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Science and Teaching for Field Instructors

Professional Learning Materials

Nature and Practices of Science

There are three core questions explored in this session: 1. "What is science?" This question addresses what makes science knowledge unique as a discipline, (the nature of science). 2. "How do scientists actually do science?" addresses the important skills and ways of thinking used by working scientists, (the practices of science) 3. "How can we help young people think like scientists to answer questions about the natural world?" This question, combined with the other two, is important to ponder for anyone who teaches science (science instruction). In this session, participants gain insight into the nature, practices and instruction of science by doing science and discussing how science helps us understand the world around us.

Outdoor science programs are wonderful settings for students to develop scientific thinking and investigation skills. The rich array of interesting stuff to investigate in outdoor settings is ideal for students to explore the nature and practices of science as they follow their own curiosity. Field experiences can engage students in a continuum of experiences ranging from focusing on science practices such as making observations, asking questions and/or explaining the natural world, to planning and conducting their own investigations, developing mental models and arguing from evidence. By participating in the model student activities in this session, participants reflect on the nature and practices of science and become familiar with activities they can use with their students to help them do the same. These experiences engage learners in the practices of science and help communicate the nature of science as an evidence-driven human endeavor to investigate, understand, and make generalizations about the natural world.

This session includes an optional introduction to the Science and Engineering Practices as described in *A Framework for K-12 Science Education* and the *Next Generation Science Standards.* Participants can explore how activities that focus on scientific practices can help make outdoor experiences more engaging for students, and deepen their understanding of scientific ideas.

Goals for the session:

- **explore and discuss what makes science different from other ways of knowing – the nature of science**
- **experience and discuss how science is done – the practices of science**
- **discuss how to provide experiences for students that support a deeper understanding of: a) where science ideas come from; b) how scientists conduct investigations; and c) learn strategies for leading students in engaging authentic science investigations.**

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

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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 Las 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.

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BEETLES™ Professional Learning Materials

Nature and Practices of Science

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TEACHING ABOUT TEACHING

This session has been designed to "practice what we preach," and is set up to reflect a learning-cycle approach to instruction. In this way, participants will experience a version of the learning cycle instructional model while they learn about the nature of science. It's important to structure the session so there are opportunities for participants to experience each phase of the model for themselves. Resist the temptation to dole out too much information too early. Simply telling instructors a definition of science goes against the whole idea—participants will gain more from engaging in science practices, reflecting on the nature of science, and thinking about how to apply this to their instruction.

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 black font on white background on as large sheets as possible. You may 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.

	Nature and Practices of Science	Activity Locations	Estimated Time
Introduction	**Thought Swap: What is Science?** This session begins with a *Thought Swap*, in which participants share their ideas about science in rotating pairs. Then they learn the goals for the session.		15 minutes
Modeling Student Activities	**Introducing What Scientists Do** The group experiences the *What Scientists Do* activity, and learn how it can be used to help discuss science practices with students.		10 minutes
	Discovery Swap In this second model student activity, pairs explore a chosen subject area in an ecosystem, such as stream organisms, then choose one to focus on. They draw, observe, write, attempt explanations, and research it. Then they share and discuss their discoveries with others.		75 minutes
	Reflecting on Student Activities Participants think about which science behaviors and practices they engaged in during the student activities, using the *What Scientists Do* diagram to reflect on the process.		10 minutes
Applying to Practice	**Sorting Statements about Science** Participants explore the nature of science, by reading Statements about Science, and discussing whether each accurately represents science.		20 minutes
	What is Science? Participants hear some common perspectives on science, then are introduced to widely recognized characteristics of science through a handout. The group discusses if and how the student activities helped exemplify these aspects of science. Participants also discuss ideas about how science may sometimes not be accurately depicted, and consider alternatives to teaching "the scientific method."		35 minutes
	Wrapping Up Participants consider the benefits of teaching about science in outdoor settings, then are introduced to some effective practices. Participants reflect on the guiding questions for the session, as well as how the session has influenced their ideas about how to teach students about the nature and practices of science.		15 minutes
	TOTAL	3 hrs	180 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 may have already experienced the session. Read through the session write-up, slides, handouts, sidebars and background section (starting on page 48) to prepare. 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 whiteboards. Modeling of student activities, especially *Discovery Swap*, should be done outdoors.
2. **Set up projection system/review multimedia.** Set up and test the projection system to be sure participants will be able to see items projected during the session.
3. **Read and familiarize yourself with *What Scientists Do*, and *Discovery Swap* student activity guides; assess your ability to lead the activities.** Choose your staff member most experienced with successfully leading these activities with students to lead this part of the session. The main body of those write-ups are embedded in this *Nature & Practices of Science* write-up. If you will be teaching the activity using the embedded write-up, we suggest that you also read through the separate BEETLES activity write-up for the two student activities, particularly the *Instructor Support* sections, taking notes on the embedded write-up included here.
4. **Identify outdoor areas for activities.** These should be nearby areas. Pay attention to local hazards, such as fire ants, and make adjustments as needed. Choose a nearby area with organisms and/or different habitats or phenomena in which participants can explore and discover different kinds of organisms or a particular phenomenon that you think will be interesting to investigate.
5. **Make sure participants are prepared.** Make sure participants bring the gear they need to be comfortable outdoors. Tell them to bring their journals, and something to write with.
6. **Make the *What Scientists Do* chart.** Using the example "What Scientists Do" on page 38 as a reference, draw the *What Scientists Do* diagram on chart paper large enough so everyone can see it.
7. **Prepare copies.** Make copies of each handout for participants. (See list at right.)
8. **Gather materials for *Discovery Swap* student activity.** This activity is best with a kid-friendly identification guide, and ideally a guide with information about whatever they are exploring. You'll also need any equipment for collecting stuff to observe (see the *Discovery Swap* write-up).
9. **Prepare Sorting Statements about Science strips.** Make 1 copy for each pair of the Science Sorting Strips, page 35, and cut into individual strips. Put each set into an envelope or attach them with a binder or paper clip
10. **Plan when you might include a break in the schedule.** We recommend after reflecting on the two student activities.
11. **(optional) Make Session Overview to post on wall.** You may choose to make a Session Overview to post on the wall during this session. Some presenters & participants prefer having it, so they can see the trajectory of the session.

Immediately before the session:

1. **Set out the handouts for the session at the front of the room.**
2. **Put the materials for the student activities in a pack to carry.**

For the group:

- ❑ projection system & computer
- ❑ slides
- ❑ chart paper and/or white board
- ❑ markers
- ❑ tape (if using chart paper)
- ❑ Large *What Scientists Do* diagram (see preparation step 6)
- ❑ Student Activity Guide for *What Scientists Do* & *Discovery Swap*.

Materials for Discovery Swap

- ❑ Guides for identifying organisms
- ❑ Guides for learning about organisms
- ❑ (*optional, depending on what you are exploring*) nets, cups, lids etc. for capturing organisms.

For each pair of participants:

- ❑ Set of *Sorting Statements about Science* strips, page 35

For each participant:

- ❑ *What Scientists Do* handout, page 38
- ❑ *Science is...* handout, page 36
- ❑ *Science is not...*handout, page 37
- ❑ (*optional*) *Teaching Science Practices in Outdoor Science Schools* handout, page 39
- ❑ (*optional*) 1 hand lens
- ❑ (*optional*) Student activity guides: *What Scientists Do, Discovery Swap*

YOU ARE HERE:

15 minutes

TEACHING NOTES

Thought Swap or Walk & Talk? The discussion questions used here can be led as a *Thought Swap* (which held in one place) near the outdoor investigation activity area you've chosen. Alternatively, you can ask them during a *Walk & Talk* (similar but done while walking; see BEETLES write-up) while the group walks to the investigation area.

Emphasizing the learning cycle. If you've already presented the *Teaching & Learning* professional learning session to your staff, you may want to point out the phases of the learning cycle during the session activities to provide more examples of learning cycle-based instruction for your staff. A useful way to do this is to have a staff member hold up a sign with the title of the learning phase, with a few summarizing bullet points about the goals of the phase, throughout any section that fits that phase.

Thought Swap: What is Science?

1. **Gather participants in a circle outdoors and introduce topic.**
   a. Gather participants in a toe-to-toe circle.
   b. Welcome participants and make sure everyone is ready to begin and has the gear they need to be comfortable during the outdoor experiences.
   c. Explain that the session is about the nature and practices of science.

2. **Explain that the session deals with *practices* of science (what scientists do):**
   a. In this session we'll discuss the practices of science - how science is conducted.
   b. We'll look into how we can provide experiences for students that help them learn how to think like scientists to answer questions and investigate the observable world.

3. **Explain that the session also deals with the *nature* of science (what makes science different from other ways of knowing) and how scientific knowledge is generated:**
   a. We'll also discuss the nature of science - what makes science different from other ways of explaining the natural world
   b. We'll look into how we can provide experiences for students that help them understand how scientific knowledge is generated.

4. **Explain that it's extremely worthwhile for science educators to think about and discuss the nature of science:**
   a. As science educators, it's extremely worthwhile to spend time thinking about the nature of scientific knowledge and how scientists come to understand and explain things.
   b. We're going to start by discussing a series of questions to share ideas we have about science.

5. **Establish lines with partners for** *Thought Swap*. **Explain:**
   a. Stand shoulder-to-shoulder in two parallel lines, so each person is facing a partner.
   b. Look across at the other line and find your partner. Give them a fist bump.
   c. Raise your hand if you don't have a partner.

6. **Include yourself, then make any necessary partner adjustments.**
   a. Make sure you, and other leaders present, all have partners for the *Thought Swap*. Stand at the beginning of one line and partner with the person at the beginning of the other line.
   b. Make partner adjustments as necessary. If there is an odd number of participants, you may choose to have a group of three.

7. **Explain how they'll discuss the question, and explain the touch of silence:**
   a. You'll get a question to talk about with your partner, and you'll have about a minute to talk.
   b. I'll signal when it's time to be quiet by gently tapping the shoulder of the people at the front of the line: the touch of silence.
   c. When you feel the touch, stop talking, and pass it on--gently!-- to the next person in line. The touch is passed all the way down both lines, until the whole group is quiet.

8. **Pose the first question for pairs to discuss. Ask:**

   ▶ *What is science?*

9. **After a minute or so, use the touch of silence, and ask volunteers to share something they heard from their partner.**
   a. After about a minute, tap the person next to you in line, and the person at the end of the other line (the person you were partnered with).
   b. Wait for the entire group to become silent as the touch is passed down the line.
   c. Ask,

      ▶ *Who can share something your partner said about what is science?*
   d. Listen, and ask follow-up questions as they offer interesting points to discuss.

10. **Send your partner to the other end of the line, and tell everyone else in that line to move one over:**
    a. Tell the person who was your partner to walk/run/dance/skip to the opposite end of their line, and tell people in the lines to cheer wildly for them.
    b. Tell that line to step one spot over, so you and everyone else is facing a new partner.
    c. The line you're standing in does not shift during the activity.

11. **Repeat steps 8 and 9 to discuss the next three questions.**
    a. Use the questions below, shifting partners after each. Pause briefly after each one to share responses with the whole group.

       ▶ *Why teach about science in outdoor environmental education programs?*

       ▶ *What aspects of science can be taught in outdoor science education programs?*

       ▶ *How can we help students think like scientists?*

12. **Point out that these questions will guide our discussions for the rest of the session.**

TEACHING NOTES

Leader participation. It's important that leaders participate with partners and involve themselves in the discussion to: 1) Hear participant's ideas in a one-on-one situation; 2) Model how you want participants to lead activities with their students; 3) Put everyone on more equal footing throughout the session.

The importance of building on prior understanding about science. It's important for all learners to access their prior knowledge/ideas about a topic they're about to study. For this session, participants need the opportunity to access their ideas about science. This allows them to consciously build upon, expand, or adjust what they already know about the topic. This is a good reason to employ *Thought Swap* or other partner share activities at the beginning of any session or activity.

TEACHING NOTES

More about the nature of science as described in the *Framework for K-12 Science Education*. "One fundamental goal for K-12 science education is a scientifically literate person who can understand the nature of scientific knowledge. In K-12 classrooms, the issue is how to explain both the natural world and what constitutes the formation of adequate, evidence-based scientific explanations." Students should engage in the practices of science to learn about how the natural world works. But they must also discuss how scientific knowledge and explanations are generated and adopted to fully appreciate science as a distinct way of knowing.

