beetles

Science and Teaching for Field Instructors

Professional Learning Materials

Evidence and Explanations

"I don't do science on my hikes, because the science takes away from kids being able to appreciate nature." - Field Instructor

When science is taught primarily as information delivery (even "fun" information delivery), or as following a recipe of steps ("the scientific method") for something you're not necessarily interested in, it *can* kill curiosity. But when outdoor science is taught as discovering the mysteries that surround us, and attempting to explain them, it does the exact opposite; it ignites wonder and curiosity about interacting with nature!

Everyone loves mysteries. We are "hard-wired" to be curious, with a desire to figure things out. The scientific enterprise is all about wonder and curiosity, about tackling mysteries, and coming up with evidence-based explanations to solve them. By providing students with inquiry routines, and encouraging them to engage in science practices, like making observations, asking questions and making evidence-based explanations to attempt to answer questions, we can give them life-long tools to stoke their curiosity and ensure that they will never be bored in nature. Engaging in these practices, developing this mind-set cultivates students' relationships with nature, and ultimately helps to create a more scientifically literate society.

It can be annoying to be around someone who is arguing without evidence, or in spite of the evidence, or is just using selected evidence and ignoring the rest. Students recognize this, too. This session helps guide instructors to teach students how to make explanations from evidence and also to evaluate the quality of the evidence they are using. The session also focuses on the importance of using the language of science. These are important science practices and important life skills that promote long term academic success.

The goals for the session are:

- **Discuss making explanations from evidence as a key practice of science.**
- **Experience field activities that help students to make explanations of the natural world.**
- **Explore different ways to evaluate scientific evidence.**
- **Discuss using science to encourage curiosity and wonder about nature.**
- **Discuss factors that lead to student *Inquiry Fever* in nature.**
- **Learn about the value of the language of science for students.**

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

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*

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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 3 by Kevin Beals. *Icons*: Backpack by Rémy Médard; Beetle by Ola Möller; Cut by Nathan Thomson; Outside by Petr Holusa; Park by Antar Walker; &Time by Wayne Middleton all from The Noun Project.

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BEETLES™ Professional Learning Materials

Evidence & Explanations

Contents

TEACHING ABOUT TEACHING

The presentations in this guide have been designed to "practice what we preach." This session reflects a learner-centered approach to instruction as participants experience a version of an effective instructional model while they learn about guiding students in making explanations from evidence. It's important to maintain the structure of the session so participants experience a mystery-based approach to nature for themselves—before discussing the implications for instructing students. Resist the temptation to provide a lot of information too early in the session. Simply telling instructors about making explanations from evidence goes against the whole idea—participants will gain more from a meaning-making experience where they experience, discuss, and process this important pedagogical topic for themselves.

PRESENTATION OPTION

Want to spend more time outdoors than in? This whole session can be done outdoors. Some slides can be skipped outdoors, but other text is important. You and your co-presenter can take turns writing text from slides on white-boards, and/or print some out using a black font on white background on as large sheets as possible. You may also want to put them in plastic page protectors.

TIMING TIP

Keep things moving. The prompts provided in the session are purposefully designed to generate productive and interesting conversations, but interesting discussions can make it challenging to stay within the estimated time frame. You may need to gently limit some of the discussion, and then pick up on the topic at another time, perhaps after staff has had some experience with applying the teaching strategies.

	Evidence and Explanations	Activity Location	Estimated Time
Invitation	**Introducing Evidence & Explanations** Participants discuss how science can be used to encourage wonder and curiosity in nature with students.	Outdoors	10 minutes
Exploration	***NSI: Nature Scene Investigators* Model Student Activity** A leader models a routine that introduces students to how to become curious about and attempt to explain mysteries in nature. Participants discuss the benefits and challenges of leading this kind of activity.	Outdoors	40 minutes
Exploration	***Inquiry Fever* Model Student Activity** A leader models leading students in *Inquiry Fever*. Participants discuss benefits and challenges of leading *Inquiry Fever*, and are introduced to necessary ingredients for achieving it with students.	Outdoors	30 minutes
Concept Invention	**Discussing Inquiry & Science Practices** Participants discuss connections with *Next Generation Science Standards*, and *Common Core State Standards.*	Indoors	10 minutes
Concept Invention	**The Value of the Language of Science** Participants are introduced to the value of coaching students in the language of science, how the language of science reflects the approach of science, as well as how instruction related to language of science relates to issues of equity and inclusivity.	Indoors	15 minutes
Application	**Evaluating the Strength of Evidence** Participants explore three criteria for evaluating the strength of evidence (quantity, size of assumption, & quality of source) by sorting cards and engaging in discussion.	Indoors	35 minutes
Reflection	**Wrapping-Up** Participants return to the guiding question and think about how engaging students in the practices of science can help build their wonder and curiosity about nature.	Indoors	10 minutes
	TOTAL	2 hrs, 30 min	150 minutes

PREPARATION

Before the day of the session:

1. **Prepare to present.** Choose who will present each part of the session (see below for info on model student activities). Consider including staff who have already experienced the session. Read through the session write up, slides, handouts, sidebars, and background (page 51) to prepare to present. The more each presenter is able to "own" the session, the better the presentation. Write notes on a printed version of the session, or however you prefer. If you choose to present the whole session outdoors, make large copies of slides and/or print out half-page copies for yourself to refer to the information on them, or write it on white-boards. Modeling of student activities should be done outdoors, but if there's severe weather, you can bring an artifact inside for *NSI*, and use an indoor collection of nature artifacts for *Inquiry Fever*.
2. **Set up projection system/review multimedia.** Set up and test the system to be sure participants will be able to see items projected during the session.
3. **Read and familiarize yourself with the *NSI: Nature Scene Investigators* Activity Guide; assess your ability to lead the activity.** Choose your staff member who is most experienced with successfully leading this activity with students to lead this part of the session. The main body of that write-up is embedded in this *Evidence & Explanations* write-up. If you'll be teaching the activity using the embedded write-up, we suggest that you read through the separate BEETLES activity write-up for *NSI: Nature Scene Investigators*, taking notes on the embedded write-up included here.
4. **Obtain an object to investigate during NSI.** It should be strange-looking and mysterious, but doesn't have to be uncommon. The NSI Activity Guide has tips on picking an object. Keep this object hidden (in a bag, etc) until the write-up says to unveil it.
5. **Identify outdoor areas for activities.** For *NSI*, all you need is a shaded level area where the whole group can be in two concentric circles, with the inner circle seated or kneeling and the outer circle standing. For *Inquiry Fever*, you need a nearby/adjacent area that has interesting stuff to explore, like plants and invertebrates. Depending on the time of year and the experience of your participants this might be a meadow, a trail with lichen/spiders/lizards/ insects, an area with logs to roll over, or a small creek area. Pay attention to local hazards, such as alligators, and make adjustments as needed.
6. **Make copies.** See list at right.
7. **Prepare the Quality of Source and Size of Assumption cards.** Cut out the cards and bundle the sets together in envelopes or with clips so they can be easily distributed to small groups of participants.
8. **Gather *Inquiry Fever* materials.** Gather clear cups, nets, hand lenses, bug boxes etc., to be used to explore organisms during *Inquiry Fever*.
9. *(Optional)* **Make Session Overview to post on wall.** You may choose to make a Session Overview to post on the wall during this session. It's not necessary for a workshop like this, but some presenters and participants prefer having it, so they can see the trajectory of the session.
10. **Plan when you might include a break in the session.** We suggest after modeling Inquiry Fever.

Immediately before the session:

1. *(optional)* **Place NSI object outdoors.** If it's not already outdoors, place the *NSI* object in the area you selected, or carry it with you.

MATERIALS

For the group:

- ❑ projection system
- ❑ computer
- ❑ slides
- ❑ *NSI* "mystery" object
- ❑ Copy of *NSI* student activity guide (available at beetlesproject.org)
- ❑ (*optional*) *Student Resources for NSI*, page 35
- ❑ (*optional*) *Instructor Questions for NSI*, page 36

For each group of 3–5 participants:

- ❑ 1 Set of *Size of the Assumption* cards, page 37
- ❑ 1 set of *Quality of Source* cards, page 38
- ❑ Exploration tools: clear cups to put organisms in, nets to catch organisms, etc.

For each participant:

- ❑ *(optional, but highly recommended)* 1 hand lens
- ❑ *Evidence and Explanations in Science* handout, page 41
- ❑ *(optional) NSI* student activity guide (available at beetlesproject.org)
- ❑ *(optional) Using the Science Framework in Outdoor Science Schools* handout, page 42 (not necessary if participants already received a copy during the *Nature and Practices of Science* session)

YOU ARE HERE:

10 minutes

TEACHING NOTES

Remember to bring your hidden NSI object outside with you, if you have not already placed it outside.

Introducing Evidence & Explanations Session

1. **Gather group outdoors & introduce the session.**
   a. Welcome and check in with participants.
   b. Make sure everyone is ready to begin and has the gear they need to be comfortable during outdoor experiences.
   c. Explain: The session is titled, *Evidence & Explanations*.

2. **Introduce the session's guiding question: *How can we use science to encourage students' wonder and curiosity in nature?***
   a. Turn and talk with a partner about the guiding question.
   b. After ~1 minute, ask volunteers to share something their partner said.
   c. Explain: This is the goal for the session: to help instructors inspire wonder in students through engaging in some scientific practices.

3. **Explain that scientists try to explain mysteries by coming up with the explanations based on evidence.**
   a. Science begins with making observations and asking questions, but it doesn't end there.
   b. The overall goal of science is to attempt to explain the mysteries around us—**to develop the best explanations based on all available evidence.**

4. **Explain that a "nature mysteries" approach taps into students' natural curiosity to figure things out by wondering, making explanations, & looking for evidence:**
   a. You can open the door for students to make explanations from evidence by approaching nature as being full of mysteries to investigate.
   b. Mysteries are inherently interesting. We're naturally curious, with a desire to figure things out.
   c. It's engaging for students to try to come up with explanations for what they observe.

5. **Explain that a "nature mystery" approach also leads to understanding, & actively engages students with nature, helping them develop relationships with the natural world:**
   a. Of course, making explanations about the natural world also improves our understanding about the natural world.
   b. When students become engrossed in this important science practice, they can simultaneously begin to emotionally connect with nature.
   c. This approach teaches students how to actively engage with nature. It's a powerful way to interact with nature.

YOU ARE HERE:

40 minutes

Modeling a Student Activity *NSI: Nature Scene Investigators*

1. **Introduce *NSI* as a routine that is a great tone-set for students to be more inquisitive about nature:**

a. We're going to model a routine that can be used with students to look at nature through the lens of solving mysteries.

b. This activity works well to set a tone of inquiry at the beginning of a field experience, and to keep it going throughout the experience.

2. **Take participants outside, bringing object & tools; pass out hand lenses to everybody.**

 a. Bring *NSI* object with you if you haven't already placed it outside.

 b. Bring any exploration tools for participants to use during the *Practice and Inquiry Fever* phase (cups, nets, bug boxes, etc.)

3. **Tell participants to behave as adults during the activity:**

 a. You'll be participating as adults, following your own curiosity, and discussing discoveries and ideas at your own level.

 b. The leader will be modeling how to lead it with *students*, so you should support the leader, not derail discussions too far off-topic, and also keep focused on how students might respond to the activity.

 c. Acting out negative student behaviors is not helpful. Imagining how your students might respond is helpful.

 d. There will be some questions asked that might seem obvious to you, but are designed for students.

4. **Model NSI routine:**

 a. Use the *NSI* student activity guide (embedded in this session script) to lead the *NSI* routine with participants, much as with students.

 b. Be sure to model how to get participants/students to:

 - make observations and ask questions
 - build upon each others' statements
 - politely disagree with each other
 - make explanations based on evidence
 - use appropriate language of uncertainty
 - change their minds when the evidence doesn't support their ideas.
 - cite sources when sharing information.

 c. Stop before the *Practice and Inquiry Fever* section of the activity to lead some debriefing discussions before moving on with the rest of the activity.

5. **Pass out handlenses now, if you're using them.**

Introducing NSI

1. **Tell learners there are mysteries everywhere in nature:**

 a. A lot of people walk through nature without noticing much–but there are mysteries everywhere in nature if you pay attention.

TEACHING NOTES

Leading NSI successfully. Although NSI is a wonderful activity and tone-set with students and adults alike, inspiring students to engage in making evidence-based explanations of mysteries in nature, it takes experience to lead it well. Instructors who don't have a lot of experience leading open exploration and discussion with students may struggle, and it can flop the first time. Choose a staff member with the most experience in those areas to lead it during this session. The person leading it should lead it with students before leading it with instructors. Pay close attention to the "surround" and scaffolding in the student activity write-up.

How should staff behave during model activities? Some leaders ask participants to behave like children during model activities, however, we've found that this often leads to exaggerated negative behaviors, and the modeling suffers (sometimes the experience is ruined). Instead, ask them to participate as adults, while imagining how students would respond. There may be times when they might get carried away with discussion of adult content to the point that it loses its effectiveness as a model, and as leader you may need to point this out and ask them to remember the level of their students, and tone down the content.

Hand lenses. Check out the *Hand Lens Intro* activity guide for tips on introducing students to hand lenses productively.

The student activity has been embedded in this professional learning write-up for your convenience. In this section, students/participants are referred to as "learners" in order to help you identify the parts that are taken directly from the student activity. The blue box differentiates the student activity from the rest of the write-up.

2. **Explain that if you know how to observe, ask questions, & make explanations–nature is exciting & interesting:**
   - **a.** Once you know these observation skills you need never be bored in nature.
   - **b.** You'll be a team of Nature Scene Investigators checking out a mystery object.
3. **Set the group up in "NSI formation" with learners in two concentric circles facing inward, with inner circle sitting/kneeling.**
   - **a.** Half the group sits or kneels in a tight circle.
   - **b.** The other half stands in a circle immediately behind them.
4. **Explain role of inner circle: making observations.**
   - **a.** The inner circle says observations out loud so everyone can hear them.
   - **b.** They will also examine the object closely (using hand lenses if available).
5. **Explain role of outer circle: asking questions about the object:**
   - **a.** Outer circle will try to ask questions that can be answered through observation by the inner circle.
   - **b.** All relevant questions, are encouraged, but questions that can be answered through direct observations–the way the object smells, feels, looks, sounds–are especially useful.
6. **Steer learners away from identification questions.**
   - If a "what is it" question pops up, tell them they'll get to that later, but for now they should focus on information they can gather from their own observations.

