beetles

Science and Teaching for Field Instructors

Student Activity Guide

Exploratory Investigation

Scientists can spend years planning, conducting, analyzing, and publishing the results of their investigations. The goal for students in this activity is not coming up with great data, but to observe and record patterns in nature, and to think about how the investigation could be improved in the future. After being assigned a general topic, such as "exploring where fungi live," students brainstorm questions, sort questions as testable or not testable, plan and complete a brief exploratory investigation, analyze the results, discuss ideas, and brainstorm ways the investigation could be improved in the future. In a short amount of time, we can give students an experience that's authentic to field science, while emphasizing how this can lead to a more thorough investigation that answers important questions about the natural world.

Students will...

- **closely observe an organism or phenomenon;**
- **learn about the ecosystem;**
- **generate testable questions;**
- **plan and conduct a short investigation; and**
- **reflect on results and how the investigation could be improved or refined.**

Grade Level:
Grades 3-8. Adaptable for younger or older students.

Timing:
~95-115 minutes. The activity can be broken up, depending on time available and student interest

Related Activities:
See "Activity Connections" on page 15

Materials:
See "Preparation" on page 3

Tips:
To ensure a successful experience, review the teaching tips found on page 2 and throughout this guide.

Setting:
An area with some type of interesting organisms or phenomena for students to investigate, and a general topic such as, " how do invertebrates interact with their surroundings in this ecosystem? "

NEXT GENERATION SCIENCE STANDARDS

FEATURED PRACTICE	FEATURED CROSSCUTTING CONCEPT	DISCIPLINARY CORE IDEAS
Planning & Carrying Out Investigations Asking Questions	Systems and System Models	Interdependent Relationships in Ecosystems

For additional information about NGSS, go to page 13 of this guide.

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Exploratory Investigation

ACTIVITY OVERVIEW

Exploratory Investigation	Learning Cycle Stages	Estimated Time
Invitation to Investigating	Invitation	5 minutes
Making Observations & Generating Questions	Exploration	15-20 minutes
Developing Testable Questions	Concept Invention	15-20 minutes
Choosing a Testable Question to Investigate	Application	20 minutes
Planning & Conducting Investigations	Concept Invention, Application	25-35 minutes
Considering Results & Reflecting on the Investigations	Concept Invention, Application, Reflection	15 minutes
TOTAL		**~95-115 minutes**

TEACHING TIPS

Field Card. On page 16 of this guide is a pocket-sized version of this lesson that you can use in the field.

Read the Instructor Support Section. Beginning on page 10, you'll find more information about pedagogy, student misconceptions, science background, and standards

Choose an interesting topic & location. Look around your area, and find an interesting topic and location for students to investigate. You may want to change locations after step III to keep students from getting restless. In that case, make sure what you want to investigate is available in both locations. For example, you could find two locations that include a creek, or have lots of spiderwebs, or decomposing logs. Choose a topic your students have shown interest in that's broad enough to inspire lots of testable questions. For example, "How do invertebrates here survive in their environment?" Or "How have humans impacted the creek?" Scout the area right before the activity to make sure the stuff you want them to investigate is there when your students will be there!

Give time for exploration. Time exploring and generating questions before investigating is valuable. Students sometimes try to answer their questions immediately with mini-investigations or work out answers by discussing with their partner.

PREPARATION

1. **Prepare Question Cards.** Copy the Question Cards sheet in this write up and cut it into individual cards. Consider attaching each one (or write each one) on an index card, and laminating them.
2. **Gather necessary materials:**
   a. For instructor:
   - 1 portable white board
   - white board marker
   - Question Cards, starting on page 19

   b. For each student:
   - (optional) 1 hand lens
   - field journal

   c. For the group:
   - Any equipment needed for collecting and containing organisms, such as nets and clear plastic cups. (See BEETLES Ecosystem Literacy and Exploration Guides for more information on tools for gathering organisms: http://beetlesproject.org/ecosystemliteracies/).
   - Optional additional equipment. Other tools that might be useful include thermometers, compasses, measuring tapes, rulers, scales, pH paper, trowels, paintbrushes, microscopes, hand lenses, bug boxes, flashlights, barometers and stopwatches. Some programs provide pre-made kits for instructors (See What's in our Backpack--http://beetlesproject.org/whats-in-our-backpack/-- for an example). Keep in mind that tools can sometimes be a distraction, and students may become more focused on a tool than on their question, so introduce them judiciously. Alternately, you could brainstorm with the students what tools they might need, and only bring out those they mention. Or, wait to show the tools you have when you get to part V "Planning and Conducting the Investigation."

TEACHING NOTES

Dealing with frustration. This activity can be a little frustrating for some students sometimes. A little bit of struggle is OK. Give enough guidance to keep the task challenging, but not too frustrating. If students do become overly frustrated, let them know that that's part of doing science - investigations don't always go smoothly and we don't always get the answers we expect. Explain that grit (working through frustrations) is an important character trait to develop. You may also want to suggest ways of working through a sticking point by modifying the investigation or their question. You can also model for them appropriate ways to express frustration and cheer lead for themselves: "I can do this!"

Helping teams succeed in different ways. It's unrealistic to expect students to conduct a perfectly designed investigation the first time, or to get a clear scientific answer to their question within a short time frame. The goal of the activity is to mess around with methods of investigating phenomena, and to learn how field scientists try to answer their questions. This can look very different for each team of students. It's OK if some teams are not able to complete their investigation, as long as they're exploring and learning about the process. Some may manage to do an investigation and gather useful results, while some may only explore one part of the process, but they can still learn plenty from the challenge. Students may refine or completely change their question through the course of their investigation as new findings draw their interest. This can lead to interesting reflections on the nature of science practice and testable questions, as well as keep the students engaged. Don't make them feel trapped in a rigid protocol, like "The Scientific Method!"