13. Briefly explain the value for teaching about nature and practices of science to all students:

a. Scientists and science educators widely agree that teaching about nature and practices of science is important.

b. It's important for *every* person, not just those who do science for a living.

c. We're surrounded by scientific and non-scientific information in the media.

d. To participate fully in society, *all* people need to understand what distinguishes science from opinion, belief, and other ways of knowing about the world.

e. Students should be aware of where scientific ideas come from: the wondering, investigating, questioning, data collecting, analyzing, explaining, evaluating and building on previous ideas.

f. Students can come to appreciate the value of scientific knowledge.

YOU ARE HERE:

10 minutes

Modeling Student Activities: What Scientists Do

1. Introduce model student activities, and lead the group to the investigation area you chose. Explain:

a. We're going to engage in model student activities that help show what makes science unique.

b. Follow me to our investigation area.

2. Introduce 2 activities and ask participants to keep in mind how they're acting like scientists. Explain:

a. We'll model two student activities:

- *What Scientists Do* - designed to get students excited about doing science
- *Discovery Swap* - in which students come up with observations, questions, and explanations for something they find interesting.

b. As you actively participate, keep in mind how you're acting like scientists and how the activities communicate what and how scientists learn from their investigations.

The *Framework for K-12 Science Education* also talks about the nature of science as an essential complement to the practices embedded in investigations, field studies, and experiments. "..learning about the nature of science requires more than engaging in activities and conducting investigations. Epistemic knowledge is knowledge of the constructs and values that are intrinsic to science." (NRC, 2012, page 79).

3. Explain to participants to behave as adults, but to keep in mind how students might respond 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 the activity with students, so try to support them by not derailing discussions or going off-topic, and staying 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.

Pre: Introducing What Scientists Do

1. **Seat group in a semicircle, write "adventure" on a sheet of paper.**
   - **a.** Explain: sit on the ground in a semi-circle, where you can see me.
   - **b.** Write the word "adventure" in the center of a sheet of paper, leaving some blank space around the word.
2. **Ask for and record words that connect with "adventure."**
   - **a.** Explain: brainstorm words that come to mind when you think of adventure. [excitement, exploration, discovery, etc]
   - **b.** Write their suggestions around the word ,"adventure."
   - **c.** Explain: students usually generate a similar list.
3. **Replace "adventure" with "science."**
   - **a.** Explain: most of these words may also describe something else.
   - **b.** Erase the word, "adventure," and replace it with the word, "science."
4. **Explain how this helps generate interest in doing science activities, and that they'll return to it after field experience(s):**
   - **a.** This helps get students excited about science field experiences.
   - **b.** After their field experience students will return to this list.
   - **c.** Then students will be asked to think about whether or not they agree with the science = adventure idea.
5. ***Turn & Talk* about what scientists do.**
   - **a.** Explain: Think about what students might say when asked 'what scientists do.'
   - **b.** After a moment, tell them to *Turn & Talk* about their ideas with a partner.
6. **Set out the large *What Scientists Do* diagram, and explain how it represents the activities of scientists.**
   - **a.** Set the diagram on the ground with only the *Core to Field Science* section showing. Say:

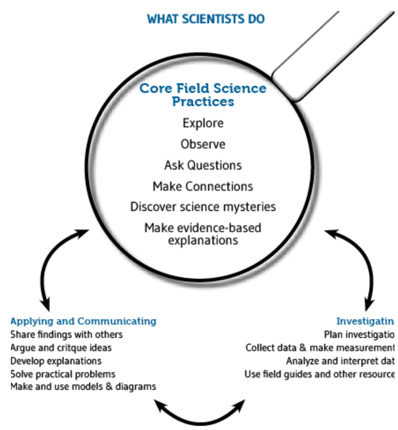
     ▶ *These are things scientists do when they're in the field investigating something in a scientific way. Today we'll do many of these.*
7. **Show object, ask cluster of 3-4 learners to make observations out loud.**
   - **a.** Unveil the mystery object so all can see.
   - **b.** Walk around the semi-circle pausing at a cluster of 3-4 learners and give them time to observe the object. Ask:

     ▶ *"What do you notice? What observations can you make about this object?"*

TEACHING NOTES

The model student activity has been embedded in this professional learning write-up for your convenience. Students/participants are referred to as "learners" 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.

What Scientists Do Diagram



TEACHING NOTES

What field scientists actually do. All field scientists engage in science practices. They maintain extensive, records of their observations through making sketches, taking photographs and collecting samples. They often use hand-held devices to input their data. Once they've collected their data, they analyze and interpret it. They use the data as evidence to build and evaluate models that support explanations. When they compare their strongest explanation to those of other scientists, they argue from evidence. They also do lots of other different tasks that depend on their subject area. Some identify and classify new plant species or perform experiments on their growth and behavior. Some collect rock and mineral samples to identify and use to map out geological patterns. Some track land animals using sounds, paw prints, scat and saliva. Others conduct censuses of endangered animal species and observe their behavior patterns and interactions. Some field scientists tag animals they've trapped with GPS collars or radio transmitters to track their movements. They collect blood, scat and other substances left behind by animals to perform laboratory analysis and genetic testing.

8. **Explain that when they "explore" and "observe' they're acting like scientists.**
   a. Explain: By exploring and making observations, you're behaving as scientists.
   b. Point out "Explore" and "Observe" on the diagram.

9. **Ask cluster of 3-4 other learners to generate questions about the object.**
   a. Show the object to a different cluster of people and ask them to come up with questions about the object.
   b. Point out which questions they ask are scientific (e.g., what might have caused the holes in it?), and which questions may be interesting to think about, but are not scientific (e.g., which part is most beautiful?)

10. **After a few responses, point to "Ask Questions" on the diagram and explain that they are asking scientific questions, like field scientists do.**

11. **The next cluster of learners states what the object reminds them of and makes connections.**
    a. Move to a different group of 3-4 and ask the following questions:
    - *What does it remind you of?*
    - *What kinds of connections can you make between the object and other things you know about?*

    b. After a few responses, point out "Make Connections" on the diagram and explain that field scientists try to make connections between what they observe and things they already know.

12. **Point out and explain "Discover Science Mysteries" in the diagram:**
    a. We're surrounded by mysteries! Everything you just did (exploring, observing, asking questions, and making connections) had to do with discovering mysteries in nature.
    b. These are the kinds of mysteries scientists try to solve, as they try to understand the natural world better.

13. **Ask the group to come up with possible explanations based on evidence to answer a question about the object.**
    a. Point out "Make Explanations Based on Evidence"on the diagram. Tell them now they'll make tentative explanations based on evidence.
    b. Refer to one of the learner-generated questions. Invite them to come up with an explanation, and to try to back it up with evidence.

14. **Point out any evidence they include in their explanations, and if they don't refer to evidence, remind them to do so.**

15. **After they've made a few explanations, explain that science is about explaining the natural world with available evidence:**
    - **a.** Scientists make the most useful and accurate explanations they can, based on the evidence that's available.
    - **b.** Solving mysteries about the way the natural world works is the goal of science.
    - **c.** Scientists do all the things listed on the diagram to create scientific explanations that help them better understand the way things work.

Modeling Student Activities: Discovery Swap

1. **Remind instructors to think meta-cognitively while you lead them in the** *Discovery Swap* **activities. Explain:**
    - **a.** I'll model an activity routine called *Discovery Swap*, that I'll lead much as I would with students.
    - **b.** Keep in mind how these activities engage you in doing things scientists do.
    - **c.** Think about how you could use these activities to help students think like scientists.

Introducing the Activity

1. *Walk & Talk* **discussing ideas about the ecosystem on the way to the study site to build ecosystem literacy.**
    - **a.** Tell learners to form two lines and discuss with a partner as they are walking to the area you've chosen for their investigations:
        - ▶ *What do you notice about our surroundings? How are the environmental conditions here different or similar to other places you've been?*
        - ▶ *What are things field scientists do to learn about an ecosystem?*
2. **When you've arrived at the exploration area, get everyone's attention.**
3. **Explain what the focus of study will be (organisms in stream, plants on cliff, etc.) and introduce importance of ecosystem literacy.**
    - ▶ *We're going to explore and study organisms kind of like scientists do.*
    - ▶ *To think like scientists we need to know a little background information about this ecosystem before we begin.*
4. **Focus attention on ecosystem literacy: environmental conditions that might be challenging for organisms found here.**
    - ▶ *What would be potential dangers or difficulties for organisms living in this ecosystem?*
    - ▶ *What are body structures or behaviors organisms might have that help them survive here?*

TEACHING NOTES

YOU ARE HERE:

75 minutes

Choosing an ecosystem and organism focus for this routine. In this activity, learners explore organisms in an ecosystem and build ecosystem literacy through focused study, discussion and research in field texts. Their observations and discussions can be focused on plants, invertebrates, leaves, pond organisms, or other groups of organisms. Discoveries can connect to specific topics—such as adaptations, ecosystems, structure and function, interdependent relationships, food webs, biodiversity, etc.—by encouraging students to focus on observations and questions related to the theme while they're studying and researching their organisms. Choose an appropriate ecosystem on your site and a focus for their explorations.

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

Build your own "ecosystem literacy" before leading this activity. To be an effective co-explorer with your instructors, it's best to know a bit about the ecosystem and organisms you'll be investigating. Scouting ahead to make sure there are organisms to find is pretty important too.

More information about developing ecosystem literacy. For additional details and examples of these types of questions see the BEETLES *Ecosystem Literacy and Exploration Guides.*

TEACHING NOTES

The role of asking questions in science. Scientific questions are often driven by curiosity about the world and how things work. They can be inspired by previous investigations, or arise from the need to solve a problem. Scientific questions are distinguished from other types of questions because the answers and explanations are supported by observable evidence that can be gathered through investigation. Learning to identify testable questions is key to being successful in performing investigations about the natural world.

Importance of students observing & drawing *before* identification. Often, when students find organisms, they ask, "What is it?" and then, when told the name, they move on to finding the next organism (while forgetting the previous organism and its name). It's part of human nature to "move on" once we know the name of something. By giving students time to focus, observe, and draw an organism without an identification key, they tend to become more truly engaged with the individual organism, and ask their own questions about it. When identification keys are passed out later, they'll have an organism they already know a little bit about, to relate to the new information.

Prompt learners to use *I Notice, I Wonder, It Reminds Me Of* as necessary. If you notice that learners are having a hard time writing observations or questions, you can remind them of these handy prompts to encourage their sharing and thinking about the organisms. This powerful routine helps set learners up with tools for making scientific observations. Whether or not your instructors have experienced that routine, you can ask them these questions: "What do you notice about it?" "What do you wonder about it?" "What does it remind you of?"

- ▶ **Stream Example:** *The organisms we find in this stream live underwater. How is living underwater different from living out of water? How do they breathe? How do they deal with currents? How do they protect themselves from predators?*

Let's Go Exploring!

1. Tell pairs of learners to find and/or catch as many of the type(s) of organisms you've chosen as they can.

- ▶ *In pairs, you'll have ~12 minutes to explore this area and collect as many organisms (pond creatures, invertebrates, small plants, etc.) as you can.*

2. Introduce techniques, safety, and boundaries.

a. If there are specific useful techniques, like kick-netting for streams, or using other tools for catching small organisms, introduce them here.

b. Describe any safety rules and boundaries that are necessary for your study site.

3. Tell learners they'll get to pick a favorite and remind them not to let their organisms go, since they'll study them during the next step.

- ▶ *Your goal during the exploration time is to be gentle with these organisms and to find as many different kinds as possible, so you can pick a favorite one to focus on.*
- ▶ *Don't release organisms you collect, because you'll need them later.*

4. Tell learners to pay attention to the structures of different organisms as they explore.

- Look at organisms' structures (the materials something is made of and how it's shaped) while you explore, and pay attention to the differences and similarities between them.

5. Facilitate exploration—circulate and troubleshoot.

a. While learners are exploring, engage them in observation and conversation about what they find.

b. Remind them to catch as many different organisms as possible.

c. Help those who are struggling with finding organisms or having a hard time working together.

Journaling About An Organism

1. Each pair chooses one organism to focus on, and releases others.

a. When energy lags, or when you think people are ready to move on, remind pairs to choose one organism to focus on.

b. They will become the group's "experts" on that individual organism by studying it and recording what they find in their journals.

c. Tell them to put the other organisms back where they found them (or as close as possible).