Making Observations & Asking Questions

1. **Unveil the mystery object & set it in center of circle.** Up till now, keep your mystery object concealed in a bag or cloth to build suspense and to make sure students are focused while you are giving instructions.
2. **Tell the inner circle to make observations & the outer circle to ask questions.**
3. **Facilitate this stage of the discussion by encouraging participation, interaction, observations, questions, and conversation:**
   - **To encourage participation establish non-verbal signals for agreement.** Invite learners to pat their heads or use an established hand signal if they noticed or wondered the same thing someone else has said.
   - **To encourage interaction, include the outer circle.** If a question from the outer circle can be answered through observation, ask students in the inner circle if they can answer the question (especially those close

TEACHING NOTES

Your excitement matters. Carry a genuine sense of excitement and curiosity—both about your mystery object and what your learners have to say. Your attitude can inspire or squash learners' energy for exploration and thinking.

***NSI* can be messy; Don't be strict.** Some outer circle learners will call out observations and some inner circle learners will call out questions. That's fine. Focus on following interest and including as many learners as possible.

Using *I Notice, I Wonder, It Reminds Me Of…* skills. It may be useful for learners who are struggling with making observations to give them the sentence starter "I notice..." and encourage them to say out loud anything they notice and to embellish and add to others' observations. Similarly, learners struggling to ask questions can use the sentence starter, "I wonder...".

Talking over each other? If learners are calling out too many observations & questions at the same time, and it's difficult for them to hear one another, ask them to slow down and wait for pauses. Last resort: ask them to raise hands.

Don't let it drag. Pay attention to the group interest and energy, and keep things moving! One of the main goals is to make learners curious, and boredom is counter-productive.

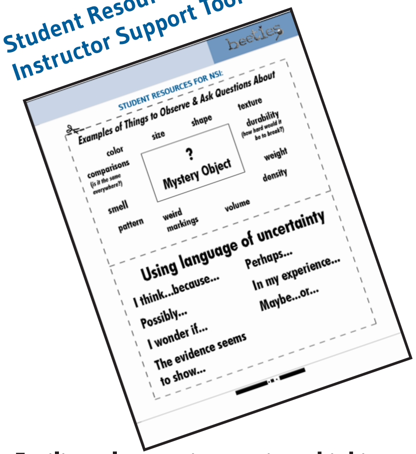
to the object). The more you can focus the inner circle on questions asked by the outer circle, the more you can engage the outer circle.

- **Focus on questions that can be answered through observations.**
- **To support the outer circle in generating questions, ask them to pass around the card** *Examples of Things to Observe & Ask Questions About* (page 35) and use it to come up with ideas for questions.
- **To encourage observations and questions, use prompts like:**
  - *What do you notice?*
  - *What colors do you see? Textures?*
  - *Is it heavy or light?*
  - *How would you describe its shape?*
- **To encourage dialogue and discussion, use prompts like:**
  - *Isaiah, do you see the holes, too?*
  - *Do you agree with what Bernice said?*
  - *Sarah, how would you describe the color?*
  - *What do you think, Juan?*

4. ***Well before*** **learners lose interest in the object, ask the circles to switch places.**
   - After a few minutes but *well before* learner interest wanes, tell the inner circle to switch places with the outer circle.
5. **Tell learners that everyone should make observations & ask questions.**
   a. Explain that at this point anyone can call out observations or ask questions no matter which circle they're in.
   b. Make sure everyone who was previously in the outer circle gets a chance to look at the object up close.
6. **Facilitate this stage of the discussion by focusing learners on an intriguing part of the object & helping them build on each others' observations to encourage discussion.**
   - **To help learners focus on one part of the object, follow learner interest, and ask "going deeper" questions like:**
     - *We've noticed this pattern of it being light on top and dark on the bottom–is there anywhere on the object it's not like that?*
     - *Are those colors everywhere, or only in certain areas?*
     - *What true statements can you say about the cracks?*
   - **To help learners build on each others' observations, ask questions like:**
     - *Does anyone want to build on what Carla was saying?*

TEACHING NOTES

Student Resource for NSI-Instructor Support Tool


STUDENT RESOURCES FOR NSI:

Examples of Things to Observe & Ask Questions About

color
size
shape
texture
durability (how hard would it be to break?)
comparisons (is it the same everywhere?)
?
Mystery Object
weight
density
smell
pattern
weird markings
volume

Using language of uncertainty

I think...because...
Possibly...
I wonder if...
The evidence seems to show...
Perhaps...
In my experience...
Maybe...or...

Facilitate learner interaction, thinking, and participation. Asking specific learners to agree or disagree with observations encourages deeper observations and respectful disagreement. Try to stir up learner-to-learner discussion, point out interesting learner statements, and ask others to respond to them. Avoid putting shy or reluctant learners on the spot with challenging questions, but encourage them by asking low-risk questions, such as, "Do you see holes in it, Lauren?" Listen for interesting directions to focus on and pursue, but be ready to switch to another if one runs out of steam.

Seek out the edges of your & learners' understanding. We become curious about things we don't know. Guide learners toward mysteries they don't understand. And don't be afraid of learner questions to which you don't know an answer. Inquiry and discussion become more authentic and interesting when the whole group, including you, is sincerely trying to figure something out.

"A question ain't really a question when you know the answer too." -— John Prine

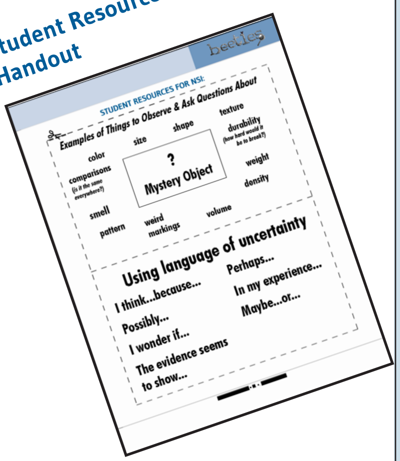
TEACHING NOTES

"Scientific inquiry shouldn't stop just because a reasonable explanation has apparently been found."

— Neil deGrasse Tyson

Remember to be a "guide on the side." Play the role of "guide on the side," managing the dialogue, encouraging participation, and helping learners clarify their statements. Avoid sharing information you have about the object until after learners have investigated the object(s) on their own and made their own explanations. If you wait, the facts and ideas that you share are more likely to be understood and be memorable because learners will be more curious and invested.

Student Resources for NSI-Handout



- *Roberto showed us that these holes go all the way through this object. What else can we notice about them? Are all the holes like that?*
- *What else can we notice about that side of the object?*

Making Explanations from Evidence

1. ***Well before*** **learners lose interest, invite them to make explanations based on evidence (more observations & questions always welcome!).**

   - Ask learners in both the inner and outer circle to start coming up with explanations based on evidence. Often learners will start to do this naturally, and you can use a learner's example to segue into this step. For example:
     - *OK, now let's move on to what Isaiah has already started doing when he said he thought the white part was the top when it was alive. Can anyone else come up with an explanation for which side is up, whether it was burned or not, where it came from, or any other things we've wondered about? And remember to share the evidence your explanation is based on.*

2. **Facilitate this stage of the discussion by following learners' interests, encouraging good science talk, & asking questions that encourage explanations, promote dialogue, & uncover learners' thinking.**

   - **To follow learners' interests, seek out learners' excitement, then follow it as they make explanations.** Be ready to shift focus if interest in a certain trait or idea wanes.
   - **To encourage good science talk, ask learners to share their evidence and to define big words they use**. If a learner makes an explanation without evidence, ask for their evidence. If a learner uses vocabulary others may not know, ask them to describe what they mean by the word.
   - **To encourage good science talk, ask learners to respectfully agree or disagree with each others' ideas, and use "the language of uncertainty."** Use learner statements to introduce language of uncertainty. When a learner begins a statement with "Maybe," "I wonder if," or other language of uncertainty, point this out to the group. Explain that it's a good example of how you talk in science, and to be open to the possibility that there may be a better explanation. Bring the "Language of Uncertainty Sentence Starters" (page 35) and hold it up during the discussion to help learners form their sentences.
   - **To encourage explanations, ask questions like:**
     - *We've wondered about _____; what's an explanation for it?*
     - *So you said, Sarah, that you saw different colors on different sides of the object. What's your explanation for that?*
     - *What do you think has happened to it?*
     - *What could have caused this?*

- **To encourage dialogue and uncover student thinking, ask questions like:**
  - *What's your evidence for that?*
  - *Would anyone like to add to that explanation, or come up with a different explanation?*
  - *What makes you think that?*
  - *So, Isaiah thinks something may have eaten it because of these small holes. What do you think of that idea, Juan?*
  - *So Roberto, you said you think this object fell on the ground at some point because of the damage you observed. Is that right? Does anyone want to build on what Roberto has said?*

3. **Keep discussion moving & transition when learners are ready.**
   - If it seems appropriate, redirect the conversation by asking a new question or checking in with the group.
4. **Explain to learners that many features we observe in the natural world are the "effects" of one or more causes.**
   a. Things we they observe in the natural world—like some of the features of this object—were caused by something.
   b. In other words, many observations can be called "effects" and whatever produced them can be thought of as the "causes."
5. **Explain that since we can't always "catch the causes in the act," we can make possible explanations for what might have happened:**
   a. It's sometimes hard to "catch the causes in the act" but, we can try to figure things out using evidence and reasoning.
   b. Trying to connect the possible causes with effects can be fun and interesting.

Sharing & Evaluating Information From Other Sources

1. **Invite learners to share what the object reminds them of, what they know or have heard, & to name their sources. Explain:**
   a. You now have the opportunity to share what the object reminds you of, and what you may have heard or already know about the object.
   b. To be scientific, you should also name your source(s) –say where you got your information—like from a book, what a friend said, or from a website.
2. **Encourage learners to share how reliable they think their sources are:**
   a. Sources can be more or less trustworthy.
   b. It's important to cite our sources for the information we share about a

TEACHING NOTES

Ask broad, not narrow questions. For the most part, try to ask broad questions (there are *many* examples included in the write-up) that have multiple possible responses, and that lead toward exploration and discussion. Try to avoid narrow questions that have one correct response, and are good for checking learners' recall, but generally not for generating exploration and discussion.

This embedded NSI exemplar includes the optional NGSS Crosscutting Concept steps about Cause and Effect as they are directly relevant to the topic of making explanations. Read through the Instructor Support section of the NSI write-up to learn more.

If you're having trouble asking questions, look at the Instructor Questions for NSI on page 36.

Instructor Questions for NSI-
Instructor Support Tool


EVIDENCE AND EXPLANATIONS
INSTRUCTOR QUESTIONS FOR NSI

topic, and to discuss how reliable we think the source is.

3. **Ask questions to encourage learner sharing, such as:**

   – *What does it remind you of?*
   – *Where have you seen something like this before?*
   – *Have you heard, seen, or read anything about something like this?*

4. **After learners have the chance to share their knowledge, share relevant information you know about the object, & include your source(s).**

   a. Try not to share everything you know about the object. If you have information that could incite more curiosity, go ahead and share it, but only *after* learners have shared their own knowledge.

   b. If learners can discover things for themselves during further explorations, don't spoil their inquiry by telling them now.

   c. Think about what facts are relevant to what learners are focused on and what might push learner observation deeper or corroborate what they have already figured out. For example, you could say:

   – *Based on your observations and explanations, you all thought this leaf was damaged by insects eating it. I've seen photos of this sort of pattern in a section on leaf damage by caterpillars in a field guide called "Tracks & Sign of Insects," and caterpillars are insects, so that supports your explanation. During our hike, let's keep looking at this type of leaf, and see if we can find more evidence, or actual insects in the process of eating them.*

6. **Debrief NSI Activity; Discuss the benefits of using the *NSI* routine with students:**

   a. Let participants know that you're stepping outside of the student activity for the moment to discuss it so far—as **instructors.**

   b. Ask:

   ▶ *What are the benefits of using a routine like this with students?*

   c. Listen to their comments, and be sure to give enough time for a variety of ideas to be brought up by the group. At this point, try to refrain from sharing benefits yourself.

7. **Bring up additional benefits of using the *NSI* activity:**

   a. After participants have shared, consider bringing up any of the following benefits, but only if they were ***not already*** discussed:

   - Provides students with a lens and a mindset, which they can use to engage with nature during a field experience, and whenever they are in the outdoors after they leave your program.
   - Everyone can see the "find" at all times, and everyone has an opportunity to explore it up close.
   - Everyone gets time to focus on observations, questions, explanations and connections.

TEACHING NOTES

"Running mysteries." Ideally, your group will still have questions about your object once *NSI* is done, that will draw them into more investigating and questions during the field experience. For example, learners who had puzzled which side of a bracket fungus was up, were able to immediately answer the question when they found some on a dead stump, but then moved on to their next question to investigate, "Do they only grow on dead wood?" Amelia Rosenman of San Mateo Outdoor Education had her students intrigued with looking for moss during a hike to figure out if it grew in soil or not.

Connections to the *Next Generation Science Standards (NGSS)*. For three-dimensional instruction, you need to think about: *What content (disciplinary core ideas) do I want students to learn? What practices will the students engage in to learn that content? What opportunities will students have to connect their understanding of the content to bigger ideas of science (cross-cutting concepts)? NSI* is particularly robust in science practices and can be a powerful experience to promote three-dimensional teaching and learning in field experiences.

Featured Disciplinary Core Ideas. The disciplinary core ideas that emerge from *NSI* vary, depending on what students are exploring and the directions student questions and instructor guidance may lead to. The main point of *NSI* is engaging students in practices of science—but the experience is richer, more valuable, and more interesting for students if it helps build toward some conceptual understanding. Instructors should pay attention to student ideas, and attempt to weave them into the disciplinary core ideas they've chosen for their field experience. It's helpful if instructors know some things about the object, and if they've thought through how to integrate it into content themes they've planned for their field experience.

- Students become aware that there are mysteries everywhere, which can generate interest in nature.
- The leader has the opportunity to efficiently coach the whole group on collaboration, scientific discussion/argumentation, language of uncertainty, open-mindedness, making explanations from evidence, citing sources and judging how reliable they are.
- Provides a structure that keeps things student- and nature-centered, not instructor-centered: encourages leader to hold back on telling information, allowing students to try to figure things out themselves.
- There's still an opportunity for the instructor to add in additional content at the end if appropriate.
- It's an opportunity for the instructor to informally assess learners, noticing if they cite evidence, use language of uncertainty, name sources of information, and cite prior knowledge related to your object.
- Making explanations can also be used to integrate the cross-cutting concept of Cause and Effect.

8. Discuss the challenges of using the *NSI* routine.

a. Ask:

▶ *What might be challenges of using a routine like this?*

b. Listen to their responses, and be sure to give enough time for a variety of ideas to be brought up by the group, for the most part refraining yourself from sharing challenges.

9. Bring up additional challenges of using the NSI activity.

- After participants have shared, consider mentioning any of the following challenges that may have not been discussed:
    - As with any unscripted activity, instructors have to be ready to follow student ideas, which may go down unpredictable pathways.
    - Students don't always have the patience for sitting and standing in whole group circle formations for very long. It's best not to overuse the whole group version of the routine, and only do it when the group is ready to focus on an exciting and mysterious find.
    - On narrow trails, it can be difficult to gather a whole group around a find.

