The Web of Inquiry:
Urban Spider Behavior

Objectives:
Students will be able to:

▪document their objective observations of animal behavior.

▪discuss their study organisms' natural history, adaptations and behavioral repertoire.

▪ask questions and derive hypotheses/predictions that lead to scientific investigation.

▪design an experiment and collect relevant data to test their hypothesis/answer their question.

▪present their work in a scientific poster.

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Time:
50 min. class period

Grade Level:
6-12

Standards:
AZ Science Strands and Concepts
Inquiry, Nature of Science, Diversity, Adaptation & Behavior
NSGSS-Core Ideas
Growth and Development of Organisms Natural Selection, Adaptation
Specific AZ, Common Core, and NGSS Standards on page 6

Background:
Behavioral ecologists explore how and why animals behave the way they do. These scientists study how natural selection shapes behavior. They ask the question: what helps animals survive and reproduce in their environment? This is important in urban environments where humans and other animals interact closely. Human activities and the structures they build in cities can cause natural selection to favor certain traits of individual animals. These traits that help individuals survive and reproduce are called adaptations.

ASU and CAP LTER researcher, Chad Johnson, studies how urbanization and natural selection affect the behavior of black widow spiders (*Latrodectus hesperus*). Black widows are a venomous species found in desert environments and they are also common in cities, where some people consider them dangerous pests. More information about his research is included in the Background for Teachers section of this lesson. Dr. Johnson collaborates with teachers using black widows to help students experience authentic scientific inquiry in the classroom. Dr. Johnson's research team can assist teachers in establishing this unit (http://www.west.asu.edu/jcjohn14/).

Classroom animal behavior studies offer students and teachers a unique and stimulating context for exploring their own scientific questions. This unit allows students to build their skills in scientific inquiry while studying the behavior of arthropods.

Many young investigators are fascinated by black widows. Our experience suggests that some "arachnophobes" (both teachers and students) may become empowered and less fearful as they learn to appreciate the lives and behavior of spiders through supervised, first-hand experience.

While our curriculum requires some training in the safe handling of black widows, this pedagogical framework can be used for behavior studies of any arthropod. Crickets, meal worms, pill bugs and wolf spiders are examples of arthropods that are easy to acquire and observe. Students may find many of these organisms when participating in the Ecology Explorer's arthropod pitfall trap protocol in urban schoolyards (http://ecologyexplorers.asu.edu).

These lessons guide students to generate their own questions about spider behavior and lead them step-wise through the hypothetico-deductive method to test their predictions in a class controlled experiment.

Students generate hypotheses through a series of scaffolded activities:

1) observing spider behavior,

2) brainstorming questions,

3) identifying independent variables that can be manipulated, and

4) modifying initial questions to more testable hypotheses.

Then the class designs methods to collect data. Finally they present their experimental process, results and conclusions in scientific posters.

Vocabulary:

arthropod: invertebrate animals from the phylum Arthropoda, which includes insects, arachnids and crustaceans

adaptation: in biology: a trait or characteristic of an organism that results from Natural Selection and helps an individual survive and/or reproduce in its environment

variation: in biology: the differences among the traits of individual organisms within a population

natural selection: a natural process where the environment causes differences in the survival and reproduction of individual organisms

urbanization: the process of people building and moving to cities, which causes environments to change from natural vegetation to human-built structures

hypothesis: a possible explanation for observations; it attempts to answer the scientific question

prediction: the expected result of a scientific test, if the hypothesis is supported

independent variable: the factor of interest in a scientific study; the factor that may cause the hypothesized effects; the variable that is changed in an experiment

dependent variable: the factor that is measured in a scientific study; the variable that will determine if the hypothesis is supported

replication: repeated trials of the independent variable; it increases the sample size in a scientific study to account for the variation in nature and any experimental errors

data: the measurements collected by a scientist in a study; the dependent variables

results: a summary of the data collected in a study that are used to evaluate the hypothesis

range: in science and math: a measure of how the data are spread out; the lowest value subtracted from the highest value; a measure of the variation in the dependent variable in a scientific study

Advanced Preparation:

Consider displaying a list or graphic organizer of the above vocabulary throughout the study. An example appears in the Background section.

Students and teachers should be familiar with spider safety and the ethical treatment of animals in research. Have a plan for the animals after the experiment is complete. The International Society of Applied Ethology offers guidelines for using animals in research: http://www.applied-ethology.org/ethical_guidelines.html

For lessons 1 and 2: Some background in distinguishing between subjective and objective observations and inferences will be useful (e.g. "The spider looks scared." vs. "The spider has eight limbs").