2. **Introduce drawing and writing as scientific tools to collect information, not to make pretty pictures. For example, say:**

   - *In your journal, you'll make a sketch of your organism and write as many observations and questions as you can, like a scientist would.*
   - *It's not about making a pretty picture. It's about noticing things accurately and writing them down.*
   - *Sometimes a drawing will help show what you noticed, sometimes words will communicate it better. Use both drawing and writing in your study.*

3. **Explain that looking at structures and thinking about how they function is something scientists do, and that they can focus on specific structures:**

   - *Thinking about the structures, body parts and features of organisms and how they might function is something many scientists do.*
   - *As you record your observations in drawing and writing in your journal, pay attention to particular structures, and think about how they might help the organism survive in this ecosystem.*
   - *You may want to focus part of your sketch on the details of a specific structure.*

4. **Pass out materials—learners record observations and questions through writing and drawing for ~10 min..**

   a. Hand out journals and pencils, and help pairs focus on their chosen organisms.

   b. Engage struggling pairs by asking questions about what they observe, and encouraging them to write these down.

   c. Allow ~10 minutes for initial observations and questions.

5. **Encourage pairs to make explanations about structures and their function based on evidence from observations.**

   - *Try to use evidence from your observations and drawings to make explanations about how the organism uses its structures to live and survive in the ecosystem.*

Identification and Further Research

1. **Explain resources for identification and further study; ask them to record what they find out, and their source(s).**

   a. After students have had at least 10 minutes to record information in journals, gather the group and show them a key, field guide, or other resource they'll use for identification, and explain how to use it.

TEACHING NOTES

Supporting scientific drawing. Emphasize that scientific drawings are accurate and detailed. Participants should write labels on their drawings to indicate special structures or features. It may free up some who are hesitant to draw if you remind them that scientific drawings are meant to record information/data, and do not need to be "beautiful."

You don't necessarily need to use field guides. *Discovery Swap* is certainly richer when you have identification keys or guide books, but If you don't have enough for everyone to use, it's plenty rich for them to focus on recording their own observations, constructing explanations from evidence, and communicating about these to others. If they can't identify the organisms, you can have them come up with their own descriptive names for the organisms and focus on sharing some of their key observations, questions and tentative explanations. You can also encourage people to make sure to record their questions and detailed observations, so that they can later consult appropriate resources, such as a science text or the Internet.

TEACHING NOTES

Informal assessment check-in. As the leader, participate in the "Cool Organism Convention" by asking questions and engaging in discussion with learners. To find out how they're doing with science practices, such as making explanations from evidence, look at their drawings and notes, listen to what they're sharing, and ask them about their explorations and explanations.

Why not do a timed rotation? Many educators frequently use timed rotations to ensure that students move systematically through a series of stations. But it can be challenging to keep all students engaged in timed rotations because some student discussions are cut off before they're finished, while others may have to be "idle" when they're waiting for everyone to be ready to move on. While some feel that students won't stay engaged without a structure to guide their movement, the advantage of having a free-choice rotation is that students get to pursue their own curiosity and spend time engaged in what truly interests them. Lack of choice can lead to students becoming more passive, which is hugely detrimental to cognitive engagement and real learning. We encourage you to try this activity in a more free-flowing and student-directed way and pay attention to what happens. The goal here is student-centered exploration, sharing, and discussion, which is more likely to occur when students have some control over what they're looking at and who they're talking to.

b. Tell them now that they've had a chance to observe and study their organism, this resource will help them identify their organism and find out more about it.

c. Tell them to write this information in their journals to remember it—**and they should also record their source(s).**

2. Encourage pairs to make careful identifications and gather information to answer their questions.

a. If learners have quickly identified (or misidentified) an organism, encourage them to not jump to conclusions.

b. Ask them to share evidence for why they made this identification (it has spots on its sides, etc.). Help them re-focus on specific observations if it helps them be more accurate.

c. If learners came up with questions about their organism, encourage them to look in the provided resources for information that might be helpful.

3. Give pairs a chance to review and write down their observations, questions, and explanations.

a. Encourage pairs to write down 2-3 compelling observations or ideas to share, and possibly a question for future study.

b. Have them also record any tentative explanations they came up with or confirmed through their research.

Cool Organism Convention

1. Explain that like scientists, they'll discuss their findings, questions, and ideas.

a. Gather the group and remind them that part of acting like a scientist is sharing ideas.

▶ *Scientists do research, ask questions, read and write papers, go to conferences and conventions, and discuss interesting ideas with each other.*

b. Explain: you'll be participating in a "Cool Organism Convention," and will be discussing each other's research, like scientists do.

2. Explain that one person from each pair of learners will be in the "A" group, and the other in the "B" group.

3. The "A" member stays with organism to share and discuss findings; the "B" member visits "A" group students to find out what they have to share.

a. Tell the A group they'll stay with their organism to share their findings and discuss their organism with B people who will come by.

4. **Explain that, after a bit, they'll switch roles and the B's will stay with the organisms while the A's circulate.**
5. **Let them know they'll be discussing their discoveries and questions—not just "lecturing" each other on what they found.**
   - *This should be a discussion, not a one-way lecture.*
   - *Person "A" will share observations, questions, ideas, & ask the "B" person what they think. "What do you think of that idea?" "Do you have a different thought?"*
   - *Person "B" will ask questions such as: "What do you mean by that?"* or, *"Did you notice anything about..."*
6. **Model a brief example of what this might look like, either by yourself, with a fellow leader, or with a student you think will do it well.**
7. **Begin the Convention with "B" group circulating and instructor participating.**
   - Go around and visit the "A" people yourself by going up to them and asking questions about what they've discovered.
8. **After ~10 minutes, call for the groups' attention and ask pairs to switch roles.**
   - When you call time, tell "B" students to remain with their organisms while the "A" students circulate.

Wrapping Up

1. **After convention has ended, tell pairs to carefully release organisms as close as possible to where they found them.**
2. **Gather the group and revisit questions about ecosystem and organisms, and record new ideas.**
   a. Return to some of the questions you asked about the environmental pressures on organisms found in this area.
   b. How have their answers changed or been expanded?
   c. Consider writing their observations and reflections on a whiteboard to share and record understanding of the ecosystem as a whole.
3. **Lead a *Walk & Talk back* to where you discussed *What Scientists Do*—reflecting on the experience of acting like a scientist.**
   - *What was it like acting like a scientist, making discoveries, and doing research?*
   - *In what other ecosystems might you find your organism, or similar organisms?*
   - *What questions do you still have about the organism you studied?*
   - *How could you find more information about these organisms?*
   - *What other organisms would you like to study in this way?*

TEACHING NOTES

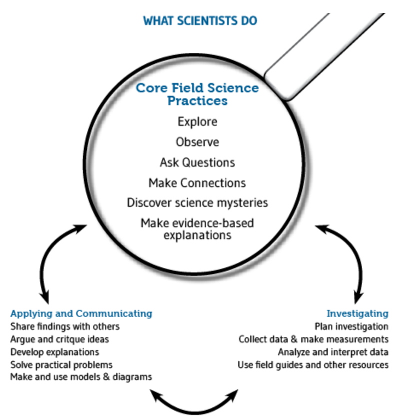
An alternative to a *Professor Hike*. This activity was designed as an alternative to *Each One Teach One/ Professor Hike*, in which students repeat information to other students that they've learned from an instructor or that they read off of a card. *Discovery Swap* puts learning in student hands by giving them the opportunity to choose what to focus on, and to make their own discoveries. They are also encouraged to discuss and wonder about their organism with peers, like scientists do, rather than lecture each other about it. This approach tends to be more engaging and productive for students, and helps them to become empowered to develop the mindset and skills to investigate the natural world throughout their lives.

Helping students notice what they have learned. Students often have a hard time reflecting on what they've learned. If you ask, they often just repeat facts they learned, not thinking about the abilities they've been learning. If you've checked in with each group as they were investigating, you can help highlight they science practices they're learning.

TEACHING NOTES

Review activity flow before debrief. You may want to review with your group the flow of activities from *Discovery Swap* before asking instructors to identify how they engaged in doing science. The *Discovery Swap* activity was divided into the following parts: Exploring different organisms; observing, drawings, asking questions, researching, and making explanations about one organism; sharing and discussing different organisms with others; reflecting on the process, and on what they learned.

Wondering about models? If participants are confused by how students might explore models during field activities, point out that food chains, webs, and pyramids are examples of models, as are diagrams of ecosystems and other systems in nature.



All BEETLES activities are designed to engage students in "Core to Field Science" behaviors (at least).

YOU ARE HERE:

10 minutes

▶ *What helped you to learn today?*

[Return to What Scientists Do]

Post: Debriefing Science Behaviors

1. **After science experiences, return to diagram with all 3 sections showing.**
   - Lay out the diagram again, this time with all the sections showing. Gather participants so all can see.
2. **Explain the two added categories: "Investigating," and "Applying and Communicating."**
   a. The "Investigating" section includes what scientists do when they design and conduct careful investigations to answer questions.
   b. The "Applying & Communicating" section includes science behaviors related to applying what's learned through investigations to other things.
   c. "Applying & Communicating" also includes communicating with others about ideas, investigations, and what has been learned.
3. **Learners discuss which science Core to Field Science, Applying and Communicating and Investigating behaviors they've experienced during the field experience.**
   a. Point out the *Core to Field Science* circle and ask for examples of how they participated in these science behaviors when studying their organisms.
   b. Do the same with the science behaviors in the *Investigating*, and *Applying and Communicating* sections.
   c. They'll likely say they engaged in all the behaviors from the *Core to Field Science* section, and perhaps some of the *Investigating* section as well. They also shared their findings from the *Applying and Communicating* part of the diagram.
4. **Point out that the arrows show that scientists go back and forth between science behaviors.**
   a. Explain how scientists move between science behaviors, doing what makes most sense to investigate their question.
   b. Make sure to emphasize that scientists don't usually follow the same step-by-step procedure to investigate the natural world.

Reflecting on Student Activities

1. **Tell participants to** *Think, Pair, Share* **about the benefits of doing this set of activities and how the instructor set them up for success.**
   a. Think, then discuss in pairs, the following questions:

      ▶ *What are the benefits of doing activities like these with students?*

      ▶ *What do students get from doing these activities?*

▶ *How did the instructor set learners up for success?*

b. Ask a few participants to share out their ideas about the questions with the whole group.

c. Listen to their ideas, and ask follow-up questions as appropriate.

2. Consider adding any of the following aspects of science practices that students may get from the activities, if the group hasn't mentioned them:

- making careful observations with scientific perspectives in mind
- practice with asking questions that can be answered through observation and/or research
- discussing tentative explanations based on evidence
- obtaining and communicating scientific information

3. Explain that all students in outdoor science schools can have rich experiences with the *Core to Field Science* behaviors:

a. There can be a lot of science in just one outdoor experience, but no single student activity is likely to include everything scientists do.

b. All students in outdoor science schools can have rich experiences with the *Core to Field Science* behaviors through activities that engage them in making observations, asking questions, making explanations, etc.

4. Explain that creating opportunities for students to engage in Investigating and Applying and Communicating activities, requires more time and focus.

a. Science behaviors like planning and carrying out investigations, analyzing data, critiquing ideas and developing models require a targeted focus on how scientists - and students - engage in these kinds of tasks.

b. It takes time to provide students with opportunities to fully experience these and to understand their purpose in science.

c. It can be a trade-off to choose to engage students in these science behaviors or to focus more deeply on the *Core to Field Science* behaviors.

5. Point out how *Core to Field Science* behaviors are foundational to other science behaviors.

a. The first part of the *Discovery Swap* activity (observing, generating questions, discussing scientific questions, and developing explanations) provides experiences with core field science behaviors that are foundational for students. They stir up student interest in engaging with nature and thinking like a scientist.

b. The rest of the *Discovery Swap* activity (obtaining information to answer questions, and discussing explanations) engage students in more ways of thinking like a scientist.

c. Students should have experience with *Core to Field Science* behaviors through activities such as *I Notice, I Wonder, It Reminds Me Of, Discovery Swap* and *NSI: Nature Scene Investigators* before engaging in other science behaviors.

TEACHING NOTES

Are science behaviors the same as science practices? The term "scientific practices" is currently preferred by science education experts when referring to the things scientists do to investigate and make sense of the natural world. The *Next Generation Science Standards* lists eight science and engineering practices that students should be engaging in to learn science ideas. The term, "science behaviors" was used during this student activity to avoid confusion with these specific NGSS science practices. BEETLES incorporated many of these NGSS practices into the science behaviors in the *What Scientists Do* activity, but translated them into kid-friendly and outdoor science specific language.