10. Explain the challenges of doing this routine for instructors who have little experience leading open exploration and student discussion:

a. There's a lot going on when you lead *NSI*: Paying close attention to the content of student comments and interactions, the mood of the group, pacing, social dynamics, moves to make as the instructor…

b. Novice instructors with little experience leading open exploration and discussions may struggle at first.

c. It can be helpful to work up to *NSI*, getting practice leading other

TEACHING NOTES

Using *NSI* during field experiences. Use the *NSI* approach & inquiry skills as much as possible, but don't overuse the formal version with concentric circles and changing roles. The formal version works best as an introduction to inquiry skills and mindset, followed by "inquiry fever." It provides students with curiosity and skills for making explanations that can be used at any time informally during a field experience—not just in the structured concentric circle format. Consider using the formation again only if there is a particularly interesting find that your whole group wants to explore. If over-used, learners may rebel against the structure.

TEACHING NOTES

simpler science discussion and exploration activities first, such as *Walk & Talk* and *I Notice, I Wonder, It Reminds Me Of.*

d. The activity works best when the instructor is comfortable improvising prompts to help guide students to build off each other's ideas, explore the quality of evidence, & discuss ideas—skills that take time to develop.

11. Explain that exploration & discussion of ideas are important for students, so discussion & exploration-leading skills are important to becoming great instructors:

a. Exploration is an important aspect of helping students develop curiosity for and a relationship with nature.

b. Discussion of ideas is a crucial part of learning for students.

c. That's why it's important for science instructors to learn how to lead these types of explorations and evidence-based discussions.

12. Instructors should try, evaluate, then try again:

a. If the activity doesn't work perfectly the first time an instructor leads it, the instructor should try it again.

b. An instructor might try to figure out small adjustments to implement instead of tackling everything at once.

c. There is lots of scaffolding in the student activity guide, including many sample questions for each stage of the activity.

d. The student activity guide is meant to be an ongoing resource that can be re-read periodically by an instructor who is working to improve their instruction.

13. Explain that instructors don't need to do NSI to begin inviting students to make explanations about nature mysteries:

a. Since NSI can be challenging to lead at first, instructors can start by integrating students making explanations into their instructional practice.

b. Make a habit of asking questions such as: what do you notice?; what do wonder?; what might be a possible explanation for that?; does anyone have a different idea?; etc.

c. Eventually use NSI because it's an efficient way to get students excited about tackling nature mysteries and coaching the group on how to do it.

14. Explain that some instructor questions can particularly encourage students making explanations from evidence:

- Here are examples of useful questions to use when students find something mysterious. They help encourage students making explanations from evidence and arguing from evidence. These questions will be available in a handout at the end of the session.
  - Do you agree with that observation?
  - What do you think is happening here?
  - What evidence would you like to have to be more certain?

A flexible format during Inquiry Fever allows learners to pursue their interests, which might change as the activity goes on. Perhaps a pair of learners try to catch a butterfly, while a nearby learner finds a spittle bug. One of the butterfly-catching learners might switch her attention and join in investigating spittle bugs, and other learners may join in too. Learners are able to follow their curiosity as different interesting finds pop up, and they are able to team up with others who share their interest.

Modeling a Student Activity: *Inquiry Fever*

YOU ARE HERE:

30 minutes

TEACHING NOTES

1. **Explain that it's important for students to have opportunities to apply *NSI* practices to their own discoveries:**
   a. Using *NSI* as a tone-set/mindset is lost if students don't get to apply the strategies to their own discoveries in nature.
   b. It's important for students to "own" the routine, so they are more likely to use it independently later on.
   c. *Inquiry Fever* is one way to give students the opportunity to apply their learning and get excited about making and explaining their own discoveries.
   d. Tell participants you're going to shift back into the student activity again to engage in *Inquiry Fever.*

Applying the Skills & Inquiry Fever

1. **Explain to learners that they can use these skills *anywhere* in nature.** Tell learners that now they know how to make observations, ask questions, and make explanations, they can learn about any part of the natural world.
2. **Take learners to an area rich for exploration, & send them to explore & use their skills with others.**
   - Tell them to find interesting stuff, and along with others, make observations, ask questions, and try to explain it using evidence.
3. **Encourage learners to make explanations about possible causes for things they observe.**
4. **Offer tools, like cups, nets, bug boxes, & hand lenses, & send learners to check out interesting things using their "NSI" skills with others.**
5. **Move between groups & help engage learners who may be less focused or don't know what to do.** Give learners time–at least ten minutes–so they can find something that interests them and have meaningful conversations. Circulate and ask questions to engage learners, such as:
   – *What do you notice about this?*
   – *What are some questions you have about it?*
   – *What's your explanation for that?*
   – *What's the evidence for your explanation?*
   – *What do you think about that explanation?*
   – *Can you come up with a different explanation?*

Wrapping Up and Making Connections

6. **Ask what it was like to use science inquiry skills in nature.**

Teaching Note. Hello there, I'm a teaching note. I'm here to offer you tips, different perspectives, and other useful information.

Note about Teaching Note. Don't listen to the "note" above. It's not an actual teaching note. It's a note about teaching notes.

Note about a note about Teaching Note. Neither are you, my friend.

Note about a note about a note about Teaching Note. For useful information, you should go read some other notes.

Good talk.

TEACHING NOTES

- Encourage learners to reflect on the science skills they just used, and what that was like for them.

7. **Explain to learners to keep looking for mysteries in nature & using their tools–both during the field experience, and beyond it:**

   a. You can keep using these skills to explore interesting things you notice during the field experience, or wherever you go- even a schoolyard, at home in your yard or in a park.

   b. Look around at how many more potential mysteries there are to investigate around you in the natural world.

   c. The way you made observations, asked questions, and came up with explanations was similar to how field scientists work.

8. **Encourage learners to make & discuss explanations coming up with possible causes for effects they observe; tell them this a useful way for scientists to learn about many parts of the natural world.**

   ▶ *When we find interesting stuff in nature, lets keep trying to figure out what caused it. Scientists think about cause and effect whenever they're trying to figure something out, because it helps them to better understand the world.*

9. **If your object is commonly found at your site, encourage learners to look for other examples to investigate further.** For example:

   – *Maybe someone can spot a bird like the one that was killed, or an animal that might have killed it.*

   – *Let's see where we find these fungi living in the woods, and if they grow on wood or the ground.*

10. **Make connections to your theme and/or concepts.**

    a. Transition into the activities that follow NSI, by reminding learners about your theme for the day/hike/field experience, and helping them to relate the topic to their investigations and explanations.

    b. Invite learners to make more observations that connect to what they have discovered through NSI. For example,

    – *I wonder how many galls we can find on our hike today and if they will be similar or different from this one. Where do you think we might find more?*

    – *Let's keep looking for more evidence of predator-prey interactions.*

    – *That was an organism adapted to survive in a damp forest. Maybe we can compare it with an organism from a dry habitat.*

2. **Debrief model activities. Ask participants to discuss a few questions on their way back indoors with a partner they were not just exploring with:**

   a. The *NSI/Inquiry Fever* student activity is over now.

   b. Find a partner—someone you were not just exploring with.

   c. As you walk back to the presentation room discuss this question with your partner:

Walk & Talk? If you are already familiar with the Walk & Talk routine, use it here with the paired discussions in steps 2 and 3 on this page, unless you prefer to keep it less structured.

TEACHING NOTES

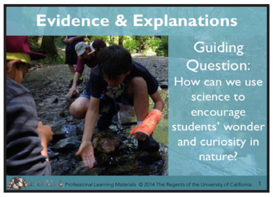
- ▶ *What did you discover and wonder, and what possible explanations did you come up with?*

3. After 2–3 minutes, ask the next question for the pairs to discuss:

- ▶ *What are benefits and challenges of leading "Inquiry Fever" during a field experience?*

4. Return indoors.

5. Show slide 1: *Evidence & Explanations*. Lead a group discussion on the benefits & challenges of developing "Inquiry Fever" in the field.



slide 1

- Ask the following questions of the whole group:

- ▶ *What are the benefits of leading "Inquiry Fever" during a field experience?*
- ▶ *What are the challenges to leading "Inquiry Fever" during a field experience?*
- ▶ *What helped encourage your observations and explanations? What didn't?*

6. Show slide 2: *Inquiry Fever Triangle*. Explain the triangle:

slide 2

a. The *Inquiry Fever Triangle* is one way of thinking about what's necessary for Inquiry Fever to "ignite."

b. Students need all three sides of the triangle.

c. Inquiry fever probably ain't gonna happen if:

- They don't have interesting stuff to investigate. [But the outdoors is generally teeming with interesting stuff!]
- If an instructor is afraid to give students permission to explore freely. [You have to relinquish some control to the students.]
- If students don't have an inquiry mindset [Some kids arrive with this, some arrive with a more passive attitude, but most only need prompting, because after all, we were **born to inquire**!]

7. Ask your group to brainstorm aspects of what's meant by an "Inquiry Mindset."

- Listen to their responses, and be sure to give enough time for a variety of ideas to be brought up by the group, for the most part refraining from sharing your ideas.

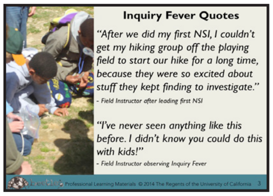
8. After participants have shared, consider mentioning any of the following aspects of an inquiry mindset that may not have been discussed yet:

- Curiosity about the world around us.
- Creative thinking used for asking questions and making explanations.
- Open-mindedness to different ideas.

- Appropriate amount of tentativeness/uncertainty about observations and explanations.

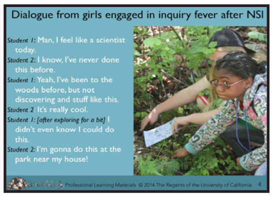
9. **Explain that students also need inquiry skills:**
    - Use of hand lenses and other relevant tools.
    - Ability to make observations, ask questions and come up with explanations based on evidence.
    - Ability to engage in exchange of ideas with peers, including respectful disagreement.

10. **Show slide 3:** *Inquiry Fever Quotes*. **Explain excitement of inquiry fever:**
    a. Let them read the quotes.
    b. When students do have these three ingredients, it can be like "taking the lid off," with students excitedly "devouring" their surroundings.
    c. When students get "inquiry fever," they are enthusiastically caught up in exploring, coming up with explanations, and finding more evidence.



slide 3

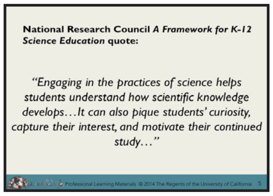
11. **Show slide 4:** *Dialogue from girls engaged in inquiry*. **Let them read quotes from some girls (pictured) who were engaged in inquiry fever after *NSI*.**
    a. This is an excerpt of dialogue from the two girls in the photo, and one other student not shown.
    b. The whole hiking group was caught up in inquiry during the field experience, but these two girls in particular spoke and acted throughout like they'd had epiphanies about themselves, and what they could do and be in nature.



slide 4

Discussing Inquiry & Science Practices

1. **Show slide 5:** *National Research Council A Framework for K-12 Science Education quote*.
    - Allow time for participants to read the quote.



slide 5

2. **Explain that current national education documents recognize the importance of engaging student curiosity through these practices:**
    a. The *Framework for K–12 Science Education,* quoted here, is the document that the *Next Generation Science Standards* is based on.
    b. These documents describe engaging student curiosity through science practices, such as making explanations from evidence, as crucial.
    c. The emphasis on engaging students in key science practices is widespread and has become a focus for current improvements to science education.
    d. Sure is nice for outdoor science schools to have national education documents advocating for curiosity through science practices!

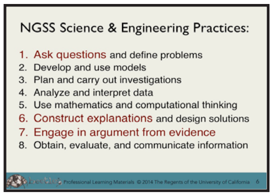
TEACHING NOTES

YOU ARE HERE:

10 minutes

Talking about *Next Generation Science Standards?* *Next Generation Science Standards* (NGSS) and the document they're based on, *A Framework for K-12 Science Education,* were written to inspire more innovative, useful, and engaging science instruction in the U.S. Whether or not your state has adopted *NGSS*, it is a useful document for planning science instruction. You can use the *BEETLES NGSS Presentation* to introduce *NGSS*, or just explain that its a new set of K–12 standards that redefines how science should be taught. We think it's an exciting and progressive move, that more clearly makes environmental education an asset instead of what some think of as a "distraction" to formal education.

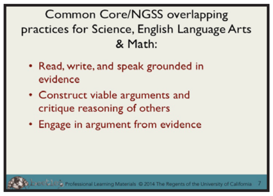
3. **Show slide 6:** *NGSS Science & Engineering Practices*. Explain that many people think that same of these practices are best done outdoors:



slide 6

   a. These are the science (and engineering) practices from the *Next Generation Science Standards*.
   b. During this session we're focusing on the practices shown in red.
   c. Many think these practices are easier to do in the outdoors than in a classroom, because when you are out of the classroom surrounded by nature mysteries, the opportunities abound!

4. **Show slide 7:** *Common Core/NGSS overlapping "practices" for Science, English Language Arts and Math*. **Read these overlapping practices from science, math, & language arts.**



slide 7

   - Give participants time to read the slide.

5. **Explain that these practices overlap science, math, and language arts:**
   a. These practices go beyond just science education, into language arts and math.
   b. These are overlapping essential "practices" shared by the *Next Generation Science Standards*, and *Common Core States Standards for English Language Arts and for Mathematics*.

6. **Explain that the emphasis on engaging students in the practices of making explanations from evidence, and argumentation, is also integral to math and language arts instruction:**
   a. Don't they look familiar?
   b. National efforts in Science, Math, and Language Arts are all emphasizing explanations from evidence, and arguing from evidence.
   c. By emphasizing these practices, you are supporting teachers and students with their efforts in science, language arts, and math.

7. **Explain that using the language of science and engaging in argument from evidence provide important life skills:**
   a. And it goes beyond science, language arts and math too!
   b. Taking part in discussions about science ideas not only helps students learn how science works, but also how to become better thinkers, inquirers, collaborators, and communicators.
   c. We all know (even kids!) how annoying it can be to be around someone who is arguing:
      - without evidence
      - in spite of evidence
      - just using selected evidence and ignoring the rest.
   d. These are important life skills. Don't we all wish that more politicians, pundits, and family members were better at being open-minded and at

TEACHING NOTES

What are science practices? The NRC uses the term practices instead of a term like "skills" to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice. Part of the NRC's intent is to better explain and extend what is meant by "inquiry" in science and the range of cognitive, social, and physical practices that it requires. *Next Generation Science Standards* (NRC = National Research Council)

What's Common Core? The full title is, *Common Core States Standards for English Language Arts & Literacy in History/ Social Studies, Science and Technical Subjects*. Along with *Next Generation Science Standards*, it's part of a national movement to provide states with thoughtful and coherent standards to prepare students for success after high school. They include a shared strong focus on student engagement, thinking, reasoning and discussing ideas. See www.corestandards.org

Read more about scientific argumentation in the background section.