Invitation to Investigating

1. ***Walk & Talk* discussing ideas about conducting a science investigation.** Lead the group to the area you've chosen for their investigations and lead students in *Walk & Talk* with a partner:
   - *What are things field scientists might do to learn about an ecosystem?*
   - *How is this ecosystem different from other ecosystems?*
   - *What are questions you wonder about this ecosystem?*

2. **Explain that scientists do short exploratory investigations to decide how to do longer investigations of ecosystems.** Point out that field scientists usually investigate ecosystems over a long period of time, and some field investigations can take months or years to complete. Developing an interesting question, figuring out how to answer it, collecting data, and making sense of the results all take time.
   - *Scientists often begin with a shorter exploratory investigation, to learn more about what is going on and how to investigate it.*

3. **Point out one goal of this exploratory investigation is to learn how parts of this ecosystem interact, by looking closely at one part.** Point out that ecosystems are complex–there are many parts of an ecosystem that can affect each other in different ways. To better explain how the parts interact, we can try to isolate one aspect of the ecosystem to understand it more deeply.

4. **Tell them they'll also learn more about how to do a field investigation**
   - *Another goal of our exploratory investigation is to learn how to design and do a scientific investigation, and to think about how it could be improved.*

Making Observations & Generating Questions

5. **Explain that field scientists usually start investigations by making observations and coming up with questions.** Explain that often field scientists make observations of a part of an ecosystem to see if they notice any interesting patterns or relationships that could be investigated further. Then they come up with questions about the possible causes of whatever patterns or relationships they noticed.

6. **Introduce the part of the ecosystem they will focus on in their investigation.** Introduce the topic you have chosen for them to provide focus. Some examples to explore: where fungi grow, macroinvertebrates in a stream, where lichen grows, tracks, scat, behavior of a particular organism, etc. Alternatively, you might choose to let them investigate whatever they want without a topic. This approach can be fruitful if you wish to focus more on the practices of science rather than specific content, or if you have self-motivated students, whose curiosity you do not want to limit.

7. **Explain that they'll have ~15 minutes in pairs, to make observations and write down questions.** Tell them the goal during the next ~15 minutes is to make observations about the part of the ecosystem the group is

TEACHING NOTES

See **BEETLES** activity *Walk &Talk* for logistics of this routine.

Read Instructor Support section on page 10 for tips on introducing new vocabulary, like "ecosystem" to students.

Choosing a guiding question. Focusing on a specific part of the ecosystem and having a broad guiding question will give students ideas on what kinds of questions to ask, and allow to you to tie their investigations to Disciplinary Core Ideas and Crosscutting Concepts. A more focused guiding question could help students less familiar with questioning and science practices. Examples of guiding questions are "How do the organisms in this area survive in their environment?", "How have humans impacted this environment?", "How does the creek affect this ecosystem?" "Where does matter go in this ecosystem?"

Framing the investigation to focus on learning about ecosystems. Students may come up with questions like, "do snails prefer M&M's or Tootsie Rolls," which is unlikely to provide any useful information to help understand nature. Making it clear that the investigation is an attempt to learn more about the ecosystem, and reminding students of this frame throughout the investigation, helps direct students towards questions that are more scientific and more likely to help them learn about ecology.

Do *I Notice, I Wonder, It Reminds Me Of* first. Students' observations and questions during this section will be richer if they've practiced those skills in an activity like *I Notice, I Wonder, It Reminds Me Of* first.

Assessment Opportunity. While students are exploring and coming up with questions, you can get a sense of how to help your students formulate investigations by listening to their conversations and engaging with them.

focusing on, and to write down as many questions about the topic as they can (in their journals, or on index cards).

8. **Introduce any necessary strategies or logistics for finding organisms; Explain boundaries and safety precautions.** If students will be catching organisms, explain how to go about it, and share any useful tools. Be clear about how to treat organisms respectfully. Go over boundaries and any necessary safety precautions.

9. **Circulate, inspire, encourage observations and probe for questions as needed, as students observe and generate questions for ~15 min.** As students explore, ask what questions they're coming up with and make sure they're recording them. Check in with students who are struggling, and redirect their focus by asking what they notice, and reminding them to look for interesting patterns.

Discussing Testable Questions

10. **Gather the group, and explain what makes a question "testable" or "not testable".**
    - ▶ *A question is scientifically testable if it can be answered through direct observation. For example, you could answer the question "Are there more horizontal spiderwebs or vertical spiderwebs in this ecosystem" by observing and counting each kind of spiderweb.*

11. **Introduce the limits of time, safety and resources for investigations.** Tell students they will only have 15 minutes for the investigation and show them available tools. Remind them the investigations must be safe for students and organisms.
    - ▶ *Scientists usually have only a certain amount of time and resources for an investigation. In our case, our questions must be investigated in no more than 15 minutes, using only the tools we have on hand.*

12. **Record criteria (bold abbreviations from this list) for testable questions on white board, so students can see it as they sort their questions:**
    - The question is **about objects, organisms or events we can observe** in the natural world
    - We can answer the question by **observing, measuring or comparing**
    - We can test our question in **15 minutes**
    - It is **safe** to test
    - We have the **tools** needed available

13. **Pass out Question Cards and pairs decide if question is testable and discuss why or why not; they can switch cards with other pairs.** Depending on the number of students, pass out one or a few Question Cards to each pair, and tell students to decide whether or not the question on each card is testable with the available site, materials, and time. Once a pair has discussed a question, they can switch cards with another pair.

14. **Ask a few pairs to read their question, and share whether they think it's testable here and now; prompt for reasoning.** As students share

TEACHING NOTES

Importance of spending time on developing testable questions. Coming up with a testable question is a common stumbling block for students, which is why we have put so much emphasis on helping them with developing this skill in this activity.