Provide information about how your program supports science practices. If your program focuses on developing certain aspects of scientific practices, this would be a good time to let field instructors know. Highlight specific goals for students and any additional activities that help provide those experiences

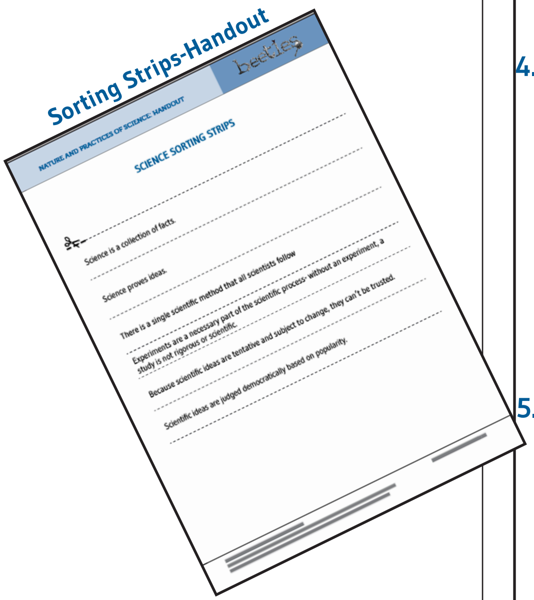
YOU ARE HERE:

20 minutes

TEACHING NOTES

Don't ask why they sorted statements as "accurate." In a moment, the groups will learn that all the statements are inaccurate. To avoid embarrassment, it's probably best not to have them invest time into explaining why they thought any were accurate. If you feel uncomfortable sharing only inaccurate statements, feel free to add a few accurate statements into the mix. One could argue whether the phrasing is too vague to judge the accuracy of some statements, but they're designed to stimulate conversation and interest in further information about them on the website.

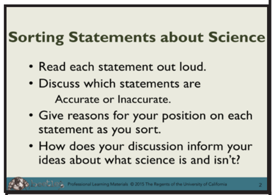
It's fine if a group decides it needs to create one or more new categories.



Sorting Statements About Science

slide 1

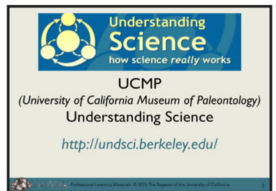
1. **Show slide 1,** ***Nature & Practices of Science*****. Gather group indoors; seat them in groups of 4-6 at tables.**
2. **Transition from engaging with the practices of science to looking at the nature of science:**
   a. Now that we've looked at how to engage students with the *practices* of science, we're going to take a look at the *nature* of science.
   b. The *practices* of science are essentially what scientists do, and the *nature of science* is more of a "big picture" view of what makes science unique from other ways of knowing about the world.
   c. To learn about the practices of science, students need opportunities to do science.
   d. But to learn about the nature of science, they need to have opportunities to reflect on what they've done, and try to answer the question, "what is science?"
   e. It's important that science educators have opportunities to look into and discuss the nature of science at an adult level, in order to be able to provide thoughtful guidance on the topic for students.
   f. Next, we'll do an activity designed to inspire adult-level discussion (not designed for use with students) about the nature of science.
3. **Introduce small groups to discussing and sorting science statements:**
   a. Your small group will receive a set of statements about science.
   b. Each strip of paper has a different statement about science on it.
   c. Your challenge is to discuss these statements with your group, and decide whether you think they are accurate or inaccurate.



slide 2

4. **Display slide 2:** ***Sorting statements about Science*****, explain purpose of sorting activity.**
   a. Reaching the "right" answer is not the point of the activity.
   b. The purpose is to discuss and think about what science *is* and what it *isn't.*
   c. You should discuss each statement thoroughly before placing it in two piles for "accurate" or "inaccurate" statements.
5. **Emphasize thinking about criteria for sorting, even with "easy" statements.**
   a. Some statements might be easy to categorize, others might be challenging.
   b. Even with the ones that seem easy, don't just sort them, discuss *why* you think they should be sorted that way.

6. **Give a set of statement strips to each small group of 4-5 participants, & tell them to begin.**
7. **Begin a whole group discussion with people sharing statements they classified as inaccurate & why they classified them that way.**
    a. After most groups have completed the sorting task, regain the attention of the whole group.
    b. Ask a volunteer to share a statement they sorted into the "Inaccurate" category.
    c. Ask them to explain why they decided it was inaccurate.
    d. Do this for a few statements.
8. **Display Slide 3: UCMP Understanding Science or access the website home page titled Understanding Science: http://undsci.berkeley.edu/**



slide 3

9. **Explain where the statements came from and reveal that they were all inaccurate.** Explain:
    a. All the statements came from a web page produced by the University of California Museum of Paleontology (UCMP).
    b. The website has a longer list of commonly held inaccurate ideas about science that scientists and science educators are attempting to dispel by providing more accurate information about science.
    c. You can go to the website to read in-depth explanations about why each of these ideas is inaccurate.

TEACHING NOTES

Helping instructors unpack how to teach about the nature of science.
It may be helpful to have participants brainstorm ways of providing opportunities for students to discuss each of these characteristics of science in the field. The group can explore discussing questions with students such as: Why do scientists use different methods to investigate the natural world? How do field scientists decide whether an explanation is accurate? How do they know whether a question is testable? How might different scientists from different fields, such as astronomy or geology, investigate their questions?

What is Science?

YOU ARE HERE:

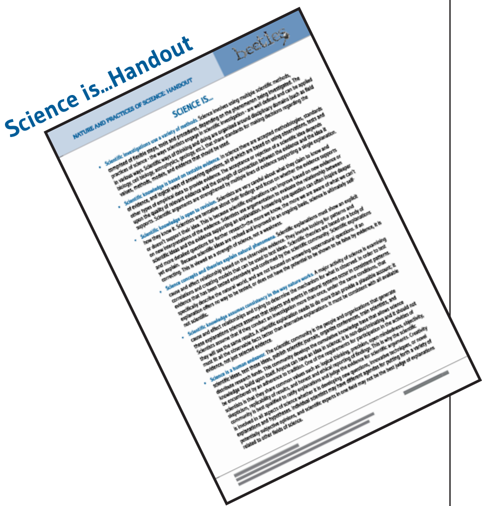
35 minutes

1. **Introduce different perspectives on science, explain:**
    - Well-known scientists and educators have also pondered the question: "What is Science?"
2. **Show slides 4-7; participants read quotes, make connections to what was shared during the *Thought Swap* discussion.**

slide 7

    a. For each quote, ask them to use a hand signal if they have heard someone in the group say something during the session in the spirit of the quote.
    b. Allow time for participants to read each one, or read them out loud.
    c. Point out and ask for any similarities to what participants shared during the *Thought Swap*.

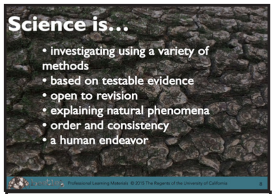
TEACHING NOTES



Another definition of science. Here's another attempt at defining science: The scientific community is involved in an on-going process of coming up with the most accurate scientific explanations for the natural world based on all the available evidence, and refining their methods for discovering and testing these ideas.

3. **Explain that science is complex, flexible, and somewhat challenging to define exactly.**

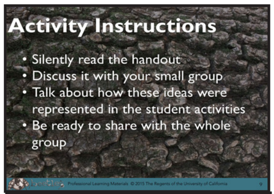
4. **Show slide 8:** *Science Is...*; **Introduce the** *Science is...* **handout. Explain,**



slide 8

   a. These important aspects of science are described more fully in a handout you'll receive.
   b. These come from consultations with scientists and science educators, the *Understanding Science* website from the UCMP and from the *Next Generation Science Standards*.
   c. These are well-recognized, essential characteristics to keep in mind as we instruct students about the nature of science.

5. **Show slide 9:** *Activity Instructions*; **Pass out the handout, give instructions for a small group discussion. Explain:**



slide 9

   a. First you'll spend a few minutes silently reading the handout, then you'll discuss it with a small group.
   b. You should also talk about how these ideas were modeled or represented in the student activities.
   c. Be prepared to share your conversations with the whole group.

6. **Lead a whole group discussion about the characteristics of science.**
   a. Get the group's attention and ask,

      ▶ *Were there items you had questions about? Any aspect of science you feel is missing on this list?*

      ▶ *What aspects of the nature of science do you think students might get from the model student activities?*

   b. Clarify any parts of the handout that may need further explanation.

7. **Explain how the** *What Scientists Do* **activity can help students understand the nature of science.**
   a. Students often learn science *content* with few opportunities to engage in and learn about the *nature and practices* of science.
   b. Students typically have even fewer opportunities for discussing *why* science is done in particular ways.
   c. Calling out the features of scientific investigations on the *What Scientists Do* chart, gives students an opportunity to discuss why scientific knowledge is accurate and reliable.

8. **Explain to participants the distinction between scientific** *practices* **and the** *nature* **of science:**

      ▶ *We teach the* **scientific practices** *when we ask students to do science as they make observations and attempt to explain the natural world.*

We teach the **nature of science** *when we ask students to reflect on and discuss what makes our observations and explanations scientific.*

9. Show slide 10: *Science is not…*; **Introduce "Science is not…" ideas.**

slide 10

- **a.** Tell participants to look at the flip side of the "Science is…" handout and read the "Science is not…" ideas.
- **b.** Read out loud the first item on the slide: "Science is not the absolute truth," and explain that this is an important point.

10. Explain that scientific investigations explore edges of understanding, rule out some explanations, and reduce levels of uncertainty about other explanations.

- **a.** Scientific investigations are designed to explore the edges of our understanding, as they attempt to rule out inaccurate explanations and explore and confirm evidence for new ideas.
- **b.** Pushing the boundaries of what is known is intentionally moving into risky territory - it's safer (but much less useful) to study something that's already well-understood.
- **c.** An investigation can never arrive at absolute certainty, but rather the goal is decreasing the level of uncertainty about a potential explanation.
- **d.** Because the scientific community operates with a healthy dose of skepticism, explanations involve lots of discussion and argumentation about the claims and evidence that support them.

11. Explain how the greater scientific community makes up for errors by individual scientists, and remains open to new evidence and better explanations:

- **a.** One way the public often misunderstands science, is by focusing on individual scientists and individual studies.
- **b.** Although we strive for accuracy and lack of bias, science is done by fallible humans.
- **c.** Individual scientists may make mistakes, but the greater scientific *community* is set up to identify errors and evaluate investigations of individual scientists.
- **d.** One of the strengths of science is the recognition that it is an on-going quest for understanding and is subject to self-critique and revision.
- **e.** This openness to new evidence and better explanations helps ensure that science progresses to a more accurate and extensive understanding of the natural world.

12. Explain that scientific debate can sometimes be misunderstood, and can be used to try to discredit the science:

- **a.** Some misinterpret why the scientific community encourages open discussion of ideas.

TEACHING NOTES

Discussing controversy about using the Scientific Method. This may be a rich and passionate discussion as some may question the emphasis on "the scientific method" and others may defend it as an important instructional tool. Many of us have been taught for years that "the scientific method" is how science is done. Some participants may react strongly to a challenge of that notion. Some who argue against this "new" idea may recognize that the scientific process is more flexible, but feel that outlining the traditional steps can help students appreciate science as an effective way of learning about the natural world. The point is to have a fruitful, thoughtful, meaning-making discussion that includes and respects different viewpoints. Enjoy the process and the discussion!

About using the term hypothesis. Often instructors and students make predictions and call them "hypotheses." A hypothesis is actually more than just a prediction–it includes a description of what you think might happen, which also includes an explanation for why this might occur. Scientists refer to hypotheses as tentative explanations. According to the Framework: "A scientific hypothesis is neither a scientific theory nor a guess; it is a plausible explanation for an observed phenomenon that can predict what will happen in a given situation. A hypothesis is made based on existing theoretical understanding relevant to the situation and often also on a specific model for the system in question." It's no wonder that it can be a challenge to help young students create relevant hypotheses based on their usually brief and limited experience investigating natural phenomena. The NGSS suggests introducing hypothesis in later grades.

