tr>
<tr>
<td>Whiteboard, 2' x 3'</td>
<td>1 per group</td>
</tr>
<tr>
<td>Peer-review guide and instructor scoring rubric</td>
<td>1 per student</td>
</tr>
</tbody>
</table>

*As an alternative, students can use computer and presentation software such as Microsoft PowerPoint or Apple Keynote to create their arguments.
Topics for the Explicit and Reflective Discussion

Concepts That Can Be Used to Justify the Evidence
To provide an adequate justification of their evidence, students must explain why they included the evidence in their arguments and make the assumptions underlying their analysis and interpretation of the data explicit. In this investigation, students can use the following concepts to help justify their evidence:

- Animals often engage in specific types of behaviors (such as migration) because these behaviors tend to increase reproductive success (or fitness).
- Animal behavior has both a proximate cause and an ultimate cause.
- Animal behavior can be influenced by a change in environmental conditions.

We recommend that you review these concepts during the explicit and reflective discussion to help students make this connection.

How to Design Better Investigations
It is important for students to reflect on the strengths and weaknesses of the investigation they designed during the explicit and reflective discussion. Students should therefore be encouraged to discuss ways to eliminate potential flaws, measurement errors, or sources of bias in their investigations. To help students be more reflective about the design of their investigation, you can ask the following questions:

- What were some of the strengths of your investigation? What made it scientific?
- What were some of the weaknesses of your investigation? What made it less scientific?
- If you were to do this investigation again, what would you do to address the weaknesses in your investigation? What could you do to make it more scientific?

Crosscutting Concepts
This investigation is well aligned with three crosscutting concepts found in *A Framework for K–12 Science Education*, and you should review these concepts during the explicit and reflective discussion.

- Patterns: Patterns are often used to guide the organization and classification of life on Earth. In addition, a major objective in biology is to identify the underlying cause of observed patterns, such as changes in the migration patterns of birds.
- Cause and Effect: Mechanism and Explanation: One of the main objectives of science is to identify and establish relationships between a cause and an effect. It is also important to understand the mechanisms by which these causal relationships are mediated.
• Stability and Change: This is perhaps the most relevant crosscutting concept to this investigation. Scientists must understand what makes a system, behavior, or an occurrence stable over time and the factors that lead to a change in the system, behavior, or occurrence.

The Nature of Science and the Nature of Scientific Inquiry
It is important for students to understand that scientific knowledge is both tentative and durable. A person can have confidence in the validity of scientific knowledge but must also accept that scientific knowledge may be abandoned or modified in light of new evidence or because existing evidence has been reconceptualized by scientists. There are many examples in the history of science of both evolutionary changes (i.e., the slow or gradual refinement of ideas) and revolutionary changes (i.e., the rapid abandonment of a well-established idea) in scientific knowledge. Scientific knowledge also varies in degree of certainty; some knowledge is well established and is not likely to change, whereas other knowledge represents only a conjecture. In this investigation, for example, the impact of climate change on the migration behavior of birds is not well understood and needs more research.

It is also important for students to understand the difference between data and evidence in science. Data are measurements, observations, and findings from other studies that are collected as part of an investigation. Evidence, in contrast, is analyzed data and an interpretation of the analysis.

You should review and provide examples of these two important concepts of the nature of science (NOS) and the nature of scientific inquiry (NOSI) during the explicit and reflective discussion.

Hints for Implementing the Lab
• Be prepared for groups to pursue different paths in completing the investigation.
• This is a very open-ended investigation, so flexibility is key.

Topic Connections
Table 13.2 provides an overview of the scientific practices, crosscutting concepts, disciplinary core ideas, and support ideas at the heart of this lab investigation. In addition, it lists NOS and NOSI concepts for the explicit and reflective discussion. Finally, it lists literacy and mathematics skills (CCSS ELA and CCSS Mathematics) that are addressed during the investigation.
### TABLE 13.2
Lab 13 alignment with standards

| Scientific practices | • Asking questions  
|                      | • Planning and carrying out investigations  
|                      | • Analyzing and interpreting data  
|                      | • Using mathematics and computational thinking  
|                      | • Constructing explanations  
|                      | • Engaging in argument from evidence  
|                      | • Obtaining, evaluating, and communicating information  
| Crosscutting concepts | • Patterns  
|                      | • Cause and effect: Mechanism and explanation  
|                      | • Stability and change  
| Core idea | • LS2: Ecosystems: Interactions, energy, and dynamics  
| Supporting ideas | • Animal behavior  
|                      | • Interactions  
|                      | • Resources  
| NOS and NOSI concepts | • Science as a body of knowledge  
|                      | • Difference between data and evidence  
| Literacy connections (CCSS ELA) | • Reading: Key ideas and details, craft and structure, integration of knowledge and ideas  
|                      | • Writing: Text types and purposes, production and distribution of writing, research to build and present knowledge, range of writing  
|                      | • Speaking and listening: Comprehension and collaboration, presentation of knowledge and ideas  
| Mathematics connection (CCSS Mathematics) | • Reason quantitatively and use units to solve problems  