Other terms related to "the language of science." Scientific discourse, science talk, academic language, and disciplinary literacy are all terms used to describe aspects of the value of providing opportunities for learners to use language in the discipline of science.

TEACHING NOTES

forming plausible explanations based on evidence?

e. What's cool for outdoor science educators is that it turns out that making and discussing explanations based on evidence for interesting things we find in nature is pretty darned engaging for students.

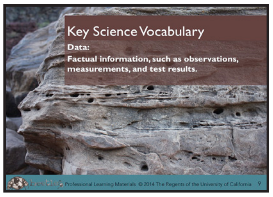
YOU ARE HERE:

15 minutes

The Value of the Language of Science

1. **Explain: It's clear that making explanations from evidence is important—now let's look more into the value of exposing students to the language of science:**
   a. We've established that making explanations from evidence is supported by national education efforts, and is also a meaningful way for students to engage with nature.
   b. Making explanations from evidence is an example of using the language of science.
   c. Now we'll look into the value of exposing students to the language of science.
   d. First, let's look at some key science vocabulary.

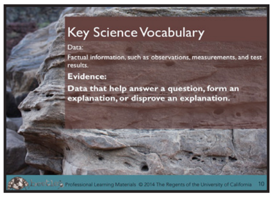
2. **Show slide 8:** *Key Science Vocabulary*. **Explain that data is information:**



slide 8

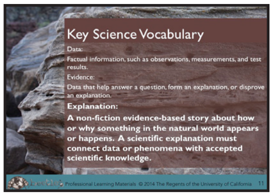
   - Data is information you collect, such as:
     - "The snake was motionless, even when we got close to it"
     - "The lizard did 'push-ups' while perched on top of the rock"
     - "The water in Salmon Creek was pH 6 at 10:00 A.M., May 29th"
     - "We counted 17 pine seedlings in the area"

3. **Show slide 9:** *Key Science Vocabulary*. **Explain that data becomes evidence, only when used to answer a question or justify an explanation:**



slide 9

   a. Data is not always evidence.
   b. Data only becomes evidence when used to try to answer a question or justify an explanation. For example:
      - "The motionless snake is evidence that it may play dead as a protection against predators"
      - "The lizard doing 'push-ups' on the rock is evidence that it may be communicating where its territory is to other lizards"
   c. Without making those connections, observations and other information are merely data.



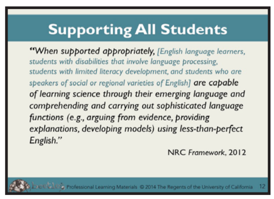
slide 10

4. **Show slide 10:** *Key Science Vocabulary*.
   - Give participants time to read the definition

for ***explanation***.

5. **Explain that evidence and explanation are generally vocabulary words students have been exposed to and are familiar with.**
   - **a.** With very young students and/or English language learners, it may be worth formally defining evidence and explanation and providing examples.
   - **b.** But many students are already familiar with the general meanings of the words, "evidence" and "explanation."
   - **c.** The important thing is for instructors to begin using these terms in the context of investigating something interesting to students.
   - **d.** Students often begin using the words "evidence" and "explanation" in their speech with a little prompting, such as:
     - "What's your explanation for that?"
     - "What evidence are you basing that on?"
     - "What do you all think of that explanation?"
     - "Does that explanation fit all the evidence we have?"

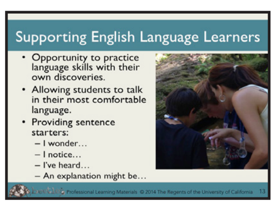
6. **Show slide 11:** *Supporting All Students*. **Emphasize that all students have the capability to engage in the critical thinking needed for learning science.**



slide 11

   - **a.** Allow time for participants to read the quote.
   - **b.** Point out the importance of providing multiple opportunities for students to use scientific language while discussing their thinking and investigating the natural world, regardless of their language abilities.
   - **c.** Research has shown that even if students are not able to express their understanding using appropriate academic language, they can still benefit from the process of arguing from evidence and making explanations.

7. **Show slide 12:** *Supporting English Language Learners*. **Explain how language development is supported when students can interact directly with nature and verbalize their ideas.**



slide 12

   - **a.** Outdoor science instruction can be an engaging setting for students who are learning English to develop and practice their language skills.
   - **b.** Exploring nature provides a context-rich environment for students to make observations, ask questions, and discuss their thoughts and ideas.
   - **c.** Making explanations about interesting objects and phenomena that are directly observable has been found to be very productive for language development, as students have concrete, shared experiences to discuss.

8. **Describe supports that can be used to help struggling students.**
   - **a.** It can be a useful step to allow students to respond and discuss their

TEACHING NOTES

Spanish translations for some of the language of science. Words like data, evidence, and explanation tend to be pretty easy for Spanish-speaking English language learners, because they are cognates, which look and sometimes sound similar to words used in Spanish and other "romance languages." Evidence = *evidencia*, Explanation = *explicación*. Data = *los datos*. Cognates are often "seen not heard." In other words, it's often easier to recognize an English word as being similar to a Spanish word when you see it spelled out, than when it's spoken. This is a reason why it's helpful for ELLs when key cognate words are shown in written form. Be sure to say that cognates are often "seen but not heard." Instructors need to write them (on a white board) in order for EL students to be able to recognize them.

Should I avoid discussion if I have English Language Learners (ELLs) in my group? Nope. It's even more important for ELLs. Exploring cool stuff in nature and discussing it can be a wonderful opportunity for ELLs. Making observations, asking questions, proposing and arguing explanations all are great language development opportunities, especially when they're centered on genuinely interesting animals, plants, or phenomena. Providing students with opportunities to truly explore and talk about what is of interest to them can be a real gift. ELLs learn language by building on what they already know and by building on language(s) they already know. We all learn language by taking it in through listening and reading, and using it by speaking and writing. You may need to provide additional scaffolding for ELLs, but they stand to gain both language skills and conceptual understanding from such experiences.

TEACHING NOTES

ideas in whatever language they find most comfortable.

b. Often they can be paired with a student who speaks the same language to allow them to practice "science talk" in their first language.

c. Providing sentence starters can help support students to participate, both in their primary language and in English.

d. These supports are important for all students, but may be particularly useful for:

- English language learners
- students with less exposure to language of science
- shy or reluctant-to-speak students.

9. Show slide 13: *Supporting Reluctant-to-speak Students*. **Explain how we can support reluctant-to-speak learners:**

slide 13

a. There are different reasons that some students are reluctant to speak during discussions.

b. It can be mortifying for some students to be called out to answer a question when they don't know what to say and this may cause them to shut down and withdraw from conversations.

c. Asking a student to share a direct observation tends to be a pretty safe question that most students can answer easily.

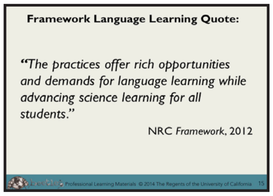
d. As students share observations, encourage those who haven't spoken by asking questions such as:

- "Does the surface feel rough to you too?"
- "What color does it look like to you, Emilie?"

e. You can also ask students to respond to something another student has said.

- "Tina, do you agree with what Angelo just said?"

10. Show slide 14: *Framework Language Learning Quote*. **Explain how using science practices are important opportunities for developing language:**



slide 14

a. Engagement in science practices is language intensive and requires students to use the language of science.

b. Making explanations & citing evidence involves significant discussion & use of the language of science.

11. Show slide 15: *Using the language of science supports student learning*. **Explain that using the language of science helps all students be successful in science:**

slide 15

a. Some students have more exposure to the language of science and other academic language at home and through informal science education opportunities, such as science centers, museums, and after-school programs.

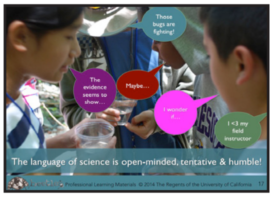
b. Other students may have had less out-of-school access or exposure to academic language.

c. For these students, providing additional exposure and practice with the language of science can help them to avoid a critical struggle with science in later grades.

d. Providing students with exposure to, and practice with, talking about evidence, explanation, and the language of uncertainty helps all students with success in science in the long run.

▶ *So what does the language of science look like?*

12. Show slide 16: *The language of science is open-minded, tentative & humble*. **Explain some of the characteristics of the language of science:**



slide 16

a. The language of science is open-minded, tentative, and humble.

b. Hmm. Can you figure out which of these student statements are *not* using the language of science? ["Those bugs are fighting," and " I <3 my field instructor."]

c. Scientists commonly use language of uncertainty to reflect their open-mindedness.

13. Explain that science is meant to be "humble," acknowledging it never achieves "ultimate truths."

a. One of the greatest strengths of science as a discipline is that by its very nature, it is meant to be "humble."

b. A scientist can never claim to have arrived at "the ultimate truth" because science is an ongoing process that constantly seeks to improve our knowledge of how the world works.

14. Explain that instructors can help students understand that science knowledge is not absolute by using appropriate "language of uncertainty":

a. Scientific talk tends to use language of uncertainty such as "the evidence seems to show..." or "perhaps it could be..."

b. Science requires being open to different explanations and/or new evidence, but different levels of uncertainty in language are appropriate for different science ideas.

c. In science, nothing is considered absolutely proven, but rather that what we know now is the best explanation we have based on all available evidence

d. It's important for instructors to model the use of appropriate "language of uncertainty" and encourage its use in student discussions.

15. Point out that appropriately tentative scientific statements can be misunderstood.

TEACHING NOTES

Appropriate language of uncertainty. By its nature, science is open to any and all ideas/explanations changing, and language of uncertainty should be used to reflect that. But some ideas are "less uncertain" than others. For example, one could take it to an extreme and say things like, "well perhaps we live on a planet, and all evidence seems to support that explanation," but generally most people, including scientists would simply say, "we live on a planet." On the other hand, when we find scat in the field, language of uncertainty is more appropriate in identifying what animal left it, "the shape and contents of the scat are evidence that it could be from a bobcat."

Why science can disprove, but can never prove things. The 20th century philosopher Karl Popper argued the notion that an explanation can be disproved, or "falsified" by science, if evidence is found to be inconsistent with it, but it cannot be proved. He argued that a scientific explanation can't be proved, because even though there may be no evidence currently available that's inconsistent with the explanation, science needs to be open to the possibility that new evidence may be discovered that could be inconsistent with the explanation. This idea has been accepted by the scientific community. Science takes open-mindedness *veeeeery seriously!*

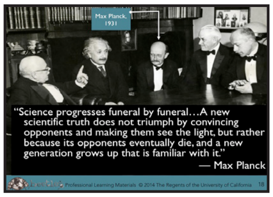
TEACHING NOTES

a. Unfortunately, the "humble" aspect of science is often misunderstood and/or misrepresented.

b. When scientists use an appropriate amount of uncertainty in stating their explanations, (famously, as in statements about climate change), the public may interpret this as a weakness of the proposed scientific ideas.

c. But language of uncertainty reflects the *strength* of an openness to better, more evidence-based explanations.

16. Show slide 17: *Max Plank Quote*. Allow time to read the quote.



slide 17

17. Explain that scientists are human, not always humble & open-minded in practice, & may resist new explanations:.

a. Of course scientists are human, and some may have a harder time than others staying open-minded and discarding outdated explanations.

b. If a scientist has spent her life's work on a particular explanation, she may be more reluctant to accept a new explanation than the next generation of scientists.

18. Explain that science is a community endeavor & progresses despite opposition from individual scientists:

a. Sometimes a turnover in generations is needed for new ideas to be accepted.

b. But science is a community endeavor, not an individual endeavor, so ideas do move forward, despite opposition from individual scientists.

19. Explain that it's important to encourage open-mindedness & language of uncertainty with students.

a. For these reasons it's important to emphasize using language of uncertainty with students when engaging them in scientific discussions.

b. When students make absolute statements, such as, "I know that...," an instructor can help encourage open-mindedness by suggesting they rephrase their statements, and modeling the use of such stems as:

- "Maybe…"
- "It seems to be…"
- "I wonder if…"
- "The evidence seems to show… "

YOU ARE HERE:

35 minutes

Evaluating the Strength of Evidence

1. Explain that students need help evaluating the strength of evidence.

a. When making evidence-based explanations and discussing them with students, it soon becomes clear that not all evidence is equal—some evidence is stronger or weaker.

b. Students (and adults) will sometimes latch onto flimsy evidence, and disregard stronger evidence.

c. Now we'll look into how to help students try to figure out the strength of evidence.

2. **Explain that you'll do some classroom-style activities on strength of evidence as adult learners, then later discuss how to address these issues with students in the field.**

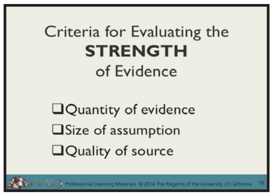
   a. The activities we're about to do are classroom activities (not field activities) appropriate for upper elementary, middle school, high school, and adult learners.

   b. Classroom teachers might do them with their students before attending your program (wouldn't that be nice?).

   c. We'll do them as adult learners to think more deeply for ourselves about evaluating the strength of evidence.

   d. Afterwards we'll discuss how *ideas* from these activities can be used with students in the field.

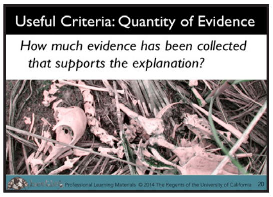
3. **Show slide 18:** *Criteria for Evaluating Strength of Evidence*. **Introduce 3 criteria that can be used to evaluate the strength of evidence. Explain:**



slide 18

   a. We'll explore three basic criteria to evaluate the strength of evidence when considering a scientific explanation:
      - Quantity of Evidence
      - Size of Assumption
      - Quality of Source

4. **Show slide 19:** *Useful Criteria: Quantity of Evidence*. **Introduce the concept of "Quantity of Evidence" and explain:**



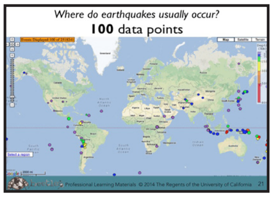
slide 19

   a. Something observed only once, by one person, is not as strong evidence as something observed:
      - multiple times by one person
      - one time by many people
      - multiple times by many people.

   b. *Generally*, the higher the quantity of evidence, the stronger the explanation.

   c. Let's look at a real world example of this.