Prior introduction to natural selection and adaptation will help students ask more substantive questions.

A basic understanding of invertebrate/arthropod structures and functions is helpful (e.g. exoskeleton, ectothermy etc.).

For lesson 3: Practice designing tables for data collection and discuss the effectiveness of different alternative table formats. Remind students how their math skills are important in science.

Materials:

- Two focal animals for each group of students, one animal in each of two treatment groups.
- Secure containers to house organisms. Containers should:

  1) be transparent

  2) allow organisms to behave as naturally as possible

  3) allow ventilation
- Exact materials will depend on the variables the class decides to manipulate (independent variable) and measure (dependent variable).
- Note cards or post it notes
- White board or chart paper
- Data sheets. The class will work together to identify the variables they will quantify and prepare a data sheet that allows them to record their observations easily.

Example Set Up for Black Widow Spiders:
We give two black widow spiders to each group of four students in separate containers. Thus, each student group has one spider in the treatment group and one spider in the control group. So, each student group is responsible for one replicate of the class experiment. Containers we use for black widows are clear plastic tubs with screened mesh lids. They are 33cm X 15cm X 20cm, which allows about five body lengths in every direction. In the case of venomous spiders, we use four sticks emerging from a styrofoam "island" for web-building surrounded by water, so spiders can not escape.

Examples of class experiments follow:

Experiment 1
Question: Are spiders more aggressive when they are hungry?

Hypothesis: Spiders attack prey more quickly if they have been starved because food is necessary for survival.

Prediction: The average time to attack prey will be shorter for spiders in the treatment group than in the control group.

Independent variable: time since last feeding

Dependent variable: time it takes the spider to attack prey

Treatment Group: spiders that have not eaten for one week

Control Group: spiders that have eaten recently

Materials: stopwatches and crickets for prey

Experiment 2
Question: Does temperature influence web-building activity of a spider?

Hypothesis: When the environment is warmer, spiders will spend more time web-building because they are ectothermic and they will have more energy available for more activities.

Prediction: Spiders in the treatment group will spend more time spinning and repairing their webs on average than the spiders in the control group.

Independent variable: temperature of the container

Dependent variable: time spent spinning and repairing web

Treatment Group: warm container

Control Group: room temperature container

Materials: heat lamps or hot packs, thermometers, stopwatches

Note to Teachers:
It is important for students to realize that not all good testable questions lend themselves to controlled experiments. Likewise, not all good testable questions require obvious treatment and control groups. Indeed, students who are not familiar with these concepts can still conduct good controlled experiments. For example, if Experiment 2 above were expanded to include a range of temperature conditions, the class might use three different groups: low, med and high temperatures. In this case each treatment group effectively serves as the control for the other two and results from all three are compared. Of course if every student group conducted their trial at a different temperature, there would be no control at all and no replication, so this would not be an example of good science.

Recommended Procedure:

Lesson 1—Initial Arthropod Observations and Developing a Research Question

1) Review the organisms' natural history and safe handling practices. In the case of black widow behavior, we take this opportunity to identify the Sonoran desert organisms that can harm people and discuss ways to avoid this.

2) Prior to observations, review the difference between observation and inference by asking students to give specific examples. (e.g. I observe the male spider is approaching the female. I infer that the male is trying to mate.)

3) Distribute initial observation animals to each group. Hand out Student Worksheet—Observations.

4) Ask students to list the types of observations they might record (e.g. size, location, color, locomotion, posture, grooming, etc). Encourage students to think of themselves as private detectives who have been hired to discover as much as they can about the situation. Emphasize this includes being as quiet as possible and minimizing vibrations so as not to disrupt natural behavior, especially with spiders. (This can be a good opportunity to recall that sound is vibration.)

5) For the next 15 minutes, ask students to write down everything they can objectively observe about their organisms.

6) Ask students to share their observations with the class. Record observations on a white board or chart paper.

7) Choose a few observations and ask the students: what questions could you ask about this observation?

8) In their student groups, guide them to generate as many questions as possible (at least 10). Have the groups record their questions on separate note cards or post-it notes in order to sort them later.

9) If time permits, conduct a second observation session to improve their observational skills based on class feedback and focus exclusively on generating questions.