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Lab Handout

Introduction
The average temperature in the United States has increased by about 1.3°F since 1910, but the increase in average temperature has not been uniform. Some states have warmed more than others (see the figure below). The pace of warming in all regions of the United States, however, has accelerated dramatically since the 1970s. This change in pace coincides with the time when the effect of greenhouse gases began to overwhelm the other natural and human influences on climate at the global and continental scales.

A map illustrating how fast each state has been warming each decade since 1970

This increase in average temperature could have a negative impact on many different species of plants and animals because it could lead to changes in seasonal weather patterns, which could then lead to droughts, habitat loss, or food shortages. Migratory birds are one type of animal that may be influenced by a change in climate because birds migrate when
the seasons change. Migratory birds tend to fly north in the spring to breed and return to the warmer wintering grounds of the south when temperatures get colder.

The migration of birds in response to a change of seasons is an example of animal behavior with both a proximate cause and an ultimate cause. A proximate cause is the stimulus that triggers a particular behavior (such as a change in temperature). An ultimate cause, in contrast, is the reason why the behavior exists. In this case, birds migrate because of food and because the longer days of the northern summer provide extended time for breeding birds to feed their young. Migratory birds, as a result, are often able to support larger clutches than nonmigratory species that remain in the tropics year round. This is clearly a benefit of migration.

Environmental conditions serve as both the proximate and ultimate cause of bird migration. Therefore, climate change could have drastic effects on bird migration because it changes seasonal weather patterns. For example, climate change could influence when the temperature drop that serves as the proximate cause of migration for many species of bird happens. Climate change, as noted earlier, can also lead to widespread droughts, habitat loss, and food shortages. These changes in environmental conditions could potentially eliminate the benefits associated with migration because they limit how much access birds have to the resources they need to survive and reproduce after they arrive at their destination.

**Your Task**

Use the All About Birds website to identify several migratory species of bird that can be found in the United States; then use the eBird online database to determine if the migration behaviors for these species have changed over the last 40 years. If you do see a change, you can then use the National Oceanic and Atmospheric Administration’s (NOAA) National Weather Service and National Climatic Data Center databases to explore weather conditions and changes in climate over the same time period.

The guiding question of this investigation is, **How has climate change affected bird migration?**

**Materials**

You may use any of the following websites during your investigation:

- All About Birds (Cornell Lab of Ornithology): [www.allaboutbirds.org](http://www.allaboutbirds.org)
- eBird: [http://ebird.org](http://ebird.org)
- NOAA National Climatic Data Center: [www.ncdc.noaa.gov](http://www.ncdc.noaa.gov)
Safety Precautions

1. Use caution when working with electrical equipment. Keep away from water sources in that they can cause shorts, fires, and shock hazards. Use only GFI-protected circuits.

2. Wash hands with soap and water after completing this lab.

3. Follow all normal lab safety rules.

Getting Started

To answer the guiding question, you will need to design and conduct an investigation using three different online databases. Your first step in your investigation, however, is to learn more about birds, why birds migrate, the different migration patterns, and which types of birds migrate. To do this you can visit the website All About Birds, which is sponsored by the Cornell Lab of Ornithology. Your next step is to learn how to use the eBird database to find information on where and when different species of bird have been observed across the United States and over time. You will also need to learn how to use the NOAA National Weather Service database to access information about current weather conditions and the NOAA National Climatic Data Center database to access historical weather conditions for different regions of the United States.

Once you have learned how to use these databases, you will need to determine what type of data you will need to collect, how you will collect it, and how you will analyze it. To determine what type of data you will need to collect, think about the following questions:

- How will you determine if there has been a change in bird migration over time?
- What will serve as your dependent variable (e.g., location of breeding and winter locations, abundance of birds, arrival and departure dates in a specific area, distance traveled)?
- What information will you need to be able to link a change in a migration pattern to a change in climate?
- What type of comparisons will you need to make (e.g., different species of bird, birds in different regions, current observations vs. past observations)?