TEACHING NOTES

Defining Science Literacy. The term "scientific literacy" has been used to describe the abilities required to understand and engage with scientific issues and ideas as an active member of modern society. This is also similar to "21st Century skills" which include things like interpreting data, evaluating evidence and analysis of claims about everything from environmental issues to vaccination policies. Understanding how science works and what counts as being scientific is critical to developing sustainable practices and solutions for the issues we face as a society.

b. They may see this openness to argue about specific scientific findings and explanations as questioning the validity of science in general.

c. The argument usually goes something like this: "Scientists don't agree, so the explanation is therefore questionable and not to be trusted." [e.g., attempts to discredit the ideas behind climate change].

d. The fact that the details and evidence for specific mechanisms are under discussion, does not refute that the explanation is well-founded.

13. Explain that science does not prove things. Science ideas include uncertainty, but some ideas survive testing and debate with higher levels of certainty.

a. In the press and in some advertising, we may hear mis-statements such as: "It has been scientifically proven that..." but nothing is ever considered "proven" in science.

b. Well-supported scientific ideas are judged as being the best, current explanation, taking into account the existing evidence.

c. Over time, scientific ideas that survive repeated testing and debate can be established as pretty much indisputable, (i.e., the existence of atoms, effects of gravity, evolution in populations of organisms).

d. Core to science is the notion that the scientific community must be open to revising a science idea if a better explanation is found.

14. Instructors should emphasize the benefits of open-minded, and tentative scientific thinking.

a. Instructors can help students understand the importance of tentative thinking in science by pointing out that, since scientific explanations may change over time, open-mindedness is key to making progress in understanding how the world works.

15. Read out loud the second item: "Science is not democratic" and explain:

a. Science is not based on how many people vote for an idea, it's based on the quality of the evidence that support the scientific claim.

b. It's not the authority of a particular scientist that's convincing to others, but rather the compelling nature of the evidence that provides the strength of an argument.

16. Read out loud the third item: "Science is not anthropocentric;" explain:

a. In science we try not to limit our view of things in nature as being centered around what's necessary or beneficial for humans.

b. It's important to avoid making human-centered assumptions about things in nature, as it may narrow a scientist's thinking.

17. Read out loud the last item on the slide: "Science is not conducted using a single scientific method;" and explain:

a. We've already discussed that science is much more than the traditional scientific method.

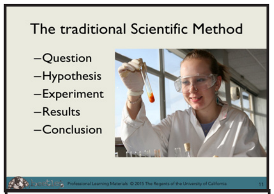
b. Scientific investigations tend to be iterative-moving back and forth between different aspects of an investigation.

c. Science investigations often involve lots of exploration, observation, and "messing around" with materials and ideas before generating hypotheses.

d. Field biologists repeatedly observe organisms in their habitat to hone investigation questions and methods.

e. The Next Generation Science Standards de-emphasize "the Scientific Method" but since this terminology is still widely used in science teaching, it's worth exploring a little further.

18. Show slide 11: *The traditional Scientific Method*; **introduce discussion about the Scientific Method.**



slide 11

a. These are the steps that describe the traditional *Scientific Method*.

b. Many scientists believe that overemphasizing these steps can limit students' ability to actively participate in science investigations.

c. Note that we didn't follow the steps of the scientific method in the order listed here during the student investigations we modeled.

d. In spite of this, we still experienced a scientific investigation that was both engaging (to students) and authentic to the way science is done.

19. Ask some of the following questions to stimulate discussion:

- *What might be disadvantages to using "the Scientific Method" during science instruction?*
- *Though we were not following "the Scientific Method," what aspects of our investigations were scientific?*
- *Are students authentically doing science during field activities such as I Notice, I Wonder, It Reminds Me Of?* (only ask this question if they are familiar with this student activity)

20. Choose some of the following ideas to share with participants, depending on the conversation.

a. The process of science is exciting, complex, and unpredictable. It involves many different people, engaged in a variety of activities that can occur in many different sequences.

b. Science is creative and practical: not rigid. If something works, it's used, if something doesn't work, other approaches replace it.

c. Each step of the "scientific method' reflects an important aspect of science, though the process is usually not that linear.

d. The steps of the "scientific method" do represent how scientists usually write up the results of their studies.

e. The scientific method is a grossly oversimplified representation of how scientists generally build knowledge.

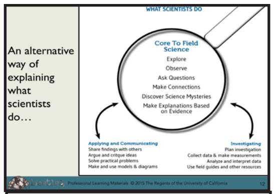
TEACHING NOTES

Background on the origins of the scientific method. "In the 1940s a man named Keeslar wished to describe the different elements of scientists' work. He began by generating a list of all the things he imagined scientists did, carefully making measurements, maintaining detailed written records, defining a research problem. This list was then turned into a questionnaire and given to many professional scientists for their response. Keeslar took the questionnaires as they were returned to him and put the items receiving the highest rankings into an order that seemed "logical" and published these findings in an education journal. Even though he was reporting on how scientists use different thinking strategies without meaning to imply a nice neat sequence, that's unfortunately how his work has been represented. A science textbook writer saw Keeslar's list and turned it into The Scientific Method—touting it as THE way science proceeds. Indeed, there is really no such thing as a singular scientific method and this list doesn't accurately portray the work of most scientists." [From Settlage, J. and Southerland, S.A. (2007). Teaching Science to Every Child: Using Culture as a Starting Point. New York, Routledge.]

TEACHING NOTES

f. The idea that there actually is no one scientific method is not a "fringe" idea. The first item listed in the *Understandings about the Nature of Science* section of the *Next Generation Science Standards* is: "Scientific investigations use a variety of methods."

21. Display slide 12: *An alternative way of explaining what scientists do*, **explain that the** *What Scientists Do* **diagram can be used by outdoor science educators as an alternative to the Scientific Method.**



slide 12

a. The *What Scientists Do* diagram is specifically for outdoor science schools to use to explain the activities of scientists.

b. It focuses on scientific practices students can experience for themselves during field investigations, and doesn't show a particular order or a step-by-step process.

YOU ARE HERE:

15 minutes

Wrapping Up

1. Students often miss out on the mystery-solving aspects of engaging in scientific discovery. Explain:

a. Elementary school students often have few opportunities to engage in science investigations.

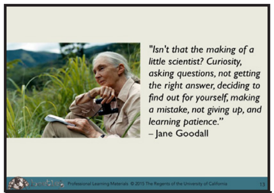
b. This leads students to the misconception that science is just a collection of facts, that nearly everything about nature has already been discovered, and that science education is memorization of those facts.

c. Science education researchers think this has contributed to a lack of student engagement in science as students progress through each grade, resulting in fewer students interested in science in middle and high school.

d. One of the most intriguing aspects of science is using scientific investigations and ways of thinking to try to solve the mysteries around us.

e. When students think like a scientist and have experiences trying to figure things out, they become engaged with science.

2. Show slide 13: *Jane Goodall quote*; **Emphasize importance of teaching about the nature & practices of science:**



slide 13

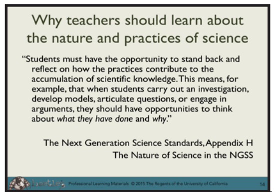
a. Take a moment to read the Jane Goodall quote.

b. One reason this session is devoted to understanding the nature and practices of science is because this is arguably the most important—yet historically neglected—aspect of science that can be taught to our students.

c. We're surrounded by scientific and non-scientific information in the world, and increasingly, citizens vote on issues involving science.

d. Understanding more about science as a way of knowing can help students recognize the value of science, and prepare students to be critical consumers of information in the media and other public forums.

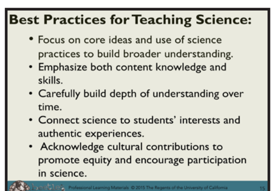
3. **Show slide 14:** *Why teachers should learn about the nature & practices of science,* **point out why field instructors and teachers need to know more about the nature of science.**



slide 14

   a. Teachers may not have had experience with doing science themselves, or building the deep content expertise needed to understand the nature of science.
   b. This can lead to teaching science as vocabulary and facts or as a rigid "scientific method."
   c. The *Next Generation Science Standards* and the *Framework for K-12 Science Education* emphasize that students must actively engage in doing science and reflecting on how it's done to learn to appreciate where scientific explanations come from.
   d. Teachers and instructors need to know enough about the nature and practices of science to lead these kinds of discussions with students.
   e. Using activities that have been developed with these goals in mind can be helpful to instructors.

4. **Show slide 15:** *Best practices for teaching science*; **Review current, well-recognized ideas about how students should learn science. Explain:**



slide 15

   a. Experts understand the core principles and theoretical underpinnings of their field, as well as many small bits of information. They are able to link these big and small ideas together in sophisticated ways to make sense of new information and novel problems.
   b. Novices, in contrast, tend to understand bits of knowledge and isolated facts, and struggle to organize and integrate them into mental frameworks.
   c. We can help students become less like science novices and more like experts by teaching important core ideas through engaging in scientific and engineering practices and discussing the nature of science.

5. **Point out the challenge of teaching this way and how connections across disciplines and emphasizing knowledge and practice are supportive.**
   a. Research on learning shows that achieving this kind of understanding is challenging, but can be built over time with be the right support.
   b. Support can include encouraging students to make connections across different disciplines and learning experiences.
   c. Emphasizing both knowledge and practices helps students develop a more flexible, coherent, wide-ranging, understanding of science.

TEACHING NOTES

The Nature of Science and the Next Generation Science Standards. These are the basic understandings about the nature of science as described in the NGSS: Scientific Investigations Use a Variety of Methods; Scientific Knowledge is Based on Empirical Evidence; Scientific Knowledge is Open to Revision in Light of New Evidence; Scientific Models, Laws, Mechanisms and Theories Explain Natural Phenomena; Science is a Way of Knowing; Scientific Knowledge Assumes an Order and Consistency in Natural Systems; Science is a Human Endeavor; Science Addresses Questions About the Natural and Material World

Research on teacher understanding about the nature of science. Science teachers who do not have experiences learning about the nature of science, tend to primarily teach the vocabulary and facts of science. They tend to neglect important aspects of science, such as how scientific knowledge is generated, and how knowledge claims are cautiously evaluated. (Gess-Newsome & Lederman, Examining Pedagogical Content Knowledge.)

Teaching that supports an understanding of how science is done. BEETLES activities demonstrate how to engage students in the practices of science in order to support deeper conceptual learning and to emphasize science as a way of learning about the natural world.

TEACHING NOTES

What does the BEETLES acronym stand for? It could be "Back!" Edward exclaimed, "the leech-eared stallion!" But it's not. It's actually Better Environmental Education, Teaching, Learning, and Expertise Sharing.

6. **Explain benefits of situating science instruction in authentic challenges and acknowledging diverse cultural contributions:**
    a. It's helpful to situate science topics and discussions in authentic problems and issues that relate to students' lives.
    b. Research has also found that acknowledging diverse cultural contributions to scientific understanding, creates an environment where all learners feel welcomed and have something to contribute.

7. **Show slide 16:** *Everybody gets in...* **and emphasize the issue of equity for science.**

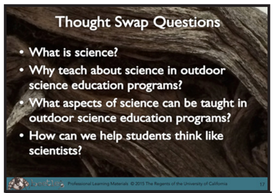
slide 16

    a. Science is no longer considered an elite topic only for those will become scientists or science educators.
    b. 21st Century learning includes science literacy for all, to ensure that all citizens have the ability to evaluate statements and solutions based on scientific ideas and evidence.

8. **Explain that the rich phenomena at outdoor science school can be an ideal setting for students to follow their own interests as they learn about the nature and practices of science.**
    a. Outdoor science schools are an ideal setting for students to engage in many science practices in authentic ways that help them understand science as a useful method for making sense of the natural world.
    b. In a classroom, investigating a bug in a cup brought in by a teacher can be a worthwhile science experience, but in the outdoors, students are *surrounded* by rich natural phenomena to explore and investigate.
    c. Students learning in outdoor settings can genuinely follow their own interests due to the wide variety of natural phenomena, which can be much harder to do in a classroom.

9. **Explain that engaging students in behaving as scientists can help outdoor science schools encourage curiosity, nature appreciation, and understanding nature of science:**
    a. When students actively explore the natural world outdoors, they become more curious and deepen their relationship with nature.
    b. Authentically engaging in scientific practices deepens their nature experience, and their understanding of the nature of science.

10. **Show slide 17:** *Thought Swap Questions*; **Remind participants of the thought swap questions from the beginning of the session.**



slide 17

    • Give participants a few minutes to review the questions from the beginning of the session.

TEACHING NOTES

11. Show slide 18: *Reflection;* **Ask participants to write in their journals about these ideas.**

slide 18

- Encourage them to note instances in which they learned something new, found a different perspective, changed their minds about anything during the session, or are struggling with an idea, and what made them do so.