10) Ask the students to identify their favorite questions. Record these on a white board or chart paper. You may ask students to vote on their favorites based on various criteria (e.g. the most exciting, practical, useful etc.).

11) This lesson should be followed up by literature/on line research into interesting traits or behaviors that students have identified. This can raise new questions and integrate technology skills and standards. Have students record their research findings and new questions on the Student Worksheet—Background Research.

Lesson 2—Turning Questions into Hypotheses and Designing the Class Experiment

1) Briefly review the main principles of observation discovered in Lesson 1. Discuss particular behaviors or traits that interest students. Discuss new information found through background literature research.

(For example, students are often curious about the size difference between male and female black widows. In this case, students can search references to discover the precise difference in mass.)

2) Begin to address the students' top questions. Discuss how they might be answered.

Ask students: What makes a question testable or not testable? Establish some criteria for a good experimental question.

<u>Example criteria</u>

▪Do you already know the answer?

▪Could you look up the answer easily?

▪Is the question meaningful—will it add to our knowledge?

▪Do you have an expected outcome?

▪Is it clear what you will manipulate and what you will measure to test the question?

3) Guide students to realize that some questions are too vague. (e.g. Why do black widows have an hourglass?)

4) Have student groups sort their note cards into two piles: testable and not testable. Have students discuss what criteria they used to sort the questions.

5) Hand out the Student Worksheet—Guide to Using the Hypothetico-Deductive Method.

6) Explain to students the concept of "turning" untestable questions into testable questions.

(e.g. Do black widows have an hourglass because it helps them scare off their enemies?) This question specifies what students want to know about the variable of the hourglass. Note it attempts to answer a "why" question; it contains the word because.

7) Assist student groups to "turn" their questions by scanning for the variables in their questions. Circle variables and discuss how to make these more specific. Ask: what else would you like to know about this variable? Rephrase the questions into testable questions.

(e.g. Do black widows have a hourglass because it helps them scare off visual predators like birds?)

8) Finally, discuss with students that many great, testable questions are not practical in the classroom. Guide students to determine which questions could be tested by them with the materials and time available.

9) Come to a class consensus on one question for the class experiment. With all arthropods, we encourage hypotheses that focus on behaviors of individuals or discrete interactions between individuals, rather than trying to quantify group behavior.

10) Ask students to recall the definition of a hypothesis. Reinforce to students that the hypothesis statement is a possible explanation of the phenomenon they want to investigate. It highlights the independent variable that will be manipulated/changed. The independent variable is the factor you hypothesize will cause the predicted effects.

11) Have students change the class question to a hypothesis statement. Ask students to note the differences between the question and the hypothesis.

12) From the hypothesis, direct students to make predictions. Ask students: What do you expect to observe in your experimental results? The prediction highlights the dependent variable(s) - the effect being measured.

13) Allow students to observe the organisms again, this time planning how they might design an experiment to

test their question. Ask students to think about what they will manipulate (independent variable) and how they will measure it (dependent variable(s)). Have students make a list of the possible experimental variables in their notes for the class to discuss. If time permits, encourage them to draw a schematic diagram of their design.

14) Explain that manipulating/changing the independent variable creates two treatment groups. Ask: What is the purpose of this? Explain that each group serves as a standard for comparison to the other. If it is appropriate to the hypothesis, this is the time to discuss the importance of a control group.

15) Explain to students that they will replicate these treatment/control groups. The experimental procedure of comparing these two groups will be done multiple times and each iteration is one replicate. For example, each group of four students may collect data about one spider in the treatment group and one spider in the control group. Thus, the entire class conducts one large experiment.

16) Finalize the experimental design and determine if any manipulations need to be established before Lesson 3 (e.g. removing food from some animals).

Lesson 3— Design Data sheet and Collect Data

1) In preparation for data gathering, discuss with students the best way to design their data sheet. Ask them to recall their dependent variable(s) and how they will be measuring them. Guide students to create a table listing the dependent variables for each treatment group. Ask, How many rows and columns will we need on the data table?

2) Ask students to recall the definition of replication. Ask students: Why is this necessary in science? If we used only one spider for our test, would you be confident in the accuracy of the results? What could you conclude? What if this spider were sick, unusually large, unusually aggressive etc.? A larger sample size helps dilute experimental error and random events. It also reduces bias in the sample by including more of the variation found in nature. This gives a more accurate representation of the phenomenon being studied. Emphasize to students that each group will conduct one part of the larger class experiment.