It's fine if different groups come up with similar questions. The important thing is that each group chooses a question that interests them, is testable, and helps learn about the ecosystem. You may want to point out that scientists often investigate similar questions, and can learn about different aspects of the same questions by doing parallel investigations.

Adjusting the activity. Some groups struggle more with sustained focus than others. For such groups, you may choose to do parts I-III at one time, then do parts IV-VI later in the day or the next day.

Systematic observation of an organism. If a team is having a hard time coming up with a testable question, you might want to have them just do a careful observation of an organism, in which they make and record careful observations. For example, they might make a list of all the different behaviors they observe (lying in sunlight, lying in shade, running, walking, moving head, sticking tongue out etc.). Tell them to also record questions they come up with, while they are observing, which may lead to testable questions.

their reasoning, coach them how to identify a scientific question–it has to be answerable through direct observation. If students mis-categorize a question as testable, help them think it through by asking how they would answer the question through observations.

15. **Point out that "what does it like?"** questions can't be answered, because **we can't ask organisms what they like, but we *can* observe what they do.** Explain that we can't know what other species like, because we can't ask them their opinions. But we can make observations about where and how they spend their time, what food they eat, where they are found, etc.

16. **Explain that sometimes we can change a non-testable question about what an organism "likes" into a testable question by thinking about what can be observed.** Show students the "Does it like being under a rock more than being in the open?" question card.
    - ▶ *You can change this question about what an organism likes into a testable question by asking how the organism might behave in different situations.*
    - ▶ *For example we can ask: "When the organism is near a rock in an open field, does it spend more time under the rock or out in the open?"*

17. **Point out that "why," & "how" questions are interesting, but are hard to test in a single investigation.** Explain that questions that begin with "why" or "how" usually need to be broken down into a series of questions that can be answered through multiple observations or investigations.

18. **Add bold abbreviations from this list of more criteria for testable questions to white board:**
    - The question starts with a word that asks about a characteristic we can observe or measure, like "**where,**" "**which,**" "**how many,**" "**how often,**" "**how long,**" or verbs like "**does,**" "**will,**" "**can,**" "**are,**" **not** words that ask for an explanation like "**why**" or "how come?"

19. **Show students the "Why do sow bugs live under logs?" question card and explain how to break it down further into observable questions.** Explain that the answer to this question could involve many different factors, so it's helpful to try to break it down further into testable questions that *can* be answered through observations.

20. **Provide examples of descriptive questions, measuring questions and comparison questions that are related to the original "why" question.**
    - **Measuring Question:** How many sow bugs are found in this area?
    - **Descriptive Questions:** What else lives under logs in this area? What's it like under the logs? (temperature, light, moisture)
    - **Comparison Questions:** Where are most of the sowbugs living? Are there more sow bugs under logs, on the ground around logs, or in the topsoil?

21. **Point out how observing where sow bugs live might help them find out more about the ecosystem in general.** Explain that as they observe under the logs where sow bugs are found and try to notice what the conditions are like, they may find other organisms living under the log and have more questions. This may lead to further questions about the ecosystem:

TEACHING NOTES

Using questions collected during the whole field experience. If you have the time, you might choose to collect student-generated questions throughout their field experiences, then use those questions as starting points for their investigations in this activity.

Assessment Opportunity. Pay attention to student discussions as they are coming up with testable questions, to help you understand how well they understand science investigations, and use this to guide your instruction during the rest of the activity.

Turning a non-testable question into one that can be investigated is a useful skill. This skill helps students design their own investigations. Learning how to take an overly complex or insufficiently specific question and convert it into one that can be tested within the constraints of the time, materials and location is key to having successful experiences doing field studies. It also allows you to accept and validate your students' particular interests and curiosity about the natural world.

"It prefers" does not mean the same thing in science as "it likes." When scientists say that a plant prefers a particular type of environment, they mean that the plant requires the conditions found in that environment in order to grow and thrive. When a stream biologist says a certain type of invertebrate prefers fast moving water, they are referring to how these conditions allow the organism to get food and oxygen from its environment. This is very different from saying organisms "like" to live in the shade or under a log. We can't know what a non-human organism actually likes, but we can observe and its behavior or its growth patterns, and we can describe those as the organism's preferences and behaviors that help it meet its needs.

What might sowbugs find to eat under the log? Is there evidence of other organisms eating sow bugs?

Choosing a Testable Question to Investigate

1. **Explain that pairs will join with another pair to form a group of four, then will have ~7 min. to sort the questions as testable/not testable.** Explain to students that they'll share their questions in a group of four, circle their testable questions, and see if there are any non-testable questions they could change into testable questions.

2. **Tell groups, after sorting and/or revising their questions, they will pick one to investigate together; remind them of criteria.** Tell them they'll get to choose one testable question that they will spend some time investigating. Remind them it should be interesting to everyone, and be able to be investigated in 15 minutes with the materials they have here.

3. **Circulate and support groups to identify/create testable questions, and help them agree on one question to investigate.** Check in with groups to assess whether students are struggling with categorizing questions as testable or not testable. Support groups that are struggling to decide on a question to investigate.

Planning & Conducting Investigations

4. **Introduce planning how to do their investigations based on their testable question.** Tell students they'll now investigate their question as a group, but they'll need to first spend a few minutes planning. Discuss what students should consider to make sure their plan for the investigation is scientific, and as fair a test as possible. Ask:
   - ▶ *What might be important to consider to make sure that our data is accurate, and our questions get a "fair test"? [students might say: take measurements the same way each time, collect data more than once, try to be as unbiased as possible when recording results, identify and control variables, etc.]*

5. **Explain to students that they will have ~10 min. to discuss and plan how to investigate their question with their small group.**

6. **Tell them to write on a whiteboard or in a journal their question, the tools they need, and the steps they'll take to answer their questions.**

7. **Circulate among students and support any who need help designing their investigation.** This is an important stage for students to get help from an instructor. The more support you can give, the more they'll likely get out of it, and the more successful their investigations will likely be. Remind students to come up with ways to make consistent measurements, and to discuss possible biases.