▶ *How might you apply ideas from this session to your science instruction?*

12. Pass out any remaining handouts.

- If you haven't already, pass out copies of the student activities and handouts for *Discovery Swap* and *What Scientists Do.*

13. Ask if there are lingering questions about the session or any of the handouts.

- Depending on time and interest you may want to end the session with a whole group discussion or you can allow time for further discussion at a staff meeting using the "Suggestions for Follow-Up Activities and Discussions" on page 28.

TEACHING NOTES

SUGGESTIONS FOR FOLLOW-UP ACTIVITIES AND DISCUSSIONS

The session is not over! A critical phase of learning anything new is application, when the learner takes new knowledge and applies it. There is some application included in the session, but with all professional learning for instructors, the rubber meets the road (or trail) when the instructors apply what they've learned to their instruction, and when they keep thinking about it and discussing it with their peers. If you want your instructors to try out "new" activities/approaches, program leader support is crucial. Even if they're excited by new ideas, it's easy for instructors, especially veteran instructors, to keep doing what they have been successfully doing already, and not try out new activities/approaches. Below are a variety of follow-up activities and discussions to dig deeper into the topic, and help you facilitate thoughtful implementation.

- **Next Generation Science Standards in Outdoor Science Instruction.** Present a "mini-session" on the NGSS to your staff, using the optional section, "Next Generation Science Standards in Outdoor Science Instruction" on page 30, and the slides included at the end of the sessions' slides. You'll need at least 1 hour to do this well.
- **Staff brainstorm of what they and you can do to encourage incorporation of nature and practices of science into instruction.** After the session reflection, your staff will have already written ideas they have about implementation. You can tap into these, and other ideas through a brainstorm of what they plan to do, and how you can support them in doing it.
- **Discussing Implementation of *What Scientists Do,* and/or *Discovery Swap*.** Assign your staff to each try out *What Scientists Do* and/or *Discovery Swap* during your next student program, and to write in their journal about how it went. Then lead them in a discussion on the activity(ies) at the end of the program during a meeting. Here are some suggested questions to focus a reflection or discussion on:
    - » What impact did the activity have on your students' understanding of the nature and practices of science?
    - » What was successful about the activity?
    - » What might you do differently the next time you lead it and why?
- **Instructor Observations.** If you do observations of instructors, discuss how you might incorporate elements from this session into the observations.
- **Continuing a discussion.** If there was a topic that came up during discussion that you had to cut off, and your staff is interested, set aside time to continue the discussion.
- **Groups research misconceptions from UCMP website sheet**. Go to the

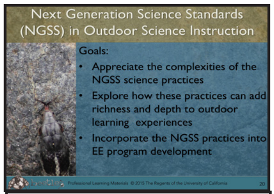
UCMP website (http://undsci.berkeley.edu/teaching/misconceptions.php#d2) and show how to navigate the misconceptions. Click on one of the misconceptions, and show the paragraph explaining why it is an inaccurate description of science. Distribute to each group a copy of the *Misinterpretations of the Scientific Process* handout, and tell them it contains explanations for each of the misconceptions about science. Ask one member of each group to read aloud what the website has to say about each of the statements they classified as accurate. Encourage groups to discuss these statements once again, incorporating the additional information. Show the "How Science Works" page (*http://undsci.berkeley.edu/article/0_0_0/howscienceworks_01*). Also found on the "Resource Library" page of the Understanding Science website is a link to "How Science Works—the flow chart." Show how each of the circles on the flow chart leads to more pages addressing what scientists really do, as opposed to the commonly taught steps of the "scientific method." Encourage them to explore the website later and tell them that part of their homework will be to examine the Understanding Science website.

- **Read selected sections from A Framework for K-12 Science Education.** Download a free PDF of the Framework document at: *http://www.nap.edu/catalog.php?record_id=13165* Print out selected pages of the Framework and assign a reading. Then lead an open-ended discussion with staff about the topic you've chosen, and how they might bring it into your program's curriculum and instruction. Where are there opportunities in your program 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. Below are some relevant sections to choose from.
    - 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)

TEACHING NOTES

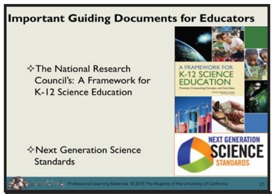
Next Generation Science Standards in Outdoor Science Instruction

1. **Show slide 20:** *Next Generation Science standards in Outdoor Science Instruction,* **introduce the goals for the mini-session.**



slide 20

2. **Show slide 21:** *Important Guiding Documents for Educators***; briefly introduce the** *Science Framework* **and the** *Next Generation Science Standards* **(NGSS). Explain:**



slide 21

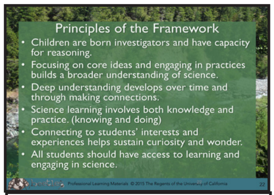
   a. The *Science Framework* and the NGSS describe and support an ambitious vision for science education.

   b. These documents mark a positive change in education, moving toward more authentic student engagement in science.

   c. They're based on current educational research about teaching and learning, that has been evolving since the 1990's.

   d. The goal is to steer education towards deep, meaningful learning opportunities that prepare students for college and careers, and develop the critical thinking skills needed to be discerning adults.

3. **Show slide 22:** *Principles of the Framework***, allow time for instructors to read them.**



slide 22

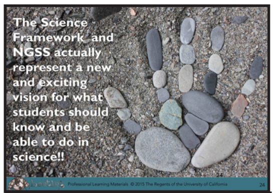
   - Emphasize that these are ideas that can provide an opportunity for both in-school and out-of-school programs to improve science teaching and learning.

4. **Show slide 23:** *Commonly heard comments***.**

slide 23

   - Explain that these kinds of statements may lead educators to think that implementing new approaches to teaching science are not really necessary.

5. **Show slide 24:** *The Science framework and NGSS...***; point out that there has been a significant shift in the vision for what students should know and be able to do in science.**

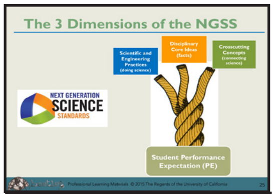


slide 24

   a. Say the next few slides will provide examples of this shift and the rationale for taking a fresh look at what and how science is taught to students.

   b. They will also have a chance to look more deeply at the "doing" of science through examining different kinds of student activities.

6. **Show slide 25: The 3 Dimensions of the NGSS; introduce the rationale for including all three**

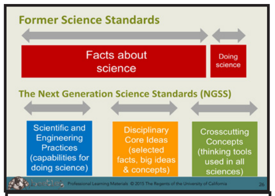


slide 25

dimensions of science in the performance expectations for students. Explain,

- **a.** The NGSS are written as performance expectations for students that weave together three dimensions: science and engineering practices, disciplinary core ideas and crosscutting concepts.
- **b.** Research suggests that students should learn science concepts by engaging in specific practices used by scientists to investigate the natural world.
- **c.** By learning science in context, as opposed to memorizing isolated facts, students can develop a deeper more coherent understanding of how the world works.
- **d.** In addition, students should learn to apply crosscutting concepts - important thinking tools that are commonly used across science disciplines - in order to make sense of their investigations.

7. Show slide 26: *Former science standards*; **explain that the emphasis is now much stronger on actually doing science and thinking about big ideas.**

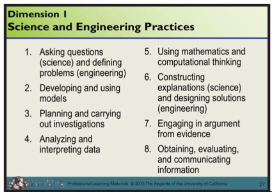


slide 26

- **a.** In previous standards, there was greater emphasis on facts students needed to know, rather than on the doing of science and understanding the big ideas that help explain intriguing phenomena.

  ▶ *The Framework says students should learn science by doing science!*
- **b.** This more balanced and realistic distribution of skills means students should spend a significant amount of time pondering scientific questions and trying to answer them, rather than just memorizing factual knowledge in order to pass tests.
- **c.** The goal is to prepare students to use critical thinking skills to solve problems and make sound decisions based on the best available scientific evidence.

8. Show slide 27: *Dimension 1 Science and Engineering Practices*; **explain how these are similar but different from inquiry skills or science processes.**



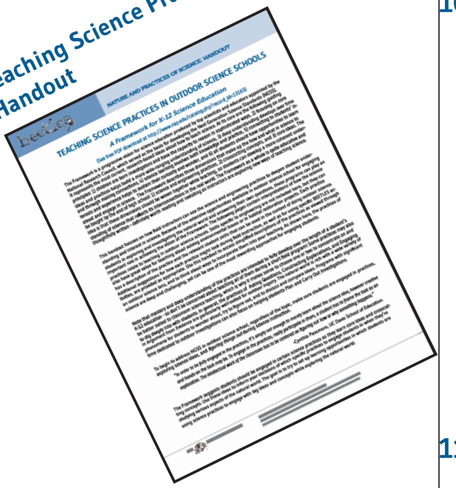
slide 27

- **a.** What were previously referred to as science process skills or inquiry skills, have been expanded upon and deepened to reflect the critical thinking that is required to make sense of science ideas.
- **b.** Rather than focusing on developing these skills separate from learning about specific science content, the NGSS now recommends that students use the science practices to learn scientific concepts.
- **c.** The science and engineering practices overlap with the literacy capacities required by the Common Core State Standards for English Language Arts and with the mathematics practices described in the Common Core State Standards for Mathematics.

TEACHING NOTES

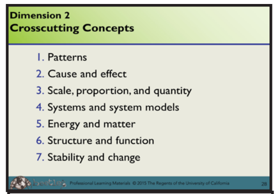
Notice that "making observations" is not included in the list of practices. The authors noted that this *is* a valuable practice for scientists because making very careful observations leads to important questions, interpretations, and explanations related to the other practices.

TEACHING NOTES



Teaching Science Practices-Handout

9. Show slide 28: *Dimension 2 Crosscutting Concepts*; **explain that the NGSS also emphasize crosscutting concepts.**

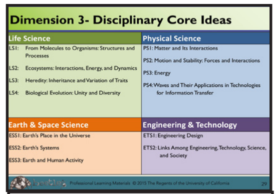


slide 28

a. Notice that the crosscutting concepts listed here look very similar to themes addressed in outdoor science schools and environmental education programs.

b. These are overarching concepts that serve as powerful thinking tools for scientists, and for students, and help us make sense of the natural world.

10. Show slide 29: *Dimension 3 Disciplinary Core Ideas*; **explain** *The Next Generation Science Standards* **have reduced the number of concepts for students to learn.**



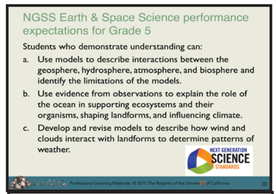
slide 29

a. The disciplinary core ideas show the specific concepts needed for students to become scientifically literate citizens.

b. The topics listed here represent a reduced set of key science ideas and concepts that students are responsible for learning K-12.

c. These concepts are designed to build throughout grade levels as students add more sophisticated knowledge in each year of schooling.

11. Show slide 30: *New NGSS Earth & Space Science performance expectations for grade 5*; **explain how the three dimensions are woven together into Performance Expectations.**



slide 30

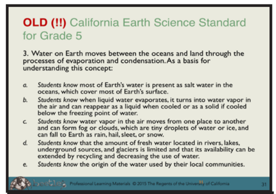
a. Performance expectations are not meant to be used as curriculum, rather they describe how students will show that they have achieved the standards.

b. Allow time for instructors to read the NGSS performance expectation.

c. Looking at this fifth grade example for Earth and Space science, you can see that each performance expectation requires that students use one of the practices of science to demonstrate their thinking about a specific science idea.

d. In some cases they must also apply a crosscutting concept (such as patterns) that is related to understanding how the natural world works.

12. Show slide 31: *Old California Earth Science Standard for grade 5*; **compare this to an example of a former fact-based science standard .**



slide 31

a. Allow time for instructors to read the California science standard.

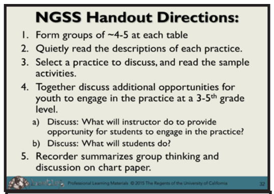
b. Notice that these are all things students can memorize and repeat back, sometimes without fully understanding.

c. It's easy to see how these kinds of standards can be used as a list to check off as you teach, in order to align your curriculum with standards.

TEACHING NOTES

d. The NGSS Performance Expectations can't be used in the same way to align curriculum – this is intentional! They require that students apply their knowledge and skills in the context of actually doing science.