3) Allow students to recall appropriate experimental procedures:

- attentive observation
- minimize effects of the observer on animals (i.e. re▪main still and quiet).
- precise data recording
- same methods for each group

This can be an opportunity to discuss another essential component of science: repeatability. Ask students: Why must we carefully document our procedure?

4) Circulate and assist students as they collect the data necessary to answer their research question.

Lesson 4 - Analyzing Results and Preparing a Scientific Poster

1) Assist students to analyze their results using relevant math and graphing skills. Often this will require calculating two averages to compare the treatment/control groups.

2) Ask students to recall why they replicated the experiment. Was there a lot of variation among replicates (student groups) for each treatment? Calculate the range for each average. Are the averages substantially different, or is there a lot of overlap between them? Based on this analysis, ask students to determine if their sample size was sufficient. Did you use enough organisms for the test? How many might be necessary to see clearer results?

3) Often results are best illustrated by a bar graph that displays the average and range for each treatment group. Consider drawing box and whisker or stem and leaf plots to include the range in the graphs.

4) Based on the data, evaluate the hypothesis. Ask students: Was the prediction met? Was the hypothesis supported? What questions do you still have? This can be an opportunity to discuss the word "proof" and some possible pitfalls of using this word in science.

5) Each group of four students can then prepare a scientific poster. The Student Worksheet—Study and Poster Self-Evaluation rubric can be used as a formative guide.

Scientific posters include:

- Introduction: background research, scientific question, hypothesis and prediction

  What was the initial rationale for the question; why was it interesting to students?

- Methods: a brief description of the procedure in past tense

- Results: a summary of the class data in tables and/or graphs that are not redundant
- Discussion: What is the importance of the results in a broader context (for: the study animals, other parts of the ecosystem, humans, society, future research)? What new questions came from the results? What would you do differently if you conducted another experiment? Why?
- Optional illustrations and/or photos

Evaluation:
Students will participate in all aspects of experimental design and implementation and complete the Student Worksheets. Alternatively, science notebooks may be used as assessment of this process. Students may complete the self-evaluation rubric. The final product is the scientific poster illustrating understanding of the organism's biology and all steps in the hypothetico-deductive method of scientific inquiry.

Extensions:
Students may display and present their findings publicly (to students, parents, school administrators, board members, etc.). This provides an "authentic" purpose for conducting the work, which may motivate students throughout the lessons, and can also be a effective evaluation tool, emphasizing individual student accountability.

Standards

Arizona Science Standards
S1-C1-GR6-8-PO1, PO2, PO3,
S1-C2-GR6-8-PO1, PO2, PO3, PO5
S1-C3-GR6-8-PO1, PO3, PO4, PO5, PO6, PO7
S1-C4-GR6-8-PO1, PO2, PO3, PO4, PO5
S2-C2-GR8-PO1
S2-C2-GR6-8-PO3
S2-C2-GR8-PO4
S4-C4-GR7-PO2, PO5
S4-C4-GR8-PO1, PO2, PO3
S1-C1-GRHS-PO1, PO2, PO3, PO4
S1-C2-GRHS-PO1, PO2, PO3, PO4, PO5
S1-C3-GRHS-PO1, PO2, PO4, PO6
S1-C4-GRHS-PO1, PO2, PO3, PO4
S4-C4-GRHS-PO1, PO2

NGSS Core Ideas:
LS1B: Growth and Development of Organisms
LS4.B: Natural Selection
LS4.C: Adaptation

NGSS Practices:
Constructing Explanations and Designing Solutions
Engaging in Argument from Evidence

NGSS Crosscutting Concepts:
Pattern
Cause and Effect

Common Core/ELA Literacy
RST7: Integrate content from diverse formats
WHTS1: Write to support claims
WTS2: Write to convey ideas and information
SL1: Participate in collaborations and conversations
SL2: Integrate oral information
SL4: Present effectively to listeners

Common Core/Mathematics
Domains:
Number and Quantity
Measurement and Data

My Arthropod Observations—What I Noticed

Observation 1

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Observation 2

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Observation 3

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Observation 4

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Observation 5

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My Arthropod Questions—What I Would Like to Know

Question 1

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Question 2

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Question 3

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Student Worksheet
Background Research

My Arthropod Research--What I learned

Question #	Answers and/or Information	Sources

More Arthropod Questions From My Research

Question 1

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Question 2

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Question 3

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Student Worksheet
Guide to Using the Hypothetico-Deductive Method

The hour glass shape illustrates the process of broad reasoning, to narrow results, and back to broad reasoning.