5. **Show slide 20:** *Where do Earthquakes usually occur? 100 data points.* **Introduce data looking at earthquake epicenters & tell pairs to discuss what they notice. Explain:**



slide 20

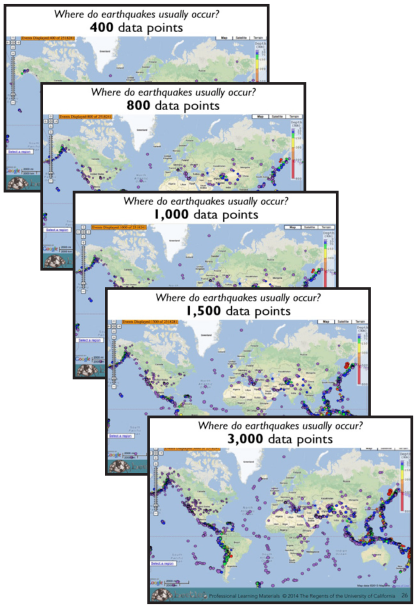
   a. An online earthquake site mapped 100 recent

TEACHING NOTES

Resources for Classroom Teachers. Check out resources for classroom teachers, including classroom versions of the two evidence sorts in this session on the BEETLES website: http://beetlesproject.org/resources/for-classroom-teachers/

earthquake epicenters.

b. With this slide, and with the next few, quietly discuss with a partner what you notice.



slide 25

6. **Show slides 21–25:** *Where do Earthquakes usually occur?* **Click through the next five slides briefly pausing for each one, then explain:**

   a. Each of these images showed data, but if used to support an explanation, that data becomes evidence.

   b. Each slide showed the same type of evidence—earthquake epicenters—but with increasing quantity of evidence.

   c. What did you notice as the quantity of data/evidence increased? [Briefly listen to their ideas, and point out when they are making explanations from evidence.]

   d. In this example, the more data points we see, the clearer the patterns become, so we can eventually clearly visualize lines along which earthquakes occur on Earth.

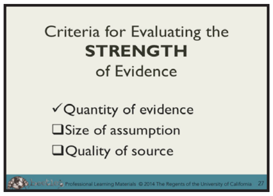
   e. Scientists used this data as evidence to support the explanation that the Earth's surface is covered in giant tectonic plates that are in motion, and that most earthquake epicenters are at the boundaries (edges) of those plates.

7. **Explain that *usually* multiple observations are stronger evidence than just one observation, but sometimes you could have a high quantity of inaccurate evidence:**

   a. In this example you can see that more evidence allows a pattern to emerge that's hard to see with less evidence or fewer data points.

   b. On the other hand, quantity of evidence alone is not enough. It's possible that many people could make a similar, inaccurate, observation.

8. **Show slide 26:** *Criteria for Evaluating Strength of Evidence*. **Explain that students may give undue weight to quantity of evidence, even when it's weaker in terms of size of assumption.**



slide 26

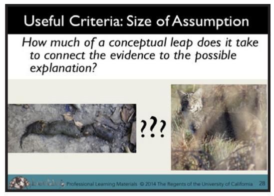
   a. When choosing between different explanations, young students will sometimes lean toward whichever has the greatest quantity of evidence, even if it's weaker evidence in terms of the size of assumption, or the quality of source.

   b. Size of assumption is the next criterion for evidence we'll look at.

TEACHING NOTES

Act like scientists. Encourage your staff to thoroughly discuss each card like scientists. For example, someone might say that the card showing a cheetah chasing wildebeest requires a small assumption, but someone else may say that just because an animal is chasing another doesn't necessarily mean it's going to eat that animal. Even the card with wildebeest hanging out of the cheetah's mouth might be challenged by someone saying that just because cheetahs eat wildebeest doesn't mean they *prey* upon them; they might be scavengers eating wildebeest that they did not hunt and kill. This might then lead into a discussion of whether an animal is a predator if it doesn't kill its own food. This is exactly the sort of meaning-making discussion you want instructors to have with students, in which they are wrestling with applying concepts with real world examples. The deeper your staff goes with their discussion, the more likely they will experience the value of analyzing and challenging one's assumptions and terms to arrive at more accurate ideas, and the more likely they might be able to facilitate conversations like this with their students.

9. **Show slide 27:** *Useful Criteria: Size of Assumption*. **Explain the concept of "Size of the Assumption."**
    a. The size of the assumption is a measure of the conceptual leap made to connect evidence to an explanation.
    b. For example, you're making an assumption if you say this is bobcat scat without having seen it emerge from a bobcat.
    c. The smaller the leap, the more likely the explanation. The bigger the leap, the less likely the explanation.
    d. The next activity will help us better understand this criterion.



slide 27

10. **Show slide 28:** *Cheetahs are predators of wildebeest*. **Explain that groups will sort evidence cards for this claim from smallest size of assumption to largest.**
    a. Each group of 4–6, will get a set of evidence cards that can be used to support this explanation: "Cheetahs are predators of wildebeest."
    b. The group's task is to put the cards in order from the smallest size of the assumption to largest size of assumption.
    c. In other words, what evidence leaves the least doubt (smallest assumption) and what leaves the most doubt (largest assumption) that cheetahs are predators of wildebeests.
    d. As you sort the cards, discuss with your group where each card should be placed, and why you think it belongs there.

slide 28

11. **Pass out cards and tell groups to begin.**

12. **After ~10 minutes, choose a group who were mostly able to agree on how to sort the cards & gather everyone around their cards.**
    a. Get everyone's attention and show them where to gather.
    b. Make sure everyone can see the group's sorted cards.

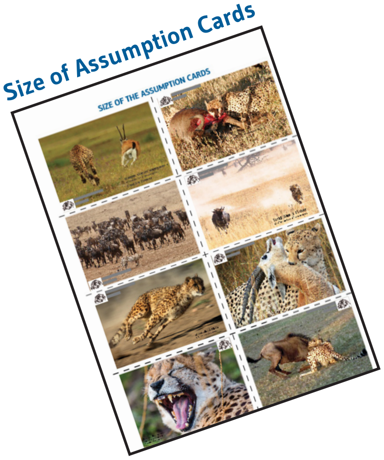
13. **Lead a brief discussion about the rationale for ordering the cards.**
    a. Ask—Are there any cards that you'd like to ask this group about why they placed them where they did?
    b. Briefly discuss any controversies.

14. **Compare examples of a card with a large assumption & one with a small assumption.**
    a. Point out two extreme *size of assumption* examples on cards:
        - one card that requires a pretty large assumption, like the picture of the cheetah's teeth.
        - one that requires a pretty small assumption, like the picture of a cheetah with a piece of wildebeest hanging out of its mouth.

TEACHING NOTES

Definition of predator. "An animal that lives by capturing and eating other animals" (from the *American Heritage Science Dictionary*.) Sometimes during these discussions this definition comes into play if they are discussing whether the evidence shows that cheetahs are predators of wildebeest vs. scavengers.

Size of Assumption Cards



Groups tend to sort the evidence cards similarly to the following order (from largest assumption to smallest):

- Cheetah's mouth/teeth
- Cheetah running
- Cheetah chasing an impala
- Cheetah with an impala in its mouth
- Cheetah stalking wildebeest
- Cheetah chasing wildebeest
- Cheetah taking down a wildebeest
- Cheetah with wildebeest in its mouth.

TEACHING NOTES

A true example of smaller size of assumption trumping quantity of evidence. A group leaves their gear for a bit and return to find that the snack food has been ransacked. Students argue that raccoons are responsible, citing the evidence that they saw a raccoon the previous night, they saw raccoon prints nearby, and that they have seen raccoons rummaging for human food before. The field instructor argues that he actually saw ravens tearing into the bags and eating the food. Judging just by quantity of evidence (3), students might decide that raccoons did the deed. But judging by size of the assumption, the one piece of evidence supporting that ravens were responsible—a reliable witness directly observing ravens in the act—is stronger. In this case, quantity of evidence loses to one piece of evidence with smaller assumptions.

Encourage participants to check out the BEETLES student activities, *Tracking* and *What Lives Here?*, for ideas about including students making explanations from evidence, and evaluating evidence based on size of the assumption out on the trail.

15. Explain that the combined evidence from all the cards is stronger than any one card by itself, which supports that quantity of evidence usually equals stronger evidence.

16. Collect the Size of Assumption cards.

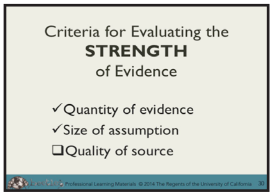
17. Provide an example of how instructors might address the size of assumptions based on evidence found in the field.

a. Students may bring up different explanations for something they've seen, such as scrape marks on the ground:

- Explanation #1: "Those look like mountain lion claw scrape marks!"
- Explanation #2: "I think those were made by Rafael, with the stick he's been dragging while we've been hiking. Look at how they looks similar to those marks."

b. An instructor can use this chance to ask which seems most or least likely, or which explanation seems "closest" to the evidence.

18. Show slide 29: *Criteria for Evaluating the Strength of Evidence: Quality of Source***. Introduce the *Quality of Source* criteria & card sort and explain:**

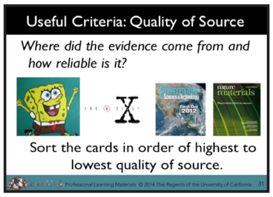


slide 29

a. Of course, not all sources of evidence are equally reliable.

b. We're going to do another card sorting activity that will help us discuss this third criterion for strength of evidence: the quality of the source.

19. Show slide 30: *Useful Criteria: Quality of Source***. Explain the activity:**



slide 30

a. Each group will get another set of cards. This time, each card will represent a different source of information, such as something you hear from a classmate, or something you read in a magazine.

b. Each group will sort the cards and place them in a continuum, from what you think is the highest to the lowest quality of source.

c. As before, work together, discussing the placement of each card.

20. Pass out cards and tell groups to begin.

21. Allow about ten minutes for talking and sorting, then gather your whole group around a different group's set of cards

a. Choose a group that was able to come to consensus about how to sort the cards.

b. Gather the group around that group's cards.

22. Lead a brief discussion about different ways the groups chose to sort the cards.

a. As in the last discussion, encourage participants to ask the focus group questions about the reasoning behind their placement of cards.
b. Encourage them to make comparisons about how their own groups placed the cards, and to share their reasoning.

23. Explain that students tend to sort cards similarly to adults, but rate their own observations high and observations of fellow students low:

a. When students have done this same activity, their discussion and placement of source cards was similar to that of adults.
b. They placed politicians and advertisements at the lower end, and scientists' observations at the higher end.
c. Interestingly, they ranked their own firsthand, yet brief, classroom observations much higher than the observations of a scientist who has spent years studying a topic.
d. But when students were asked if they trusted their classmates' observations over those of scientists—the answer was "no way!"

24. Explain how this activity has encouraged students to point out weaker and stronger sources:

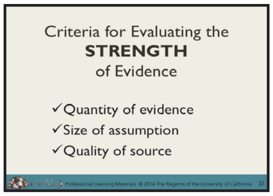
a. Students usually pick up very quickly on the differences in the quality of various sources.
b. It doesn't take much exposure for students to begin citing their sources, and pointing out low- or high-quality sources themselves.
c. A higher quality source cited by students is often a nature film.
d. Prior to doing this activity, students often contribute information they have heard without volunteering the source.
e. After reflecting on the quality of different sources, they still sometimes cited weak sources like, "I saw it on Sponge Bob," but would follow up with something like, "Yeah, but that's a totally weak source."

25. Explain how instructors can encourage student awareness of citing and judging quality of sources without doing the card sort:

a. Even with students who have little, if any, exposure to thinking about the quality of sources of evidence, an instructor can easily incorporate the citing of sources of information into dialogue in the field.
b. For example, instructors can ask:
    - What's your source for that? Where did you hear that?
    - How strong a source do you think that is?
    - Do you think that's a very trustworthy source for science information or not?

26. Show slide 31: *Criteria for Evaluating the Strength of Evidence*. **Explain that we should use these criteria in combination:**

a. When evaluating evidence we, like scientists, should think about all three criteria together



slide 31

TEACHING NOTES

Participants could become quite involved in this discussion, as there are various ways to determine the quality of each source. It's a very worthwhile discussion, but could make the session overly long if you let it fully run its course. Decide on how much time you can allow for the conversation, so you can limit the discussion accordingly. Consider bringing it up again at another staff meeting, if it seems like your staff could benefit from more discussion time.

TEACHING NOTES

and use our best reasoning. For example:

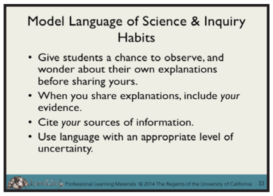
- If there's a large quantity of evidence but it's from a lower quality source, then it may not be as reliable as having less evidence from a high-quality source.
- A lot of evidence with large assumptions is generally not as strong as a lower quantity of evidence with smaller assumptions.

YOU ARE HERE:

10 minutes

Wrapping Up the Session

1. **Show slide 32:** *Model Language of Science & Inquiry Habits*.
   - Give participants time to read the slide.



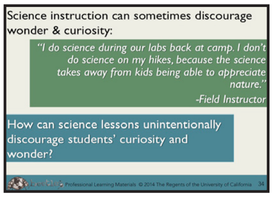
slide 32

2. **Explain how instructors can promote a culture of inquiry by using language of science & inquiry habits:**
   a. Instructors can nurture a culture of inquiry with student groups by modeling language of science and inquiry habits.
   b. It's easy to fall into the habit of telling a lot of information to students, and representing it as factual, without using language of uncertainty, and without citing sources.
   c. We should all be cautious about overconfidently providing facts.
   d. Instructors can use appropriate language of uncertainty, share evidence, and cite their sources.
   e. For example, an instructor might say:
      - "I read an article in *Nature* magazine about a study on bird beaks, and the study found that..."
      - "I was on a hike with a respected naturalist, and she said..."
      - "I was watching birds once, and I'm not sure, but I think I saw..."

3. **Explain that focus on these science practices will help make a more scientifically literate public and prepare more students to do science:**
   a. This is how we can build a more scientifically literate public who will be better at making thoughtful decisions.
   b. This is how we can get more students interested in science and help build a workforce that can help address the issues related to quality of life on this planet.

4. **Show slide 33:** *Science instruction can sometimes discourage wonder and curiosity*. **Lead a brief whole group discussion about how this instructor may view science and how science instruction may discourage curiosity.**

   What do you think may have influenced the instructor to make this statement?



slide 33

▶ *How do you think this instructor or others who share this opinion might view science instruction?*

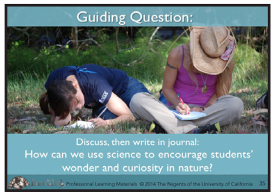
▶ *How can science lessons unintentionally discourage student wonder and curiosity?*

5. Point out the following if your group has not brought them up:

a. The instructor may think of science as delivery of information, or rigid, or merely teaching about *the* scientific method.

b. This instructor probably doesn't view science as a process in which students can explore mysteries in nature and come up with their own ideas and explanations.