To determine how you will collect your data, think about the following questions:

- Where in the eBird and NOAA databases will you look to gather the information you need?
- What tools in the eBird and NOAA databases will you need to use?
- How will you keep track of the data you collect from the three different databases, and how will you organize the data?
To determine how you will analyze your data, think about the following questions:

- How will you demonstrate that a change in climate is or is not related to a change in the migration behaviors of bird species?
- How will you quantify a difference or amount of change?
- What type of calculations will you need to make?
- What type of graph could you create to help make sense of your data or to share the data with others?

**Investigation Proposal Required?** □ Yes □ No

**Connections to Crosscutting Concepts and to the Nature of Science and the Nature of Scientific Inquiry**
As you work through your investigation, be sure to think about:

- the importance of identifying patterns,
- the importance of identifying the underlying cause for observations,
- how systems go through periods of stability and change,
- the nature of scientific knowledge, and
- the difference between data and evidence in science.

**Argumentation Session**
Once your group has finished collecting and analyzing your data, prepare a whiteboard that you can use to share your initial argument. Your whiteboard should include all the information shown in the figure below.

To share your argument with others, we will be using a round-robin format. This means that one member of your group will stay at your lab station to share your group’s argument while the other members of your group go to the other lab stations one at a time to listen to and critique the arguments developed by your classmates.

The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. In order to critique an argument, you will
need more information than what is included on the whiteboard. You might, therefore, need to ask the presenter one or more follow-up questions, such as:

- Why did you decide to focus on those data?
- What did you do to analyze your data? Why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?
- How confident are you that your claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

**Report**

Once you have completed your research, you will need to prepare an investigation report that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!

Checkout Questions

Use the following information to answer questions 1–3. A biologist is interested in mealworm behavior. He sets up a box as shown below. He uses a neon lamp for light and constantly waters pieces of paper for moisture. In the center of the box he places 20 mealworms.

One day later he returns to see where the mealworms ended up.

Biologists use the concepts of proximate and ultimate cause for behavior to explain this type of observation.

1. Describe the concept of a proximate cause of a behavior.
2. Describe the concept of an ultimate cause of a behavior.

3. Use the concepts of proximate and ultimate causes of a behavior to explain why the mealworms moved to one side of the box.

4. All scientific knowledge is certain and does not change.
   a. I agree with this statement.
   b. I disagree with this statement.

   Explain your answer, using examples from your investigation about animal behavior.

5. Evidence is data that are used to support a claim.
   a. I agree with this statement.
   b. I disagree with this statement.

   Explain your answer, using information from your investigation about animal behavior.
6. Scientists often attempt to identify patterns in nature. Explain why the identification of patterns is useful in science, using an example from your investigation about animal behavior.

7. Scientists often attempt to identify the underlying cause for the observations they make. Explain why the identification of underlying causes is so important in science, using an example from your investigation about animal behavior.

8. Biological systems often go through periods of stability and change. Explain what this means, using an example from your investigation about animal behavior.
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Are you interested in using argument-driven inquiry for high school lab instruction but just aren’t sure how to do it? You are not alone. This book will provide you with both the information and the instructional materials you need to start using this method right away. *Argument-Driven Inquiry in Biology* is a one-stop source of expertise, advice, and investigations.

The book is broken into two basic parts:

1. **An introduction to the stages of argument-driven inquiry**—from question identification, data analysis, and argument development and evaluation to double-blind peer review and report revision.

2. **A well-organized series of 27 field-tested labs** that cover molecules and organisms, ecosystems, heredity, and biological evolution. The investigations are designed to be more authentic scientific experiences than traditional laboratory activities. They give your students an opportunity to design their own methods, develop models, collect and analyze data, generate arguments, and critique claims and evidence.

Because the authors are veteran teachers, they designed *Argument-Driven Inquiry in Biology* to be easy to use and aligned with today’s standards. The labs include reproducible student pages and teacher notes. The investigations will help your students learn the core ideas, crosscutting concepts, and science and engineering practices found in the *Next Generation Science Standards*. In addition, they offer ways for students to develop the disciplinary skills outlined in the *Common Core State Standards*.

Many of today’s teachers—like you—want to find new ways to engage students in scientific practices and help students learn more from lab activities. *Argument-Driven Inquiry in Biology* does all this even as it gives students the chance to practice reading, writing, speaking, and using math in the context of science.