8. **Once everyone has a workable plan, tell students they'll have ~15 minutes to do their investigations and record data.** Explain to students that they should be recording their data in their journals, and that they could also draw and record observations in writing about other things they

TEACHING NOTES

On variables. Designing a "fair test," involves identifying the different variables involved, and deciding which you're going to try to keep the same, and which you're going to vary. Ideally, this is modeled with an example, and then, more importantly, through coaching students as they think through a question they're interested in investigating. With middle school students, thinking and talking about variables is particularly important, so you might want to get a sense of how well they understand this concept, and if they know the difference between dependent and independent variables. Then you can use this information to guide how you coach them.

On being a co-investigator with your students. It can be incredibly engaging to investigate an authentic mystery about nature. Even if you have investigated the same organism with different groups of students multiple times, there's always more to discover and think about. Make sure you act as a co-investigator, and remain curious about investigating the topic. Value student ideas without trying to lead them to a particular answer. If they get the sense that you have specific answers you're aiming for, the investigations will likely feel false, and students may be reluctant to share their ideas. As a co-investigator/instructor, you may judiciously share some of your own ideas and important additional information, using appropriate language of uncertainty and citing your sources. Keep in mind that it can be very empowering for students to find out information for themselves, both through their own investigations and carefully guided reasoning.

TEACHING NOTES

Help students connect their discoveries with other aspects of the ecosystem. For example, if a group investigates whether ladybugs are most often found in sunlight or shade, you might ask how this information might help us understand more about how ladybugs function in the ecosystem. Do they think ladybugs are more active in the day time? How much light is there during a day? How does it change over a year? How might investigating how sunlight and shade influence other organisms help us be better at managing land? For example, knowing that salmon do better in cooler, shaded water, has inspired some land managers to plant trees along streams. This has not only increased the numbers of salmon, but because salmon support so many other organisms in an ecosystem (they are eaten by bears, ravens, wolves, eagles, gulls, river otters etc.) these other organisms have benefited too. Even the trees that provide the shade have benefited from nutrients from dead partially-eaten salmon left on the banks.

Giving students a chance to redo their investigations. If you have time and students are still interested, you might choose to return to this activity later during their field experience. For the second time around, you can challenge students to redo their investigations using what they learned during their first explorations. They might try to improve the first investigation or answer a related question.

notice, especially if their investigation isn't very active (like watching an organism sit in one place for 15 minutes).

9. **Hand out tools.** If you have tools available that will be useful for the students' investigation, hand them out at this point. Only give out tools that are relevant.

10. **Support students as they conduct investigations.** Tell students to begin their investigations. Check in with groups to make sure they're recording data and on task. As issues arise, help students figure out how to adjust their investigations to improve them.

11. **Give students a time warning, and help early finishers extend their investigations if necessary.** Let groups know when they have ~5 minutes left. If groups finish early, ask, "How could you be more sure about your results?" suggest that they make more observations to help them better understand the ecosystem, or suggest that they investigate another related question.

Considering Results & Reflecting on Investigations

12. **Give the groups a chance to look at their data and discuss what they found.** Have each group briefly share their findings to the the larger group. You could ask:
    - *What data did you gather?*
    - *What did you notice about it?*
    - *Did anything surprise you?*
    - *Did you see any patterns?*

13. **Explain that scientific explanations are based on lots of evidence, but early on in an investigation, scientists may come up with more tentative explanations based on less evidence.** Emphasize that further testing would be needed to get reliable scientific explanations, but preliminary and tentative explanations can guide future studies. Explain even though the investigations were exploratory and can be inconclusive, they can still lead to a deeper understanding.

14. **Have the groups discuss among themselves tentative explanations to prepare to share their results; model using the language of uncertainty.**

15. **After groups have had a chance to discuss, call on a few groups to share their tentative explanations.** Remind them to use scientific language of uncertainty. Give students the chance to ask follow-up questions and if they are engaged, you can lead them in a short discussion about explanations that intrigue them, and whether the evidence supports their reasoning.

16. **Ask students how they could improve their investigations.** Have them discuss, and then share out:
    - *If you did it again, what improvements would you make to your investigation, your question, or to your data collection methods to make it more fair and accurate?*

- *How would you investigate your question further, if you had more time and tools?*
- *How could you test your tentative explanations?*

17. **Point out that these were exploratory investigations, just to begin figuring out what might be useful and testable questions about this ecosystem, and to try out some field investigations.**
    - *Exploratory investigations usually don't give us final answers, but may give us information to understand how to best investigate our questions.*
    - *A field scientist would probably do more than one exploratory investigation to try different investigation methods to decide on the best one, and to decide which questions are worth further study.*
    - *Scientific investigations often last months or years, to get better data.*

18. **Lead students in a *Walk & Talk* with the following questions to reflect on their learning.**
    - *What was challenging about your investigation?*
    - *What was surprising? Exciting?*
    - *What did you learn about the ecosystem?*
    - *Do you have any new questions as a result of your investigation?*
    - *What is an organism or a part of the natural world you could investigate near your home or school?*

TEACHING NOTES

Helping students notice what they have learned. Students often have a hard time reporting what they have learned. If you have already checked in with each group as they were investigating, you can help highlight things you noticed that they were learning.