6. Show slide 34: *Guiding Question*. **Revisit the guiding question for the session; explain:**



slide 34

a. Briefly re-discuss the guiding question with a partner.

b. Then write your own response to this question in your journal, including anything you want to make sure you remember and take away from this session, questions you have, and connections you're making.

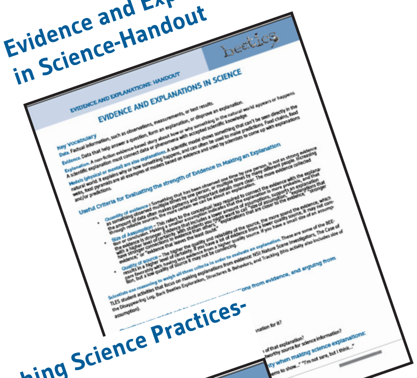
7. Pass out handout(s).

a. Pass out one copy of the *Evidence and Explanations in Science* handout to each participant.

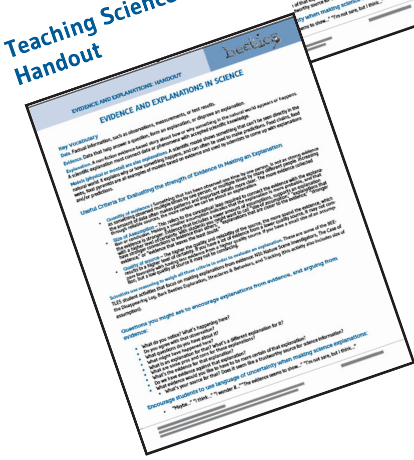
b. Unless they already have it from the *Nature & Practices of Science* BEETLES session, pass out copies of the *Teaching Science Practices in Outdoor Science Schools* handout.

TEACHING NOTES

Evidence and Explanations in Science-Handout



Teaching Science Practices-Handout



APPLYING SESSION TO INSTRUCTION

The session is not over! A critical phase of learning is applying new knowledge and instructional strategies to authentic teaching situations. There is some application included in each session, but as with all professional learning, the rubber meets the road (or trail) when the instructors apply what they've learned to their own teaching. If you want your instructors to try out new activities and teaching approaches, they must keep thinking about and discussing these ideas with their peers. It's crucial for program leaders to create supported opportunities for these kinds of reflective discussions. Even if staff are excited by new ideas for teaching, it is easier, particularly for veteran instructors, to keep doing what they have been successfully doing already, without incorporating new practices. Below are a variety of follow-up activities and discussion ideas to dig deeper into the topic of this session. This guidance is provided to help you facilitate thoughtful implementation of research-based instructional strategies and practices with your staff.

Other BEETLES professional learning sessions help instructors develop exploration & discussion leading "chops." The BEETLES professional learning session *Making Observations* helps instructors guide students in exploration. *Questioning Strategies* helps instructors build skills for leading exploration and discussion. The *Promoting Discussion* session provides more experience with discussion-leading, including many useful routines. The session *Constructing Understanding* provides instructors with more of the pedagogical theory behind the approach.

- **Lead a whole group brainstorm with staff about what can be done to encourage incorporating making explanations from evidence into their teaching.** After completing the session reflection prompt, your staff will have written ideas for implementing these ideas into their instruction. You can build on these, and add other ideas through a group brainstorm generating concrete actions for what they plan to do, and how you can support them to incorporate these teaching approaches.
- **Reflecting on and discussing implementation of making explanations.** Assign your staff to try out making explanations from evidence with students, either by leading *NSI: Nature Scene Investigators*, or through informal discussion, during the next student program. Make sure they reflect on how it went, and write in their journals about their successes and challenges. After everyone has had a chance to lead an explanation-focused activity and reflect on it, then lead staff in a reflective discussion at the end of the student program. Here are some suggested questions/prompts for focusing your discussion:
  - How did you incorporate the scientific practice of making explanations from evidence into students' other field experiences (e.g., explorations, journals, sit spots etc.)? Did the activity inspire your students to notice nature mysteries, make explanations, and to engage with nature?
  - What was successful about the activity?
  - What might you do differently the next time you lead this type of activity and why?
  - What ideas do you have about incorporating this scientific practice in the future?
- **Instructor observations focused on strategies from the session.** If you routinely do observations of instructors, discuss how you might incorporate elements from this session into what you look for during a teaching observation.

- **Continue a discussion topic from the session.** If there was anything interesting that came up during the session, but discussion was cut short due to time constraints, consider picking up on the topic afterward. If it seems that your staff is engaged in the topic and would benefit from continuing the discussion, you can set aside some time to do so.
- **Practice Leading an *NSI* Routine with staff.** Bring in an intriguing natural object and ask a volunteer to lead your staff in an *NSI: Nature Scene Investigation*, so they can practice and receive feedback on leading the routine. You can also go to an interesting find on your site, such as a carcass or a wood rat nest, and have a volunteer practice outdoors. Be sure to have some participants observe and provide feedback to the volunteer, focusing on "moves" made by the instructor and how they affected the "learners" in the investigation.
- **Lead a discussion on guiding student explanations.** Once instructors have started incorporating more student explanations into their teaching, many will find that it can be a challenge to redirect students who come up with far-fetched explanations. Have your staff share any stories of this challenge occurring, then have them brainstorm various instructor moves, questions, activities, statements, etc., that might help gently redirect students.
- **Assign your staff a reading related to the ideas in this session.** Tell them to use active reading strategies like underlining important points, writing out questions and connections in the margins, and asking critical questions like who wrote this, who is the audience, etc. Have them pair up with someone else and compare their notes and ideas, then bring this discussion into the whole group. Here are some suggested readings:
  - **The section title, *How to Think Like a Naturalist and Scientist,* from The Laws Guide to Nature Drawing and Journaling by John Muir Laws.** Ask, What thoughts or ideas stood out to you? Did anything in this passage surprise you? When was the last time you changed your mind about something significant? As instructors, what are some ways that we can create a culture in which it is OK—or even encouraged—to admit when you're wrong?
  - **The following sections from the Framework for K–12 Science Education (the document on which the Next Generation Science Standards is based).** Lead an open-ended discussion with staff about the topic you've selected, and how they might bring it into your program's curriculum and instruction. Where are opportunities to provide students with experiences in doing science? Note that the practices are not called "Science Practices," but "Science and Engineering Practices." You might choose to only discuss the science aspect of the practices, or include engineering as well.
    - Scientific and Engineering Practices (pages 41–53).
    - Practice #1: Asking Questions (pages 54–56).
    - Practice #6: Constructing Explanations and Designing Solutions (pages 67–71).
    - Practice #7: Engaging in Argument from Evidence (pages 71–74).

Some other BEETLES student activities focused on explanation from evidence in addition to *NSI: Nature Scene Investigators*, including: *The Case of the Disappearing Log, Bark Beetles Exploration, Structures & Behaviors, Tracking,* and *What Lives Here.*

Download a free PDF of the Framework at: http://www.nap.edu/catalog.php?record_id=13165

See full citation for *Mountain Time* in references list. Mountain time is only available from lulu.com in both print or digital editions.

– **Chapter 2, pages 33–40, from *Mountain Time* by Ken Norris.** Ken Norris was an influential scientist, conservationist, teacher, "professor of wonderment," and former Professor of Natural History at the University of California, Santa Cruz. This chapter is about how naturalists make observations, ask questions, and come up with explanations for what they see. It includes insights by the author into how naturalists operate as well as examples of how to lead (university) students to engage in a naturalist mindset, much of which is also applicable to younger students. Facilitate a discussion of the chapter using the following prompts: What are some points/quotes you found interesting? What are some questions and/or connections you made? Summarize in your own words the author's perspective on what a naturalist does, as described in the chapter. Discuss your interpretation of what the author means by each of the following quotes:

Print and pass out copies of these quotes to lead discussion using the final prompt. Ask instructors to choose one to discuss in pairs, then have the whole group discussion.

"To many scientists, what the naturalist does seems like guesswork. Yet truths keep emerging from the naturalist's hands anyhow, because he begins by taking in the natural world on its own terms."

"This *gestalt* of a wild world provides what I rather irreverently call my 'baloney filter.' After a time, it's hard to fool a naturalist or country kid about a stream bottom like this."

"My 'throwing-away muscles' must be just as good as my 'asking muscles.' I call this whole process, 'spinning the wheel.'"

"Spinning the wheel always generates more questions than get answered."

"No wonder our national parks are just scenery to most people. Not many people 'spin the wheel.'"

"But you can also be blinded by what you think you know… Not infrequently the child's wide-open eyes will see what no one else sees."

"Will what I learn be real?"

"We humans live and see within our own limited time frame, while other creatures live in time-worlds nearly separate from ours."

Quotes from *Mountain Time* by Ken Norris

STUDENT RESOURCES FOR NSI:

Examples of Things to Observe & Ask Questions About

color

size

shape

texture

comparisons
(is it the same everywhere?)

?
Mystery Object

durability
(how hard would it be to break?)

smell

weight

pattern

weird markings

volume

density

Using language of uncertainty

I think...because...

Perhaps...

Possibly...

In my experience...

I wonder if...

Maybe...or...

The evidence seems to show...

INSTRUCTOR QUESTIONS FOR NSI

Questions that encourage observations. Use these questions to encourage observations about the physical characteristics of an object or discovery. This helps students get to know the object and gather observations that can later be used as evidence for explanations.

- What do you notice?
- What does it remind you of?
- What can you find out by using your other senses- smell, touch, etc?
- How heavy/dense is it?
- What can we say about its shape?
- We haven't heard from you, Sarah. Check out the size- what do you see?
- What color is it? Is it the same color everywhere?

Questions that encourage student dialogue. Use these questions to involve all members of the group and to model the importance of multiple perspectives and corroboration in scientific investigation. Questions that ask a student to agree or disagree with another's observations are low-risk and help involve students who may be reluctant to speak. They also encourage student-to-student dialogue.

- Isaiah, do you see the holes, too?
- Do you agree with what Bernice said?
- Does it seem to be that way from your perspective, also?
- What do you think, Juan?

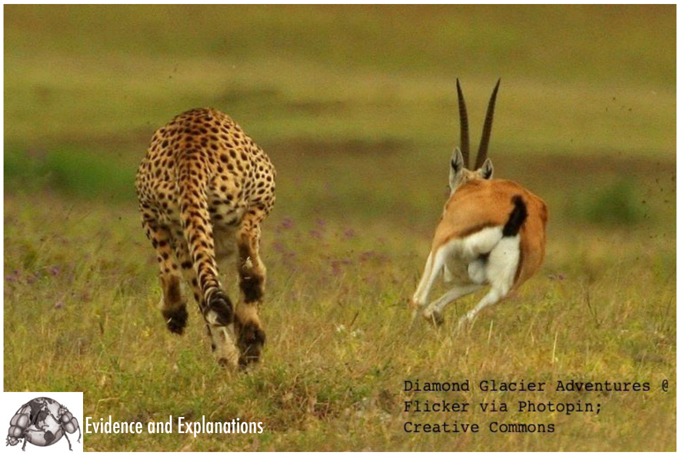
Questions that deepen observations about a specific feature or phenomenon. Use these questions to follow student curiosity about a specific aspect of an object or discovery going beyond general observations. Restating a student's observation before asking another question helps keep the discussion on-track.

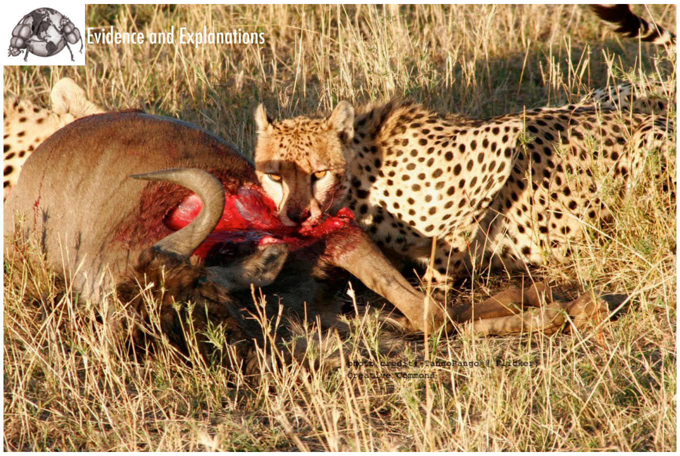
- Is there any pattern to what we're observing? If so, is there any place on the object where the pattern does not exist?
- So, Roberto showed us that these holes go all the way through this object. What else can we notice about them? Are they like that everywhere?
- Where have you seen something like this before?
- Is there anything else on the object that could be related to this?

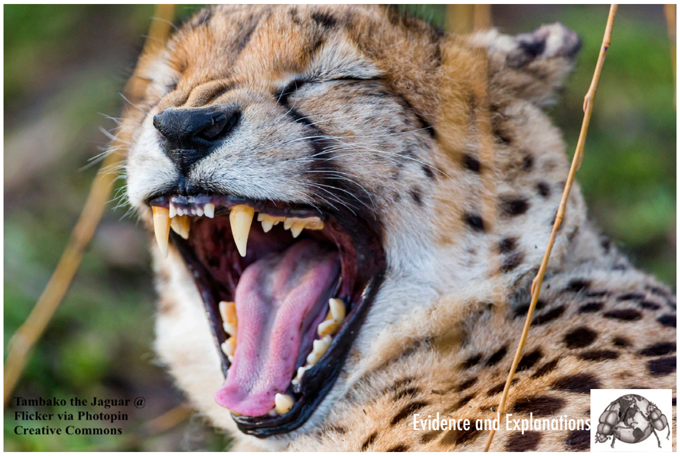
Questions that encourage explanations. Use these types of questions to find out what students are thinking and to encourage them to begin to make explanations based on what they've observed. Make sure students share the evidence behind their explanations.

- What makes you think that?
- How long do you think it has been that way? What's your evidence?
- If it reminds you of an accordion, do we see any evidence it functions like one? Why could that be important?
- Where did this object come from? How long has it been here? How can we tell?
- Has this object been altered by outside forces?
- What could have caused this? Do your observations back up that idea?
- Can anyone else come up with an explanation for what this is or where it came from?