GENERAL

DEDUCTION

SPECIFIC

INDUCTION

GENERAL

1. Make observations about the natural world

2. Ask a question about your observation

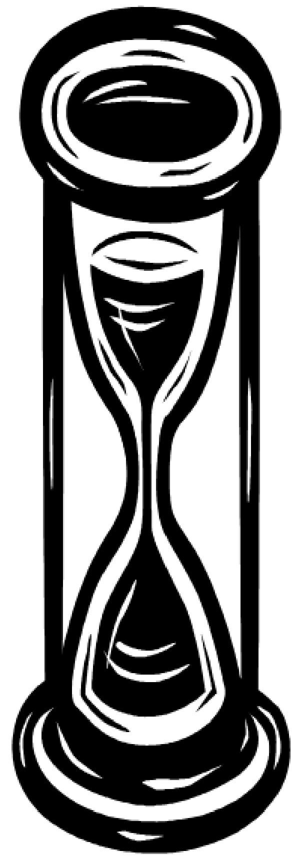
3. Form a **hypothesis** - a possible explanation for your observation

4. Test your hypothesis with a **prediction**- a result you expect to see if your hypothesis is supported

5. Design a test of your hypothesis

6. Collect data and analyze your results – evaluate your hypothesis

7. Make conclusions and ask a new question



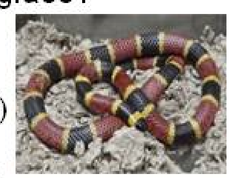
Turning Questions into Hypotheses

My observation:
- I observe that black widows have a bright red hourglass on their bellies.

My question:
- Why do black widows have an hourglass?

Is my question testable?
- NO! Scan for variables and circle them.
- Explore these variables further.
- What do you really want to know about those variables? Be specific.

Ask more questions about your variables:
- What would happen if black widows didn't have an hourglass?
- What is important to black widows? What benefit could they get from the hourglass?
- Do other animals have hourglasses or bright coloration?



Background research reveals a possible explanation: WARNING COLORATION! (APOSEMATIC)

Rephrase your question: Do black widows have an hourglass to scare off predators?

I hypothesize that: Black widows have a red hourglass because: it helps scare away predators

Based on my hypothesis I predict that: If I put black paint over the red hourglass, then black widows would be attacked by predators more often.

Designing a Class Experiment

Our Class Experiment

Scientific Question:

____

____

Hypothesis:

____

____

Prediction:

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____

Experimental Design
Draw and label how you will set up and conduct your class experiment here. How many replicates are there?

JULIE ANN WRIGLEY GLOBAL INSTITUTE of SUSTAINABILITY
ARIZONA STATE UNIVERSITY

Student Worksheet
Study and Poster - Self Evaluation

Student Name: ____ Total Score: _____________

Category	9-10	6-8	3-5	0-2
Required Elements	The poster includes all required elements and additional info.	All required elements are included on the poster.	All but 1 of the required elements are included on the poster.	Several required elements were missing.
Content - Accuracy	At least 7 accurate facts are displayed on the poster.	5-6 accurate facts are displayed on the poster.	3-4 accurate facts are displayed on the poster.	Less than 3 accurate facts are displayed on the poster.
Data Presentation	Detailed graph and/or chart representing spider data collection; clearly labeled, easy to read, colorful graphics.	Detailed graph or chart representing spider data collection; clearly labeled and fairly easy to read.	Graph or chart representing most of spider data collection; labeled, readable.	Graph or chart shows very little data collection or missing.
Graphics - Relevance	All graphics are related to the topic and make it easier to understand. All borrowed graphics have a source citation.	All graphics are related to topic; most make it easier to understand. Borrowed graphics have a source citation.	All graphics relate to the topic. Most borrowed graphics have a source citation.	Graphics do not relate to the topic OR several borrowed graphics do not have a source citation.
Use of Class Time	Used time well during each class period. Focused on getting the project done. Never distracted others.	Used time well during each class period. Usually focused on getting the project done. Never distracted others.	Used some time well during class; some focus on getting the project done but occasionally distracted others.	Did not use class time to focus on the project OR often distracted others.

How did you decide which information to include on your poster?

If you were to complete this poster again, what would you do differently?