TEACHING NOTES

Instructor Support

Teaching Knowledge

Choose an aspect of an ecosystem for students to focus on before leading this activity, and scout ahead of time to make sure that part of the ecosystem is present and observable enough for students to take part in rich investigations. If you ask students to design an investigation that relates to where fungi grow and there's little to no fungi present in the research area, those students won't have a rich experience designing an investigation (and will likely mostly experience frustration looking for a phenomenon that isn't present). Scout ahead of time, and do some research on your chosen topic-both by spending some time observing it before you're out with students, and (ideally) by looking up any previous scientific research that's been done. This kind of knowledge will help you guide students towards testable questions, and to help them connect what they learn in their investigations to the ecosystem as a whole. Even if the topic you choose is well-known to you, be open to the possibility of students' discoveries and ideas, and be a co-investigator and collaborator with students during their investigations.

For students to be successful in *Exploratory Investigation,* **they'll need to have developed their observational skills.** Use a routine like *I Notice, I Wonder, It Reminds Me Of* to build students' skills in making accurate observations and generating questions before doing *Exploratory Investigation.* Coming up with a testable question and a way to answer it is a complex process-students' discussion of how to approach a question will be richer and more productive if they have had some exposure to methods for collecting data in the field. Older students will likely be more able to engage in this process than younger students. It might help younger students to initially take part in some structured investigations, in which the question and methods for data collection have already been planned, and move towards engaging in the creative processes of generating questions and designing methods for investigation. Make a decision about when to do *Exploratory Investigation* based on your students' prior knowledge and experience.

The primary goal of Exploratory Investigation is for students to learn about the nature of science by engaging in scientific practices involved in conducting an investigation. But, as the Next Generation Science Standards point out, students will not effectively learn about the nature of science and science practices by just engaging in them. They also need to spend some time reflecting on the practices and nature of science that they were engaged with. They need to spend some time discussing what scientists do, how they acted like scientists, how much longer and more careful actual scientific investigations are, and how much thoughtful effort is behind generating scientific information. That's why we recommend using the BEETLES activity, *What Scientists Do* as both a pre and post *Exploratory Investigation* activity.

Conceptual Knowledge

Striving for authentic field study. It's generally accepted in outdoor science education that it's valuable for students to engage in scientific investigations, and the Next Generation Science Standards certainly supports that. But many field instructors are reluctant to do this with their students, because they're afraid that many students may get turned off to both science and the outdoors if forced to take part in highly structured investigations of questions that may not be of interest to them. And others are afraid that students will walk away with inaccurate ideas about how science is conducted if they engage in an investigation that is much shorter and less careful than actual scientific investigations. We designed this activity as a kind of compromise: it's engaging for students, and it's relatively authentic to actual early investigations of a topic meant to prepare for a more full and careful investigation. We also think that there's great value in doing an activity like this outdoors, rather than a pre-designed structured investigation, because it's easier for students to follow their own interests when outdoors than when in a classroom. Within the spectrum of structured investigations students might take part in, *Exploratory Investigation* is meant to resemble one part of the process of field scientists- one that is possible for students to take part in during their time at an outdoor science school. This type of investigation is authentic in that it engages students in the process of designing their own investigation around a specific topic and phenomenon in the natural world. A working field scientist wouldn't have a question and methods handed to them, as is the style of many structured science investigations students are often exposed to. A field scientist also wouldn't be told "go investigate anything you want in the world!"- a prompt that, for students, might be overwhelming and likely wouldn't lead to an ecologically relevant or interesting investigation. Generally, scientists have a field of study- which often gives some limitations on the organisms and phenomena the scientist focuses on, and the types of questions they'd investigate. For example, a soil scientist working within a department that specialized in geochemical cycling would have limitations on the facet of the natural world they explored and the types of questions they investigated. Students don't have that internalized structure when they approach an investigation, and the scaffolding in this activity offers it to them through focusing their study to a certain part of the natural world.

The concept and value of an exploratory study. The concept of "exploratory research" is common to many different fields of study. It plays a role when a question, topic, problem, or methods are not yet defined. In field science a scientist often needs to do an initial, exploratory study of natural phenomenon in order to more fully develop a viable research question and sound methods of study. In his essay "Untangling the Bank," Bernd Heinrich, the famous biologist and raven expert, writes about the role of an exploratory field study as he describes observing a phenomenon of caterpillars that had chewed leaves they'd eaten off of a tree- presumably so birds wouldn't see these "signs" of insects and prey on them. The first thing he did was an exploratory investigation, which involved some care in methods but not to the extent of a full stud., Then Heinrich honed his question of whether or not birds would perceive, react to, and more often strike areas where leaves had evidence of being munched by insects. Heinrich's initial and quick "exploratory investigation" of the phenomenon helped him to develop his investigation, and the structure of that kind of preliminary investigation is one that many field scientists have internalized and engage in without necessarily naming,

TEACHING NOTES

TEACHING NOTES

identifying, and separating each step. *Exploratory Investigation* makes these steps clear to students and allows them to recognize it as a useful framework.

Introducing new vocabulary. It's best to choose just a few hard words to focus on, introduce them in context, explain their meaning, use them multiple times, in both spoken and written form, and encourage students to use them. If students don't know the word "ecosystem," take a moment to define it here, (or in prior activities leading up to this one), and use the definition and new vocabulary word repeatedly. It takes about 7 exposures to a "hard word" for students to fully adopt it. Introducing too many hard words at the same time can lead to student confusion. "Ecosystem" = a community in nature of living and non-living things that are connected with each other. Note: ecosystem in spanish is "ecosistema."

Common Relevant Misconceptions

- **Student and Instructor Misconception.** There is a single scientific method that scientists follow, so incorporating science into outdoor experiences means following these steps.
  More accurate ideas. The "Scientific Method" is often taught in science courses as a simple way to understand the basics of scientific testing. In fact, The Scientific Method represents how scientists usually *write up* the results of their studies (and how a few investigations are actually done), but it is a grossly oversimplified representation of how scientists conduct investigations. The process of science is exciting, complex, unpredictable, and often iterative. It involves many different people, engaged in various different activities, in different sequences.