13. Show slide 32: *NGSS Handout Directions*; **Pass out the** *Teaching Science Practices in Outdoor Science Schools* **handout to each small group.**



slide 32

14. Introduce NGSS handout and instructions for small group discussions. Explain:

a. Pass out the *Teaching Science Practices in Outdoor Science Schools* handout. Explain: The left hand column is a description of each practice, and the right hand column describes possible field activities that could engage students in that practice.

b. Read each description, then select one to discuss in depth with your group.

c. Read the sample activities and brainstorm additional activities that you could use to engage students in this science practice.

d. If there is time, you can move on to discus another practice.

15. Explain that science practices are most applicable, but engineering practices may also be relevant.

a. The practices described here are for both science and engineering, two disciplines that the Framework explains are closely connected.

b. In outdoor science programs, the engineering practices can be applied to "environmental engineering" activities, such as habitat restoration.

16. Participants read and discuss the Science and Engineering practices.

a. Allow ~15 minutes for small groups to read and discuss ideas for creating opportunities for students to engage in practices in outdoor science programs.

b. Circulate and help clarify the descriptions as needed.

17. Point out that it's possible to feature aspects of the nature of science in a variety of activities:

a. For students to gain understanding of science, every science activity should ideally highlight some aspects of the nature and practices of science.

18. Emphasize being selective and thoughtful about aligning teaching to the Framework and NGSS. Explain:

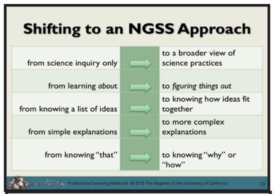
a. The Science Framework and the NGSS were written to create a vision for science education that involves creating in-depth, meaningful learning experiences that inspire students to want to learn more about the natural world.

b. It would be impossible to address all the appropriate grade level standards in a meaningful way during a week at outdoor science school.

TEACHING NOTES

c. A more thoughtful approach would be to choose a limited number of practices and/or cross-cutting concepts to focus on, and to provide multiple opportunities for students to engage with and discuss these ideas throughout a multi-day program.

19. Show slide 33: *Shifting to an NGSS Approach*, and explain that these are the major shifts to keep in mind when making instructional decisions.



slide 33

SCIENCE SORTING STRIPS

Make 1 set of Science Sorting Strips for each pair of participants. Cut into individual strips and put each set into an envelope or attach them with a binder or paper clip.

Science is a collection of facts.

Science proves ideas.

There is a single scientific method that all scientists follow

Experiments are a necessary part of the scientific process- without an experiment, a study is not rigorous or scientific.

Because scientific ideas are tentative and subject to change, they can’t be trusted.

Scientific ideas are judged democratically based on popularity.

SCIENCE IS...

- **Scientific investigations use a variety of methods.** Science involves using multiple scientific methods, comprised of flexible steps, tools and procedures, depending on the phenomenon being investigated. The practices of science - the ways scientists engage in scientific investigation - are well defined and can be applied in various ways. Scientific ways of thinking and doing are organized around disciplinary domains (such as field biology, cell biology, astrophysics, geology, etc.), that share standards for making decisions regarding the values, methods, models, and evidence that should be used.
- **Scientific knowledge is based on testable evidence.** In science there are accepted methodologies, standards of evidence, and logical ways of answering questions, all of which are based on using observations, tests and other types of empirical (based on testing or experience) data to provide evidence. The acceptance or rejection of a scientific idea depends upon the quality of relevant evidence and the strength of connection between the evidence and the idea it supports. Scientific arguments are strengthened by multiple lines of evidence supporting a single explanation.
- **Scientific knowledge is open to revision.** Scientists are very careful about what they claim to know and how they know it. Scientists are tentative about their findings and focus on whether the evidence supports or doesn't support their idea. This is because scientific explanations can improve based on new evidence or on new interpretations of the evidence. Scientists use argumentation to evaluate the relationship between scientific ideas and the evidence supporting an explanation. Answering one question can often inspire deeper and more detailed questions for further research—the more we know, the more we are aware of what we can't yet explain. Because scientific ideas are revised and improved in an ongoing basis, science is ultimately self-correcting. This is viewed as a strength of science, not a weakness.
- **Science concepts and theories explain natural phenomena.** Scientific explanations must show an explicit cause and effect relationship based on the observable evidence. They involve looking for patterns and correlations and creating models that can be used to test ideas. Scientific theories are based on a body of evidence that has been tested extensively and confirmed by the scientific community. Scientific explanations specifically describe the natural world, and are not focused on answering supernatural questions. If an explanation offers no way to be tested, or does not have the potential to be shown to be false by evidence, it is not scientific.
- **Scientific knowledge assumes consistency in the way nature works.** A major activity of science is examining cause and effect relationships and trying to determine the mechanism for what is observed. In order to test these explanations science assumes that objects and events in natural systems occur in consistent patterns. Scientists assume that if they conduct an investigation more than once, under the same conditions, that they will see the same results. A scientific explanation needs to do more than provide a plausible account; it must fit all the observable facts better than alternative explanations. It must be consistent with all available evidence, not just selected evidence.
- **Science is a human endeavor.** The scientific community is the people and organizations that generate scientific ideas, test those ideas, publish scientific journals, organize conferences, train scientists, and distribute research funds. This community develops the cumulative knowledge base that allows science knowledge to build upon itself. Anyone can have an idea in science; it is non-discriminating and it should not be encumbered by an adherence to tradition. One of the requirements for participation in the activities of scientists is that they share common values such as: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. This is why the scientific community is best qualified to ratify explanations and judge the evidence for scientific arguments. Creativity is involved in all aspects of science whether it is developing new questions, innovative techniques, or novel explanations and hypotheses. Individual scientists may have different agendas for putting forth a variety of potentially subjective opinions, and scientific experts in one field may not be the best judge of explanations related to other fields of science.

SCIENCE IS NOT...

- **The absolute truth.** Scientific knowledge is only our current best approximation based on all available evidence. In science, no explanations are considered "proven." All explanations are open to replacement or refinement, if warranted by new evidence. Yet most scientific knowledge is durable, and has withstood the test of time and extensive critique by peers.
- **Democratic.** Science is not based on how many people vote for an idea, it's based on the evidence. It doesn't matter how many scientists there are with a particular opinion—the evidence is what counts. It's also not the authority of the scientist, but the quality of the evidence that provides the strength of the argument.
- **Anthropocentric.** In science, we try not to limit our view to only seeing things in nature that are related to human survival. Nature was not made for us, we co-evolved together on this planet. Therefore, scientists avoid attributing particular aspects of nature to their potential benefit for humans. Scientists also try to stay away from viewing other organisms' behavior as reflecting human-like intentions and feelings.
- **A single "Scientific Method."** There is no one method for doing science. Science involves many different steps and procedures, depending on the field of science and the question being investigated. The process of science is exciting, complex, and unpredictable. It involves many different people, engaged in a variety of activities that can occur in many different sequences.

WHAT SCIENTISTS DO

Core to Field Science

Explore

Observe

Ask Questions

Make Connections

Discover science mysteries

Make evidence-based explanations

Applying and Communicating

Share findings with others
Argue and critique ideas
Develop explanations
Solve practical problems
Make and use models & diagrams

Investigating

Plan investigation
Collect data & make measurements
Analyze and interpret data
Use field guides and other resources

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 students' 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 both profound and accessible--definitely worth reading and revisiting as instructors explore 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 outdoor science. Additional suggestions for how each practice might look during field instruction, as well as for using specific BEETLES activities, are provided. Use this handout to access descriptions of the practices as viewed through an outdoor science lens, and to think about ways to incorporate them into your teaching. The practices of science are deep and challenging, yet can be a rewarding approach for engaging students.

Note that mastery and deep understanding of the practices fully develop over the length of a student's K-12 education - so don't be concerned about teaching all of them during a field program! Some practices may also be better suited to classroom science teaching, so choose the ones to concentrate, on and dig deeply into them with students. 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, discuss and argue about from evidence. 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 cross-cutting concepts. Use these ideas to inform your decisions of which specific practices to engage students in when they're studying the natural world. The goal is to set up learning opportunities in which students are using science practices to engage with big ideas and concepts while exploring the natural world.

Science and Engineering Practices Explained

	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 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 nature; *e.g., What do bees do?* • Distinguishing scientific questions; *e.g., What might be causing this log to decompose?* from non-scientific questions; *e.g., Which is your favorite leaf?.* • 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 and interesting stuff in nature, and have students ask questions about it. Recognize which questions are scientific, try to refine some questions to be testable, and practice asking scientific questions during discussions. *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 each other about observations and explanations. Through *Interviewing an Organism* students focus on asking questions that can be answered through 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 testable under the conditions of the field experience, attempt to investigate one of their questions, then discuss findings, and how the investigation could be improved.

	Description of Practice & Student Abilities	Field Examples & Teaching Notes
2. Develop and Use Models	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. 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. All models are inaccurate in some way(s), otherwise they'd be the "real thing." Whenever students are exposed to any kind of model, they should be encouraged to come up with things that are inaccurate, and ways that the model might be made more accurate. *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.	*General Approach:* Food webs, food chains, nutrient cycles, 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: Using 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. When students create their own models for explanations using visual representations, realia or diagrams, they are making their thinking visible for themselves and each other, as well as their instructor. NOTE: When students play a predator-prey game, they are not necessarily learning about modeling. A game that simulates a process in nature can be considered a model if it is used to make predictions, or to support students' explanations. Models should be evaluated for both accuracies and inaccuracies, in order to avoid unintentionally instilling any misconceptions. *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.

NATURE AND PRACTICES OF SCIENCE: HANDOUT

	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 don't usually have the time to 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 is 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, and 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 macro-invertebrates in slow-moving or fast-moving water. Or students could engage in a habitat comparison study to try to answer if there are the same kinds of animals in riparian and 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 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 a range of 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 toward 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 the students 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 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. • Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems. • Organizing simple data sets to reveal patterns that suggest relationships.	*General Approach:* Have students collect, calculate and summarize quantitative data. For example, students can use data collected during a stream study to calculate 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 to 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 understanding 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 second-hand, 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 second-hand 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, come up with explanations for what is happening to the log, discussing the strength 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 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 make claims about them. • Listening to the ideas of others and keeping an open mind. • Coming up with evidence-based explanations and sharing their reasoning. • Comparing the strengths and weaknesses of different explanations. • Politely disagreeing by citing 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 make the best case to convince each other. 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, so that fits the explanation that they were getting water [reasoning]. " *Specific BEETLES activities:* During *NSI: Nature Scene Investigations*, students compare their explanations to those of others and weigh their strengths. In *The Case of the Disappearing Log*, students come up with explanations for what is happening to the log, discussing the strength and weaknesses of each explanation. In *Bark Beetle Exploration*, students discuss the ramifications of bark beetle population increases.

	Description of Practice & Student Abilities	Field Examples & Teaching Notes
8. Obtain, evaluate, and communicate information	Scientists must 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 scientists' working time. Exposure to the language of science is particularly important for students who hear less academic language outside of school than others, or for whom English is not their first language. Students who can decode the words, may still 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 opportunities 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 diagrams in field journals. • Citing and evaluating sources of information; *e.g., "My source is Spongebob show, but that's probably not a very strong source for science information."*	*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 make note of how certain they are based on the source of their information. *Specific BEETLES activities:* During *Discovery Swap* activity, 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.

BACKGROUND INFORMATION FOR PRESENTERS

Why Reflecting on the Nature and Practices of Science Is Important. We're constantly presented with scientific and non-scientific information. We vote on many issues that are informed by scientific ideas. To understand the meaning and value of scientific information, it's important to understand how scientists gathers information, and come up with explanations. (The National Science Education Standards, National Research Council, 1996). According to *A Framework for K-12 Science Education (NRC, 2012)*:

"...when students carry out an investigation, develop models, articulate questions, or engage in arguments, they should have opportunities to think about what they have done and why. They should be given opportunities to compare their own approaches to those of other students or professional scientists. Through this kind of reflection they can come to understand the importance of each practice and develop a nuanced appreciation of the nature of science."

The *Next Generation Science Standards* call on science educators to move beyond having students just learning about science. They encourage teachers to guide students to inquire about the natural world, using the methods that scientists use themselves. Being able to critically inquire about the world prepares students not only for future science studies, but also to increase their ability to make informed decisions based on evidence and to acquire new knowledge. Teaching students about the nature of science also increases their interest in science (Lederman, 1999; Meyling, 1997; Tobias, 1990).