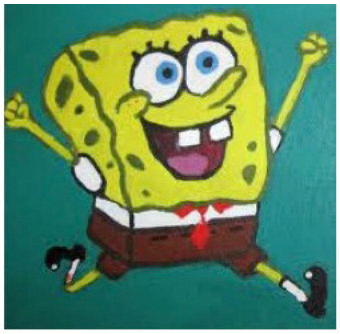
SIZE OF THE ASSUMPTION CARDS







QUALITY OF SOURCE CARDS



Fiction TV Shows

Evidence and Explanations

Scientists of disciplines not their own

(Not the one they primarily study)

Evidence and Explanations

Scientists in the discipline of study

Evidence and Explanations

Politicians

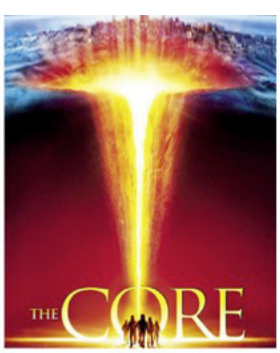
Evidence and Explanations

Publications by Universities or Websites ending in .edu

Evidence and Explanations

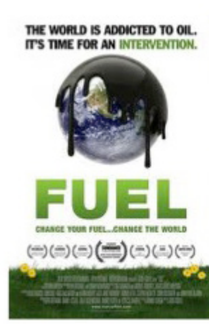
Publications by Government Agencies or Websites ending in .gov

Evidence and Explanations



Fiction Movies

Evidence and Explanations



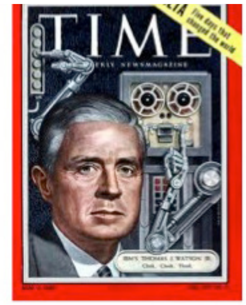
Documentary Movies

Evidence and Explanations

QUALITY OF SOURCE CARDS

Public Broadcasting Services

Evidence and Explanations

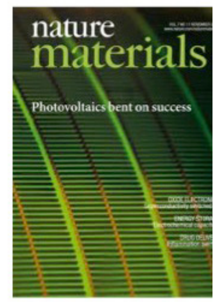


News Magazines

Evidence and Explanations

Newspapers

Evidence and Explanations



Science Journals

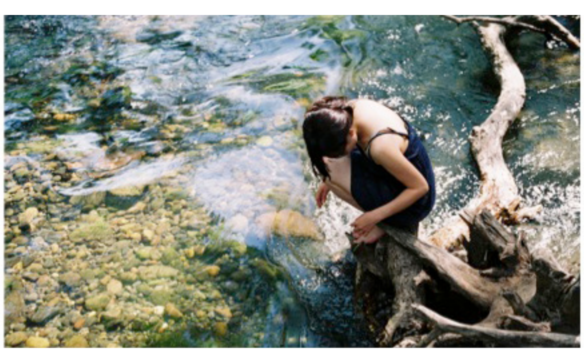
Evidence and Explanations

Network Science TV Shows

Evidence and Explanations

Science Textbooks

Evidence and Explanations



Something you observe

Evidence and Explanations

Something a friend says

Evidence and Explanations

QUALITY OF SOURCE CARDS

Something we observed in Science class

Evidence and Explanations

Something your parent said

Evidence and Explanations

Advertisements/Infomercials

Evidence and Explanations

Wikipedia

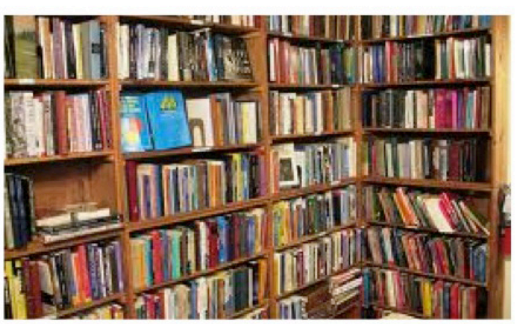
Evidence and Explanations

Science Books

Evidence and Explanations

Blogs

Evidence and Explanations



Fiction Books

Evidence and Explanations

Social Media

Evidence and Explanations

EVIDENCE AND EXPLANATIONS IN SCIENCE

Key Vocabulary

Data. Factual information, such as observations, measurements, or test results.

Evidence. Data that help answer a question, form an explanation, or disprove an explanation.

Explanation. A non-fiction evidence-based story about how or why something in the natural world appears or happens. A scientific explanation must connect data or phenomena with accepted scientific knowledge.

Models (physical or mental) are also explanations. A scientific model shows something that can't be seen directly in the natural world. It explains why or how something happens, and can often be used to make predictions. Food chains, food webs, food pyramids are all examples of models based on evidence and used by scientists to come up with explanations and/or predictions.

Useful Criteria for Evaluating the Strength of Evidence in Making an Explanation

- **Quantity of Evidence.** Something that has been observed one time by one person is not as strong evidence as something observed multiple times by one person, or multiple times by many different people. Increasing the amount of data often makes patterns and important details more clear. The more evidence collected through reliable sources, the more certain we can be about an explanation.
- **Size of Assumption.** This refers to the conceptual leap required to connect the evidence with the explanation or conclusion. Making a smaller assumption indicates that the explanation is more probable, and that the evidence is stronger. Evidence that includes a lower amount of assumptions supports an explanation with a higher level of certainty. With students you might want to call "size of assumption," terms such as, "explanations that have stronger connections to evidence than others," "explanations that are closer to the evidence," "stronger evidence," or "evidence that leaves the least doubt."
- **Quality of Source.** The higher the quality and reliability of the source, the more sound the evidence, which results in a higher level of certainty. If you have a lot of evidence from a lower quality source, it may not compare favorably with having less evidence from a higher quality source. If you have a small size of an assumption, but a low quality of source it may not be convincing.

Scientists use reasoning to weigh all three criteria in order to evaluate an explanation. These are some of the BEETLES student activities that focus on making explanations from evidence: ***NSI: Nature Scene Investigators, The Case of the Disappearing Log, Bark Beetles Exploration, Structures & Behaviors***, and ***Tracking*** .

Questions that encourage explanations from evidence and arguing from evidence:

- What do you notice? What's happening here?
- Do you agree with that observation?
- What questions do you have about it?
- What might have happened here?
- What is an explanation for that? What's a different explanation for it?
- What are some pros and cons for those explanations?
- What's the evidence for that explanation?
- Do we have evidence against that explanation?
- What evidence would you like to have to be more certain of that explanation?
- What's your source for that? Does it seem like a trustworthy source for science information?

Sentence starters that encourage language of uncertainty:

- "Maybe..."
- "I think..."
- "I wonder if..."
- "The evidence seems to show..."
- "I'm not sure, but I think..."

TEACHING SCIENCE PRACTICES IN OUTDOOR SCIENCE

A Framework for K–12 Science Education

(See free PDF download at http://www.nap.edu/catalog.php?record_id=13165)

The *Framework* is a progressive vision for science education produced by top scientists and educators appointed by the National Research Council, which served as the basis for developing the *Next Generation Science Standards (NGSS).* It represents the most current, research-based ideas about how to teach science. At its core are the following guiding principles: (1) children are born investigators and have the capacity to reason in sophisticated ways, (2) focusing on core ideas and practices helps build a more wide-ranging understanding of science, (3) deep understanding develops over time and through making connections, (4) science learning involves both knowledge and practice, (5) connecting to student interests and experience helps to sustain their curiosity and wonder, and (6) all students should have opportunities to learn about and engage in science. The *Framework* describes three dimensions that make up the how and what in science to be taught by the end of high school: (1) science and engineering practices, (2) crosscutting concepts, and (3) core ideas. The idea is that these dimensions should be woven together while teaching, so students can develop a more coherent understanding of science that reflects its interconnections in the real world. The *Framework* as a whole is quite educative and thoughtfully written—definitely worth reading and revisiting as instructors are exploring new ways of teaching science.

This handout focuses on how field instructors can use the science and engineering practices to deepen student understanding and interest in science. Because of the extensive opportunities available in outdoor science school for engaging students in exploring and investigating the natural world and answering their own questions, these programs can play an important role in achieving the vision of the *Framework*. The following pages contain interpretations of how the science practices relate to teaching in outdoor science schools. Skills specific to engineering are not included here, but they can also have great value for teaching about solving environmental issues or in habitat restoration projects. Each practice has a description of the practice and the relevant student skills that can be used in the context of doing outdoor science. Additional suggestions for how each practice might look during field instruction, as well as for using specific BEETLES activities, are provided as appropriate. Use this handout to access simplified descriptions of the practices as viewed through an outdoor science lens, and to think about ways to incorporate them into your teaching. As shown here, the practices of science are deep and challenging, yet can be one of the most rewarding approaches for engaging students.

Note that mastery and deep understanding of the practices are intended to fully develop over the length of a student's K–12 education—so don't be concerned about teaching all of them during a short field program! Some practices may also be better suited to classroom science teaching, which is why it makes sense to choose one or two to concentrate on and dig deeply into with students. In general, the practices of Asking Questions, Constructing Explanations, and Engaging in Argument from Evidence are particularly well-suited for outdoor inquiry. The natural world is rich with a wide variety of phenomena for students to wonder about, try to figure out, and to discuss and compare ideas. Programs with significant time dedicated to outdoor investigations can also focus on helping students Plan and Carry Out Investigations.

To begin to address *NGSS* in outdoor science school, regardless of the topic, make sure students are engaged in practices, exploring science ideas, and ***figuring things out*** during science instruction.

> *"In order to be fully engaged in the practices, it's simply not enough to merely learn about the science idea, however creative and hands-on the task may be. To engage in the practices, really participate in them, a student has to frame the task as an exploration. The intellectual work of the classroom has to be centered on figuring out how or why something happens."*
>
> — Cynthia Passmore, UC Davis School of Education

The *Framework* suggests students should be engaged in certain science practices as they learn core ideas and crosscutting concepts. Use these ideas to inform your decisions of which specific practices to engage students in when they're studying various aspects of the natural world. The goal is to try to set up learning opportunities in which students are using science practices to engage with big ideas and concepts while exploring the natural world.

	Description of Practice & Student Abilities	Field Examples & Teaching Notes
1. Ask Questions and Define Problems	Questions are the engine that drives science and engineering. The outdoor environment is rich with mysteries for students to wonder and ask scientific questions about. Outdoor science instructors can address questioning in rich ways by directly engaging students with interesting aspects of nature, giving students an inquiry mindset and skills, providing lots of opportunities for discussion of science ideas, and coaching students in how to participate in productive discussions. For students, coming up with an interesting and testable question is often the hardest part of planning an investigation. Practice in generating and identifying testable questions is valuable, even if they don't actually investigate the questions further. *Question-asking abilities we can help students develop at outdoor science school:* • Asking questions about the natural world; *e.g., What do bees do?* • Distinguishing scientific questions; *e.g., What is causing this log to decompose?* from non-scientific questions; *e.g., Which is cutest?.* • Asking and refining questions that are testable, and can be answered through observations and investigations, *e.g., Which type of tree does this fungus grow on?* • Asking questions about each other's observations, explanations, reasoning, and data interpretation, *e.g., "What's your evidence for that explanation?"*	*General approach:* Find cool stuff, have students ask questions about it, recognize which questions are scientific, try to refine some questions to be testable, and question each other during discussion of science ideas. *Specific BEETLES activities:* During *I Notice, I Wonder, It Reminds Me Of,* students learn to generate lots of different kinds of questions about something in nature, then discuss which questions are scientific. During *NSI: Nature Scene Investigators*, students ask questions about intriguing evidence found in the field, attempt to answer some through observations, and learn to question one another about observations and explanations. In *Interviewing an Organism* students focus on asking questions that can be answered through deeper observations of the organism. In *Discovery Swap* students observe an organism, come up with questions, record them in their journals, and discuss possible explanations for their questions. They share observations and ask each other questions to get to deeper understandings. In *Exploratory Investigation*, students write down questions about the chosen topic, discuss which are immediately testable, and which are not under the conditions of the field experience, attempt to investigate one of their questions, then discuss findings and how the investigation could be improved.

<table>
<tr><th></th><th>Description of Practice & Student Abilities</th><th>Field Examples & Teaching Notes</th></tr>
<tr><td>2. Develop and Use Models</td><td>Models are used as tools in science to represent ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. All models are inaccurate in some way(s), otherwise they'd be the "real thing." Modeling tools are used to: develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and make it possible to go beyond the observable and imagine a world not yet seen.

Modeling abilities that we can help students develop at outdoor science school:
Making drawings or diagrams to represent events or systems.
Using a drawing/model as the basis of an explanation, or to make predictions.
Using different types of models to represent phenomena.
Discussing the limitations of models and suggesting ways they could be made more accurate.</td><td>General Approach: Food webs, food chains, nutrient cycles, and food/energy pyramids are all different models that can be used to explain some aspect of ecosystems that can't be directly experienced. For example: Use a food web to predict what might happen to the ecosystem if wolves were re-introduced, or use both a food web and a nutrient cycle to represent interactions that occur in an ecosystem. Whenever students are exposed to any kind of model, they should be encouraged to come up with things that are inaccurate about the model, and ways the model might be made more accurate.

NOTE: If you have students play a predator-prey game, that doesn't necessarily mean that they're doing modeling. Some outdoor science simulation games might be considered models, but only if they are used to make predictions, or if they are used by students to make explanations. It's also important that the model is evaluated for both its accuracies and inaccuracies.

Specific BEETLES activities:
In the Moon Balls activity, students use a model of the Sun, Earth, and Moon to explain (and test their explanations for) the phases of the Moon.

In the activity, Food, Build, Do, Waste, students make a chart that is a model of the inputs and outputs in the system of a living organism.</td></tr>
</table>

	Description of Practice & Student Abilities	Field Examples & Teaching Notes
3. Planning and Carrying Out Investigations	There are many ways to conduct investigations in science—not just one scientific method. Scientists investigate and observe the world with essentially two goals in mind: (1) to systematically describe the world and (2) to develop and test explanations of how the world works. The first goal is accomplished through systematic observations, where a scientist makes a plan, decides on the conditions, follows the plan, then carefully observes and records what happens over time. These investigations often lead to questions that can be explained through experimentation. In an experiment, a scientist makes a comparison between two situations, keeping all conditions the same except one (i.e., the variable). Because variables are often hard to control outdoors, field investigations tend to be long-term, systematic observations. Scientists often begin by conducting several shorter exploratory investigations where the main goal is to figure out how to refine the question and investigation methods. *Investigation abilities we can help students develop at outdoor science school:* • Coming up with questions that can be tested/investigated during the field experience. Ideally, these should come from students' interests and ideas. • Deciding what data should be collected, what tools are needed, and how data should be recorded. • Deciding how much data is needed to be reliable. • Planning field-research procedures, identifying variables and controls (when appropriate). • Discussing flaws in investigations, and how they might be improved.	*General Approach:* During a brief experience at outdoor science school, students can't usually develop and conduct extensive, or even fully reliable science field investigations. But it can be possible to engage students in authentic "exploratory investigations" in which students come up with a scientific question, do some preliminary observations, discuss how their understanding changed as a result, and think about how to improve the investigation. For example, after exploring lichen, bark beetles, or another aspect of nature, students can come up with a question based on patterns they observed. Students then engage in a "quick and dirty" investigation, by briefly observing and collecting some data (e.g., *Let's count how many holes are in this area, and how many of them have spider webs in them*). If there's more time available, students can do more extensive and careful studies that occur over several days. *Specific BEETLES activities:* In *Exploratory Investigation*, students come up with testable questions, plan an "exploratory investigation" to answer one question, carry out the exploratory investigation, discuss how the investigation could be improved if it were to be done again, then come up with tentative explanations for their results. For example, students might engage in a stream study by designing and conducting an investigation to find out if there are more macroinvertebrates in slow-moving or fast-moving water. Or students could engage in a habitat study through designing and conducting an investigation to answer if there are more animals in riparian or conifer communities. In *Spider Investigation*, students discuss the parameters of carrying out a fair test to find out whether there are more spider webs located in one area as compared to another.