- **Student and Instructor Misconception.** A prediction is the same as a hypothesis.
  More accurate idea. A hypothesis is actually more than just a prediction– it includes a description of what you think might happen, which includes an explanation for why this might occur. This is why scientists also refer to hypotheses as tentative explanations. According to the *A Framework for K-12 Science Education*: "A scientific hypothesis is neither a scientific theory nor a guess; it is a plausible explanation for an observed phenomenon that can predict what will happen in a given situation. A hypothesis is made based on existing theoretical understanding relevant to the situation and often also on a specific model for the system in question." It's no wonder that it can be a challenge to help young students create relevant hypotheses based on their usually brief and limited experience investigating natural phenomena. The NGSS suggests introducing hypothesis in later grades.

- **Student Misconception.** Conclusive scientific data can be collected in an hour.
  More accurate information. Yes, it is valuable for students to plan and undertake a short, focused study. In this process, students learn about scientific practices and gain a better understanding of their surroundings. But gathering publishable scientific information requires specific procedures and is a process that can often take months or years to complete. Anyone can use science practices and procedures to learn

more about their surroundings, but a full investigation takes more time than this investigation.

Connections to the Next Generation Science Standards (NGSS)

BEETLES student activities are designed to provide opportunities for the "three-dimensional" learning that is called for in the NGSS. To experience three-dimensional learning, students need to engage in practices to learn important science content (Disciplinary Core Ideas) and relate that content to big ideas in science (Crosscutting Concepts). In simple terms, students should be exploring and investigating rich phenomena, trying to figure out how the natural world works. Exploratory Investigation engages students in the practices of Planning and Carrying Out Investigations and Asking Questions to build understanding of disciplinary core ideas related to Interdependent Relationships in Ecosystems, and to relate those ideas to the crosscutting concept of Systems and Systems Models.

Featured Science & Engineering Practices

Engaging students in Planning and Carrying Out Investigations. According to the National Research Council's A Framework for K-12 Science Education, students should take part in a variety of different investigations throughout their educational career- some investigations that are more structured, in which an instructor shares a question students investigate to reach a certain learning goal- and other investigations in which students are engaged in the process of question development and method design. Exploratory Investigation is designed to support students in generating their own questions and designing a short study. It's important that in addition to taking part in investigations, students understand how the process of investigation they're taking part in relates to the nature of science and how field scientists might work. To really give students the opportunity to better understand the nature of field science, don't skip over the steps in which students talk through the design of their investigation, and give them ample time to reflect on what they might do differently in the future, and what their data can't tell them. Make sure students understand that their study is "exploratory," and is a process a field scientist might use to see if a question is viable enough for longer study- and that though they definitely learned about their surroundings in the process, scientists would undergo a much more extensive process to get more conclusive "results."

Engaging students in Asking Questions. During the section on Developing Testable Questions, students also engage in the practice of Asking Questions as they sort questions as "testable" or "not testable" based on certain criteria. The ability to come up with testable questions is often a stumbling block for students in planning investigations, which is why much attention is paid to this skill during the activity. Don't miss the opportunity to deepen students' ability to develop testable questions by explaining how to convert a non-testable question into a testable question that can be answered through direct observation.

TEACHING NOTES

Featured Crosscutting Concept

Learning science through the lens of Systems and Systems Models. It's a "big idea" in science that "the natural world is complex; it is too large and complicated to investigate and comprehend all at once." (the National Science Education Standards). Scientists often isolate one system (like an ecosystem, as opposed to the whole biosphere), or components of it to learn more about the larger systems that make up the world. In Exploratory Investigation, students study one part of an ecosystem through an investigation to learn more about the ecosystem as a whole- and it's important that the investigation is framed so students understand that's a goal of the experience. Make that clear to students when you introduce the investigation. It's also important that students reflect on the fact that field scientists might undertake a similar process in order to deepen their understanding of an ecosystem. Make sure to point out to students that they could examine any system through an investigation to learn more about that system, while deepen their understanding of how the world works in the process. Note: Patterns is another cross-cutting concept that could be applied during this activity in rich ways.

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. The NGSS make it clear that students need multiple learning experiences to build their understanding of disciplinary core ideas. Exploratory Investigation offer students an opportunity to develop their understanding of disciplinary core ideas related to Interdependent Relationships in Ecosystems.

MS-LS2-2 states that "Although species involved in interactions vary across ecosystems, patterns of their interactions with their environments, both living and non-living, are shared." Regardless of the focus of their investigation, students will deepen their knowledge of the patterns of species' interactions with their environment as they make observations, generate questions, and complete their investigations. Students will also deepen understanding of the concept that organisms are dependent on their interactions with their environments, and can only survive in places where their needs are met (MS, 5-LS2-1). For example, if students' general topic was "where do fungi grow in this ecosystem," observations they made about where fungi were present and not present would relate to the conditions in which that species of fungi could survive.

If possible, give students time to delve into conversations about what their results might tell them about the ecosystems within their study groups, and check in with those groups to informally assess what learning has happened for students. Use this to inform your decisions about which activities to engage students in to deepen their understanding of relevant content.

Performance Expectations to Work Towards

No single activity can adequately prepare students for an NGSS performance expectation. Performance expectations are designed as examples of things students should be able to do to demonstrate their understanding of content and big ideas in science after engaging in multiple learning experiences and instruction over a long period of time. They are not the "curriculum" to be taught to students. Below are some of the performance expectations that Exploratory Investigation can help students work towards.

5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

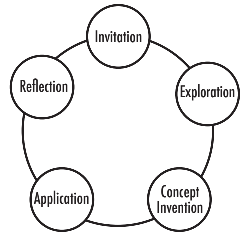
Activity Connections

Set students up for success in this activity by giving them practice making observations and asking questions with an activity like *I Notice, I Wonder, It Reminds Me Of.* Help them get more out of learning about the nature of science by using *What Scientists Do* as a pre and post to this activity. For students to understand how science is done and where scientific information comes from, they need to notice and reflect on how they have been involved in science practices. The introductory part of the *What Scientists Do* activity sets students up to think about and notice scientific practices, and the debrief at the end helps students to reflect on the practices they have engaged in and how they contribute to scientific investigations. Consider doing *Spider Investigation* first depending on students' experience with field methods and data collection to expose them to a more structured investigation. Afterwards, if your goal is to continue to develop students' understanding of concepts around interdependent relationships in ecosystems, try an activity like *Discovery Swap*.

This style and template for an "exploratory investigation" could be used following almost any BEETLES Exploration activity, such as *Bark Beetle Exploration*, *Lichen Exploration*, *The Case of the Disappearing Log*, *Tracking*, *Bird Language*, or *Spider Exploration*. During those activities, students build understanding of those phenomena and are prepared to generate and investigate interesting questions if they are guided through the process outlined in *Exploratory Investigation*.

If possible, encourage students to consult other resources–like books, field guides, or the Internet–when they return from their field experience to see what other research has been done about the topic they explored.

TEACHING NOTES



Exploratory Investigation completes a full learning cycle. Within a sequence of many activities, it could serve as a concept invention or application for students who are studying a specific part of the natural world.

FIELD CARD

Cut out along outer lines and fold along the centerline. This makes a handy reference card that will fit in your pocket.

Exploratory Investigation

Invitation to Investigating

1. Walk & Talk discussing ideas about conducting a science investigation:
   - ▶ *What are things field scientists do to learn about an ecosystem?*
   - ▶ *How is this ecosystem different than other ecosystems?*
   - ▶ *What are questions you wonder about this ecosystem?*
2. Explain that scientists do exploratory investigations to decide how to do longer investigations of ecosystems.
   - ▶ *Scientists often begin with a shorter exploratory investigation, to learn more about what is going on and how to investigate it.*
3. Point out one goal of this exploratory investigation is to learn how parts of this ecosystem interact , by looking closely at one part.
4. Tell them they'll also learn more about how to design a field investigation, and then think about how it could be improved.

Making Observations & Generating Questions

1. Explain investigations begin with making observations and coming up with questions.
2. Introduce the part of the ecosystem they will focus on in their investigation.
3. They'll have ~15 minutes to make observations, and write questions.
4. Introduce strategies for how and where to find organisms; explain boundaries and safety.
5. Circulate, inspire, encourage observations & probe for questions as needed, as students observe and generate questions for ~15 min.

Developing Testable Questions

1. Gather group & explain what makes a question testable.
   - ▶ *A question is scientifically testable if it can be answered through direct observation. For example, you could answer the question "Are there more horizontal spiderwebs or vertical spiderwebs in this ecosystem" by observing and counting each kind of spiderweb.*

2. Introduce the limits of time, safety, and resources for investigations.
   - ▶ *Scientists usually have only a certain amount of time and resources for an investigation. In our case, our questions must be investigated in no more than 15 minutes, using only the tools we have on hand.*
3. Record criteria for testable questions on white board:
4. objects, organisms or events we can observe; observing, measuring or comparing; 15 minutes; safe; tools
5. Pass out question cards & pairs decide if question is testable and discuss why or why not; they can switch cards with other pairs.
6. Ask pairs to read question and share whether they think it's testable here & now; prompt for reasoning.
7. Point out the "what does it like?" questions can't be answered; can't ask organisms what they like, but we can observe what they do.
8. Explain how to convert a non-testable question about what an organism "likes" into a testable question, by thinking about what can be observed.
   - ▶ *"Does it like being under a rock more than being in the open?" can be changed to "When the organism is near a rock in an opren field, does it spend more time under the rock or out in the open?"*
9. Point out that "why" & "how" questions are interesting but hard to test in one investigation.
10. Add sentence starters to white board: where, which, how many, how often, how long, does, will, can are. NOT why or how come?
11. Show "Why do sowbugs live under logs?" card and explain how to break it down further into observable questions.
12. Provide examples of descriptive questions, measuring questions and comparison questions related to the original "why" question.
    - ▶ *Measuring question: How many sowbugs are found in this area?*
    - ▶ *Descriptive questions: What else lives under logs in this area? What is it like under logs? (temperature, light, moisture)*
    - ▶ *Comparision questions: Where are most of the sowbugs living? Are there more sowbugs under logs, on the ground around logs, or in the topsoil?*

Continued on next page

www.beetlesproject.org

FIELD CARD

Cut out along outer lines and fold along the centerline. This makes a handy reference card that will fit in your pocket.

Continued from previous page

13. Point out how observing where sowbugs live might help them find out more about the ecosystem in general.

Choosing a Testable Question to Investigate

1. Explain pairs will join another pair to form a group of 4 and sort their questions as testable and not testable.
2. They'll then pick one to investigate together; remind them of criteria; allow ~7 minutes for selecting and revising.
3. Circulate and support groups to select questions.

Planning & Conducting Investigations

1. Introduce planning based on their testable question.
2. Discuss what they should think about to make their investigations scientific and a fair test.

   ▶ *What might be important for us to consider to make sure our data is accurate, and our questions get a "fair test"?*

3. Groups have ~10 min. to plan & discuss their investigations.
4. Tell them to write their question, tools & steps.
5. Circulate and support groups to design investigation plans.
6. Hand out tools.
7. Groups conduct exploratory investigations for ~15 min.; suggest they draw and take notes as they observe during their investigation.
8. Circulate, give a time warnings and help early finishers extend investigations as needed.