	Description of Practice & Student Abilities	Field Examples & Teaching Notes
4. Analyzing and Interpreting Data	Scientific investigations produce data that must be analyzed in order to make sense of it. Because data patterns and trends are not always obvious, scientists use various tools, such as graphing, to identify significant features and patterns in the data. Scientists look for what may have caused errors in investigations, and calculate the degree of certainty in the results. Certain kinds of field surveys lend themselves to collecting this type of quantifiable data; e.g., species counts, measuring of environmental factors such as temperature, water pH, stream flow, etc. *Data analyzing & interpreting abilities we can help students develop at outdoor science school:* • Recognizing the need for collecting data and sharing with others. • Analyzing data, looking for patterns, or examining data to see if it supports a previous explanation. • Recognizing surprises, when data is in conflict with expectations, and using this as an opportunity to adjust explanations based on results. • Summarizing data using charts, graphs, tables, etc. • Recognizing patterns in data that suggest relationships worth investigating further. • Distinguishing between causal and correlational relationships in nature *(e.g., The size and shape of the holes found in the tree are evidence that they were caused by boring beetles. However, the turkey vulture numbers increasing in the same year that the local team wins the World Series is correlational, not causal).*	*General Approach:* An instructor can share data collected previously and ask students if they notice trends or patterns that differ from the data they collected themselves. After collecting data in the field, ask students to create a visual representation that indicates what they learned from the data. For example, students can use data collected during a stream study to create charts and graphs to visually display their data and make interpretations and explanations. *Specific BEETLES activities:* In *Exploratory Investigation*, students try to make sense of the results of their investigations. Students use a stem plot graph to analyze the data collected during the *Spider Investigation* activity, and try to explain any patterns they identify.

	Description of Practice & Student Abilities	Field Examples & Teaching Notes
5. Use mathematics and Computational Thinking	In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks, such as: constructing simulations; solving equations; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches can enable scientists and engineers to predict the behavior of systems and test the validity of such predictions. *Mathematics and computational thinking abilities we can help students develop at outdoor science school:* • Using grade-level-appropriate mathematics and statistics in making calculations and analyzing data.	*General Approach:* Have students collect, calculate, and summarize quantitative data. For example, students can use data collected during a stream study to calculate the average number of macro-invertebrates found at each study site, the diversity (i.e., number of different species) of macro-invertebrates found, and the speed of the water flow at each study site. Or, after a rain, students can count the number of earthworms in a square meter of soil on a large field, measure the field, then multiply to estimate the total number of individuals present. Students can use a formula to calculate the approximate deer population in an area based on the quantity of deer scat.

	Description of Practice & Student Abilities	Field Examples & Teaching Notes
6. Construct Explanations and Design Solutions	The overall goal of science is to attempt to explain the mysteries around us and develop the best explanations based on all available evidence. In science, an explanation is a non-fiction, evidence-based story about how or why something in the natural world appears or happens. Scientific explanations must connect data (which can include observations) or phenomena with accepted scientific knowledge; *e.g., an explanation that claims leaves come from animals contradicts an understood, undisputed fact in the natural world.* Students enjoy coming up with explanations for things they wonder about in nature, and this can be a powerful way for them to interact and develop a relationship with the natural world. The overall goal for students is to construct logically coherent explanations of phenomena that incorporate their current understandings of science, and are consistent with the available evidence. *Explanation-making abilities we can help students develop at outdoor science school:* • Developing an inquiry lens and mindset, which they can use to explore and engage with nature in various settings. • Coming up with evidence-based explanations for things they observe and wonder about in nature. • Using what is known about accepted scientific knowledge in making explanations. • Linking explanations to evidence and models; i.e., food webs or nutrient cycles. • Using evidence (either directly observed or secondhand, i.e., something they've read) to support or refute explanations. • Developing explanations for what may have caused something to happen. • Identifying gaps or weaknesses in explanations (i.e., in their own explanations, or those of others).	*General Approach:* Encourage the overall practice of students finding interesting "mysterious" things in nature, thinking of questions about them, coming up with possible explanations, and discussing strengths and weaknesses of their explanations, based on evidence. *Specific BEETLES activities:* During *NSI: Nature Scene Investigations*, the instructor coaches students on how to develop and politely discuss reasonable evidence-based explanations to explain their observations. They compare their ideas to those of others and weigh their strengths. They also evaluate the strength of the sources of secondhand information. In *The Case of the Disappearing Log*, students make observations about a decomposing log, use a key to identify evidence of different organisms, read about the organisms on information cards, and come up with explanations for what is happening to the log, discussing the strengths and weaknesses of each explanation. In *Tracking*, students consider the size of the assumption (the conceptual leap) they are making when creating an explanation based on their evidence.

	Description of Practice & Student Abilities	Field Examples & Teaching Notes
7. Engage in Argument from Evidence	Scientific argumentation is a crucial part of how science knowledge is generated. A scientist proposes an argument that explains something about the natural world, then, along with other scientists, attempts to identify its weaknesses and limitations. Argumentation is based on the notion that science is a collaborative endeavor, and "group-think" and critique leads to more accurate explanations. Scientists also use argumentation to debate and decide issues about things like the best investigation design, and how to make sense out of data. Discussion of ideas is a crucial part of learning for students, so giving them the opportunity to engage in argumentation not only represents the nature of science accurately—it's also a great way for students to learn together. *Argumentation abilities we can help students develop at outdoor science school:* • Becoming curious about mysteries in the natural world, and attempting to explain them. • Listening to the ideas of others and keeping an open mind. • Coming up with evidence-based explanations and sharing them with others. • Comparing the strengths and weaknesses of different explanations. • Politely disagreeing using evidence and reasoning. • Distinguishing evidence from opinion. • Using reasoning and evidence to identify possible weaknesses in scientific arguments (appropriate to the students' level of knowledge). • Identifying flaws in their own arguments and improving them based on critique from others. • Constructing a scientific argument/explanation and explaining how evidence supports the claim. • Recognizing that a scientific argument includes a claim, evidence, and reasoning.	*General Approach:* When students are coming up with explanations based on evidence to explain mysterious things in nature, and when they are comparing and discussing the merits of different explanations, they are engaged in scientific argumentation. This approach can be cultivated throughout any field experience. For example, during a hike, students may come across a pile of bones. Students disagree about which animal the bones are from, and they can use features of the bones as evidence to try to convince one another. Or, students may observe feathers strewn about an area and wonder "what has happened here?" They can come up with different explanations and discuss the strengths and weaknesses of each one. *Note:* This type of argumentation is very different from the everyday definition of "argument" (i.e., an angry disagreement). A scientific argument is a statement or series of statements for or against something, that includes a claim, evidence, and reasoning. For example: "I think the deer was going down to drink some water [claim], because the tracks look like the deer tracks in the field guide [evidence], and the tracks look like they are headed in the direction of the creek [reasoning]. *Specific BEETLES activities:* During *NSI: Nature Scene Investigations*, students compare their explanations to those of others and weigh their strengths and weaknesses. In *The Case of the Disappearing Log*, students come up with explanations for what is happening to the log, discussing the strengths and weaknesses of each explanation. In *Bark Beetle Exploration*, students discuss the ramifications of bark beetle population increases.

<table>
<tr><th></th><th>Description of Practice & Student Abilities</th><th>Field Examples & Teaching Notes</th></tr>
<tr><td>8. Obtain, Evaluate, and Communicate Information</td><td>Scientists need to be able to communicate clearly and persuasively about the ideas and methods they investigate. Reading, interpreting, discussing, and producing text (all forms of communication) take up the majority of a scientist's working time. Exposure to the language of science is particularly important for students who hear less academic language outside of school than others, or who don't speak English as their first language. Even students who can decode text well may struggle with comprehending informational texts in science. All students need exposure to and guidance about different forms of non-fiction texts, including field guides, diagrams, graphs, etc. Using field journals is an authentic way of providing the opportunity for students to communicate through writing and drawing.

Science text & communication abilities we can help students develop at outdoor science school:

• Reading and using appropriate scientific text, including field guides, diagrams, words, tables, and graphs to communicate their understanding or to ask questions.
• Creating scientific text, including writing, drawing, and making diagrams in field journals.
• Citing and evaluating sources of information, e.g., "My source is Sponge Bob show, but that's probably not a very strong source for science information."</td><td>General Approach: Have students access science texts (such as identification keys and field guides) when appropriate, in order to build knowledge of the organisms and ecosystems they are investigating. Make a habit of having students record information in field journals that they can use as the basis for discussions and sharing information.

For example, students can use symbols, drawings, and written descriptions in their journals to make a map of an area focusing on the presence of certain plant species, then use their notes to talk to peers about trends and patterns they noticed.

After conducting a habitat study, a group of students creates a poster presentation to share their findings with the rest of their class.

Students may use journals to record observations and questions about three different types of leaves using both drawing and writing.

When describing connections between organisms on a food web, students can take note of how certain they are based on the source of their information.

Specific BEETLES activities:
During Discovery Swap, students draw and record observations and questions about an organism, generating science "text." They also use science text in the form of a key to identify their organism, and a booklet with information on their organism. During a "Cool Organism Convention," they discuss their findings, questions, & ideas with others.

During an NSI activity, students name the sources for the information they share with the group.</td></tr>
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BACKGROUND INFORMATION FOR PRESENTERS

Making Explanations from Evidence as an Important Practice of Science in Outdoor Schools

We know a lot more about the teaching and learning of science now than we did 20 or even 10 years ago. Formerly, many educators believed that teaching was the process of transmitting knowledge to students, and that students could learn science adequately from reading about it in textbooks and hearing about it from lectures. We now know that learners do not retain much through these passive modalities, and what little they do retain tends to be lower level recall-type information. Later, science educators explored providing hands-on experiences with materials, organisms, and phenomena for their students. This approach increases student engagement and improves their familiarity with and intuitive "feel" for how the natural world works, but does not, on its own, lead to deeper conceptual understanding of generalizable science concepts. Newer research on science learning and cognition points to the importance of a multi-faceted approach that approximates the way that scientists themselves come to understand the natural world. Learners, including scientists, conduct their own "hands-on" investigations, read as much as they can, and, perhaps most importantly, talk and write about their ideas. The goal of this talking and writing, or scientific discourse, is to form evidence-based explanations that make sense of the world.

Scientists and science learners engage in this discourse in particular ways. They do their best to form a plausible explanation (orally or in writing) that is based upon the evidence that is available to them. This evidence can come from a variety of sources, such as their own investigations and observations, things they have read or been told, or from reasoning they've done alone or with others. These explanations, or claims, together with the evidence on which they are based, and reasoning, are considered a "scientific argument." In the midst of a rich student discussion, many possible explanations may emerge, each supported by different pieces of evidence and reasoning.

This is the point at which educators can gently guide students to the next level of meaning-making by helping them consider the strength of the evidence on which each explanation is based. Does it matter if one piece of evidence came from a student's firsthand observation, while another came from a field guide, another from something heard on a TV show, and another from something a student thinks she remembers that a teacher told her last year? Which is stronger evidence about the diet of coyotes in the hills around your outdoor science school in the foothills of California? (1) A student saw coyote tracks near what he thinks is a gopher hole and infers that coyotes eat gophers; (2) A student read an article on the Internet that says coyotes that were studied in Washington State mainly preyed on small rabbits so she infers that coyotes in California would do the same; or (3) Students found what they are pretty sure is coyote scat and found the skull of a mouse in it, so they infer the coyotes here eat mice.

When students "open-mindedly" compare, discuss, and evaluate the strength of the evidence for various explanations, they are "arguing from evidence." When students change their minds in light of a different explanation that is supported by stronger evidence than their own, it's important to point out that they have not "lost the argument," but rather have demonstrated one of the most highly valued and celebrated scientific habits of mind—intellectual honesty and integrity. Changing one's mind or adding to one's understanding in light of new and compelling evidence is the highest form of learning, and we know it's not an easy task for any learner. Argumentation helps learners embrace and retain new ideas. Learners confronted with scientific explanations that are new to them, might be able, for a short time, to repeat them back on a test, but often do not accept or fully retain those explanations until they are convinced that there is compelling evidence against their own previous explanation. Research tells us that this is true because our human brains need to understand not only why the "right answer" is accurate, but also why all the wrong answers (or less right answers!) are inaccurate.

This "new" way of thinking about teaching and learning is messy and sometimes at first uncomfortable. It requires some time to engage in thoughtful discussions, and it requires that students understand the value of listening carefully to one another as much as to the instructor. Residential outdoor science programs are ideal settings to engage students in their own vivid firsthand observations of nature, then spend time discussing and making meaning of those observations.

***Constructing Explanations* and *Arguing from Evidence* are two of the science practices described in the NRC's *The Framework for K–12 Science Education* and the *Next Generation Science Standards*.** The *Framework* states the following about explanation:

> *The goal of science is the construction of theories that can provide explanatory accounts of features of the world. (NRC Framework, 2012, p. 52)*
>
> *Asking students to demonstrate their own understanding of the implications of a scientific idea by developing their own explanations of phenomena, whether based on observations they have made or models they have developed, engages them in an essential part of the process by which conceptual change can occur. (NRC Framework, 2012, p. 68)*
>
> *The study of science and engineering should produce a sense of the process of argument necessary for advancing and defending a new idea or an explanation of a phenomenon and the norms for conducting such arguments. In that spirit, students should argue for the explanations they construct, defend their interpretations of the associated data, and advocate for the designs they propose. (NRC Framework, 2012, p. 73)*

The *Framework* **states the following about science goals in general:**

> *The overarching goal of our framework for K–12 science education 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. (NRC Framework, 2012, p. 1)*

Argumentation

What? Why would we teach kids to argue? Some folks get thrown off by the term, "argument," because they are thinking of the third definition in the Merriam-Webster definitions shown below, instead of the first two that apply to this usage:

- a statement or series of statements for or against something.
- a discussion in which people express different opinions about something.
- an angry disagreement.

Next Generation Science Standards on argumentation: "In science, reasoning and argument are essential for identifying the strengths and weaknesses of a line of reasoning and for finding the best explanation for a natural phenomenon. Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation for the phenomenon being investigated."

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