Considering Results & Reflecting on the Investigations

1. Groups look at data for patterns and discuss what they learned from their investigations. Ask,

   ▶ *What data did you gather? What did you notice about it? Did anything surprise you? Did you see any patterns?*

2. Explain that scientific explanations are based on lots of evidence, but early on in an investigation, scientists may come up with more tentative explanations based on less evidence.
3. groups discuss among themselves tentative explanations to prepare to share their results; model using the language of uncertainty.
4. A few groups share their tentative explanations.
5. Ask students how they could improve their investigations. Have them discuss, and then share:

   ▶ *If you did it again, what improvements would you make to your investigation, your question, or to your data collection methods to make it more fair and accurate?*

   ▶ *How would you investigate your question further, if you had more time and tools?*

   ▶ *How could you test your tentative explanations?*

6. Explain these were exploratory investigations to begin figuring out what might be useful and testable questions about this ecosystem, and to try out some field investigations.

   ▶ *Exploratory investigations usually don't give us final answers, but may give us information to understand how to best investigate our questions.*

   ▶ *A field scientist would probably do more than one exploratory investigation to try different investigation methods to decide on the best one, and to decide which questions are worth further study.*

   ▶ *Scientific investigations often last months or years, to get better data.*

7. Walk & Talk:

   ▶ *What was challenging about your investigation?*

   ▶ *What was surprising? Exciting?*

   ▶ *What did you learn about the ecosystem?*

   ▶ *Do you have any new questions as a result of your investigation?*

   ▶ *What is an organism or a part of the natural world you could investigate near your home or school*

www.beetlesproject.org

Question Cards For Sorting

cut out and paste to small index cards

Does it like being under a rock more than being in the open?

Are there worms living in the sand here?

Why do sow bugs live under logs?

What other organisms is it most closely related to?

On which surface does it turn right-side-up fastest:

a. sand?
b. sawdust?
c. dirt?

Are there more of them in the slow moving water or in the fast moving water?

Question Cards For Sorting

cut out and paste to small index cards

How does it move around?

What does it look like when it's an adult?

Does it react to movement?

Which surface can it move faster on:
a. rock?
b. sand?

How much time does it spend:
a. moving
b. resting

Will it spend more time in the Sun or shade?

ABOUT BEETLES™

BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) is a program of The Lawrence Hall of Science at the University of California, Berkeley, that provides professional learning sessions, student activities, and supporting resources for outdoor science program leaders and their staff. The goal is to infuse outdoor science programs everywhere with research-based approaches and tools to science teaching and learning that help them continually improve their programs.

www.beetlesproject.org

The Lawrence Hall of Science is the public science center of the University of California, Berkeley. *www.lawrencehallofscience.org*

Principal Investigator and Articulate Beetle: Craig Strang
Project Director, Lead Curriculum & Professional Learning Developer, and Idea Beetle: Kevin Beals
Project Manager, Professional Learning & Curriculum Developer, and Beetle Herder: Jedda Foreman
Curriculum & Professional Learning Developer and Head Fireball: Lynn Barakos
Curriculum & Professional Learning Developer and Champion-Of-All-The-Things: Emilie Lygren
Research and Evaluation Team: Bernadette Chi, Juna Snow, and Valeria Romero
Collaborator, Super Naturalist, Chief Scalawag and Brother-from-Another-Mother: John (Jack) Muir Laws
Project Consultants: Catherine Halversen, Mark Thomas, and Penny Sirota
Advisory Board: Nicole Ardoin, Kathy DiRanna, Bora Simmons, Kathryn Hayes, April Landale, John Muir Laws, Celeste Royer, Jack Shea (emeritus), Drew Talley, & Art Sussman.
Editor: Lincoln Bergman
Designer: Barbara Clinton

The following programs have contributed to the development of these materials by field testing and providing invaluable feedback to the development team. For a complete list of contributors and additional partners, please see our website at beetlesproject.org/about/partners/

California: YMCA Camp Campbell, Rancho El Chorro Outdoor School, Blue Sky Meadow of Los Angeles County Outdoor Science School, YMCA Point Bonita, Walker Creek Ranch, Santa Cruz County Outdoor Science School, Foothill Horizons Outdoor School, Exploring New Horizons Outdoor Schools, Sierra Nevada Journey's School, San Joaquin Outdoor Education, YMCA Camp Arroyo, Shady Creek Outdoor School, San Mateo Outdoor Education, Walden West Outdoor School, Westminster Woods.

Other locations: Balarat Outdoor Education, CO; Barrier Island Environmental Education Center, SC; Chincoteague Bay Field Station, VA; Eagle Bluff Environmental Learning Center, MN; Great Smokey Mountain Institute at Tremont, TN; Wellfleet Bay Wildlife Sanctuary-Mass Audubon, MA; Mountain Trail Outdoor School, NC; NatureBridge, multiple locations; Nature's Classroom, multiple locations; North Cascade Institute Mountain School, WA; Northbay, MD; Outdoor Education Center at Camp Olympia, TX; The Ecology School, ME; UWSP Treehaven, WI; Wolf Ridge Environmental Learning Center, MN; YMCA Camp Mason Outdoor Center, NJ; and YMCA Erdman, HI.

Photos: Pages 1 and 2 by Kevin Beals. *Icons*: Backpack by Rémy Médard; Growth by Arthur Shlain; Cut by Nathan Thomson; Outside by Petr Holusa; Park by Antar Walker; &Time by Wayne Middleton all from The Noun Project.

Funding from 2012-2015 for BEETLES publications such as this one has been generously provided by the S.D. Bechtel, Jr. Foundation, The Dean Witter Foundation, and the Mary A. Crocker Trust.

To contact BEETLES™, email beetles@berkeley.edu