Understanding the nature of science is important particularly for anyone who teaches science. Science teachers who do not have a background in the nature of science tend to teach vocabulary and facts, neglecting more important aspects of science, such as how scientific knowledge is generated, and how knowledge claims are cautiously evaluated. Children and adults, including science teachers, hold both accurate and inaccurate ideas about what science is. Many science teachers have not had the opportunity to reflect on the nature of science. (Gess-Newsome & Lederman, Examining Pedagogical Content Knowledge.) DATE??

What is Science? Science teachers and scientists agree that science is a valuable way of knowing. Science is a set of practices as well as the historical accumulation of knowledge. The scientific enterprise is a union of science, mathematics, and technology, as well as logic and imagination. Science assumes that the world around us is understandable, and that the basic rules that exist in one part of the universe can be applied to others. Like many other systems of thought, science is a quest for truth, yet in science, nothing is ever completely proven. Science is open to new evidence and ideas, and actively seeks them out. Science helps us understand the world around us, and in a practical sense, it has great predictive value. See the handouts, "Science is..." on page 36 and "Science is not..." on page 37

Science, Evidence, and Explanations. At its core, science is about evidence. Science is an attempt to understand the natural world (i.e., everything that is not supernatural). Scientists make observations and collect data in as objective a manner as possible. Scientific explanations are based on all the available evidence. Explanations that are based on selective evidence, and ignore or exclude evidence that doesn't support the explanation, are "pseudoscience."

Science is Self-correcting and Durable. In science, evidence, investigations, and explanations are discussed and reviewed by peers. Investigations are repeated, and if the results are not comparable, the results are questioned. More evidence is always sought out, and if an accepted explanation doesn't match new evidence, it is revised or replaced. In this sense, science is self-correcting. Scientific knowledge and explanations are accepted within the scientific community based on consistency and strength of argument. Scientific knowledge evolves over time as the community of scientists inquires in different and deeper ways to uncover new evidence that changes and/or refines the accepted understanding of the natural world. Despite this embrace of change, and acknowledgment that science cannot attain "absolute truths," most scientific knowledge is durable. New evidence sometimes leads to refinement of current ideas, rather than complete rejection.

The Myth of the Scientific Method. A common misconception about science is that there is a single scientific method—a series of sequential steps scientists follow to arrive at a conclusion. This myth has been spread widely by science educators, but is a source of frustration for scientists who are aware of its limitations in describing what they do. The source of the myth is described in the following quote:

"In the 1940s a man named Keeslar wished to describe the different elements of scientists' work. He began by generating a list of all the things he imagined scientists did: carefully making measurements, maintaining detailed written records, defining a research problem. This list was then turned into a questionnaire and given to many professional scientists for their response. Keeslar took the questionnaires as they were returned to him and put the items receiving the highest rankings into an order that seemed "logical" and published these findings in an education journal (McComas, 2000). Even though he was reporting on scientists' uses of different thinking strategies without trying to describe a nice neat sequence, that's unfortunately how his work has been used. A science textbook writer saw Keeslar's list and turned it into The Scientific Method—touting it as THE way science proceeds. Indeed, there is really no such thing as a singular scientific method and this list doesn't accurately portray the work of most scientists (which makes us wonder what teachers are trying to portray by drilling students on the scientific method)." [From Settlage, J. and Southerland, S.A. (2007). Teaching Science to Every Child: Using Culture as a Starting Point. New York, Routledge.]

In actuality, there are many different paths scientists follow to answer questions. The methods used by an astronomer studying a distant star are quite different from those used by a field biologist studying an insect. The scientific enterprise also involves human imagination and creativity. The NRC *Framework* states the benefits of recognizing the breadth and variety of methods used in science:

> *"For example, the notion that there is a single scientific method of observation, hypothesis, deduction, and conclusion—a myth perpetuated to this day by many textbooks—is fundamentally wrong. Scientists do use deductive reasoning, but they also search for patterns, classify different objects, make generalizations from repeated observations, and engage in a process of making inferences as to what might be the best explanation. Thus the picture of scientific reasoning is richer, more complex, and more diverse than the image of a linear and unitary scientific method would suggest."*

Scientific investigations are peer-reviewed, reflecting the fact that the real "scientific method" is bigger than the work of an individual scientist or even the combined work of a particular group of scientists. Scientific discourse and communication are instrumental. Scientific papers are published in journals reviewed by other scientists. Shared critique and discussion of methods and ideas are ongoing within the scientific community.

To clarify the overlapping and iterative aspects of doing science, the Framework for K-12 Science Education uses Figure 3-1, "The Three Spheres of Activity for Scientists and Engineers" to describe scientific activities. The first sphere is observing and investigating the world, and the second is evaluating what is found out through investigation. The third sphere is using what is learned through investigating and evaluating to make sense of data and develop theories, models, explanations and solutions. The arrows from the center sphere show that the discourse-based activities of arguing, critiquing and analyzing are taking

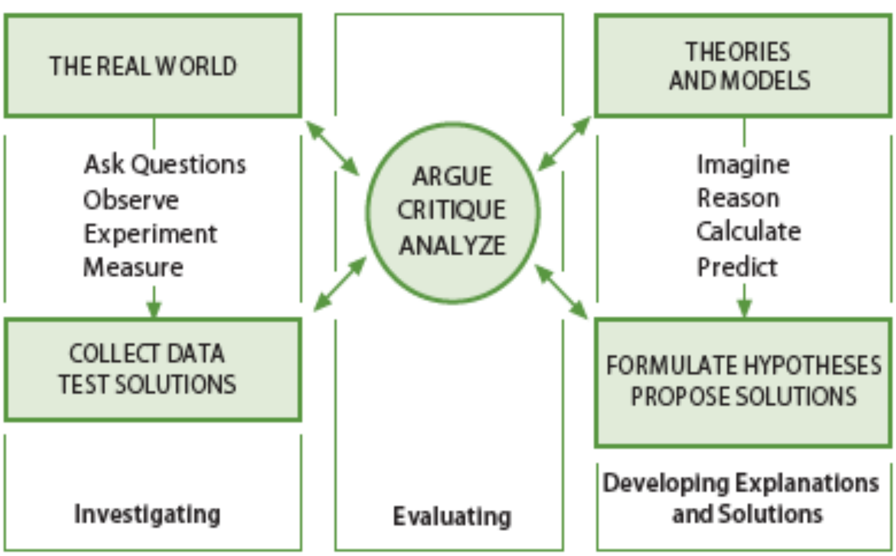


FIGURE 3-1 The three spheres of activity for scientists and engineers.

place all along the way, as we investigate and attempt to explain the natural world. This diagram represents science as an iterative, fluid, self-adjusting endeavor, and NOT as a linear, step-by-step process. The activities of scientists are also represented on the"What Scientists Do" chart, but organized into categories that are related to field activities commonly experienced by students in outdoor science programs.

Science and Human Nature. Although a goal in science is to be objective, in reality, the evidence that is collected is interpreted, and influenced by current scientific perspectives and by the society, culture, and even the scientists' sometimes-unavoidable subjectivity. There are patterns and habits of human thinking that present challenges in scientific endeavors, but the methods of science have been designed and re-designed to try to account for these.

Scientific Facts, Laws, and Theories. These three terms describe important aspects of the nature of science, but are often misunderstood. Each has a meaning in common usage that is different from its meaning in the scientific community, and this can cause confusion. These are the definitions as written by the National Academy of Sciences.

Fact: In science, an observation that has been repeatedly confirmed and for all practical purposes is accepted as "true." Truth in science, however, is never final, and what is accepted as a fact today can be modified or even discarded in the future.

Law: A descriptive generalization about how some aspect of the natural world behaves under stated circumstances.

Theory: A well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses.

The contention that evolution should be taught as a "theory, not as a fact" confuses the common use of these words with the scientific use. In science, theories do not turn into facts through the accumulation of evidence. Rather, theories are the end points of science. They are understandings that develop from extensive observation, experimentation, and creative reflection. They incorporate a large body of scientific facts, laws, tested hypotheses, and logical inferences. In this sense, evolution is one of the strongest and most useful scientific theories we have. [Adapted from Teaching About Evolution and the Nature of Science (1998). National Academy of Sciences, Washington, D.C.: National Academy Press.]

Scientific Hypotheses According to the Framework. "A scientific hypothesis is neither a scientific theory nor a guess; it is a plausible explanation for an observed phenomenon that can predict what will happen in a given situation. A hypothesis is made based on existing theoretical understanding relevant to the situation and often also on a specific model for the system in question."

Science and Language. Although "scientific proof" is a an expression that's often used by the general public, use of the words, "prove" or "proof" in science is generally inappropriate, because they imply that scientific ideas can be absolute truths. There are also many other words used in science that also are used in everyday language. Misunderstandings often arise when these words have very specific meanings in science, but more vague or sometimes quite different meanings in everyday language. The word "theory" in common language is often used to describe an idea that is a guess or an explanation that has not been well tested. In science, as noted above, it is actually used to describe big ideas that are supported by a large body of scientific facts, laws, tested hypotheses, and logical inferences. See Vocabulary Mix-ups, in the Misconceptions About Science section of University of California Museum of Paleontology (UCMP) Understanding Science website: http://undsci.berkeley.edu/teaching/misconceptions.php

Note: Before presenting this session, even if the leaders are experienced science teachers and/or scientists, we strongly recommend they read the handouts and teaching notes on Science Is… and Science is not… (see "Science is…" on page 36) It's also recommended to spend some time exploring the UCMP *Understanding Science* website: http://undsci.berkeley.edu/

Science Misconceptions and FAQs

Which is most important? Learning science facts and names or learning scientific ways of thinking and doing?

From the NRC Framework:

"Science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge. Both elements—knowledge and practice—are essential. In science, knowledge, based on evidence from many investigations, is integrated into highly developed and well-tested theories that can explain bodies of data and predict outcomes of further investigations. Although the practices used to develop scientific theories (as well as the form that those theories take) differ from one domain of science to another, all sciences share certain common features at the core of their inquiry-based and problem-solving approaches.

"Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Any education that focuses predominantly on the detailed products of scientific labor—the facts of science—without developing an understanding of how those facts were established or that ignores the many important applications of science in the world misrepresents science and marginalizes the importance of engineering."

Science classes sometimes revolve around dense textbooks, but these collections of facts provide only part of the picture. Science is a body of knowledge that one can learn about in textbooks, but it is also a dynamic process for discovering how the world works and building knowledge into powerful and coherent frameworks.

Misconception: "It's important to teach the Scientific Method (question, hypothesis, experiment, results, conclusion) in residential outdoor science programs."

"The Scientific Method" is often taught in science courses as a simple way to understand the basics of scientific testing. In fact, the Scientific Method represents how scientists usually write up the results of their studies (and how a few investigations are actually conducted), but it is a gross oversimplification of how scientists build knowledge. Science is exciting, complex, and unpredictable. It involves many different people, engaged in many different activities, in many different orders.

"What appears to [the working scientist] as the essence of the situation is that he (sic) is not consciously following any prescribed course of action, but feels complete freedom to utilize any method or device whatever which in the particular situation before him (sic) seems likely to yield the correct answer… In short, science is what scientists do, and there are as many scientific methods as there are individual scientists." (Percy W. Bridgman —"On Scientific Method") DATE

Misconception: "Scientists are unbiased."

Scientists do strive to be unbiased as they consider different scientific ideas, but scientists are people too. They have different personal beliefs and goals — and may favor different hypotheses for different reasons. Individual scientists may not be completely objective, but science can overcome this hurdle through the action of the scientific community, which scrutinizes scientific work and helps balance biases.

In science, evidence, investigations, and explanations are discussed and reviewed by peers. Investigations are repeated, and if the results are not comparable, the results are questioned. More evidence is always sought, and if an accepted explanation doesn't match new evidence, it is revised or replaced. In this sense, science is self-correcting. Scientific knowledge and explanations are accepted within the scientific community based on consistency and strength of argument. Scientific knowledge evolves over time as the community of scientists inquires in different and deeper ways to uncover new evidence that changes and/or refines the accepted understanding of the natural world. Despite this embrace of change, and acknowledgment that science cannot attain "absolute truths," most scientific knowledge is durable. New evidence sometimes leads to refinement of current ideas, rather than complete rejection.

Misconception: "Science is analytical." OR "Science is creative."

Perhaps because the Scientific Method presents a linear representation of the process of science, many people think that doing science involves closely following a series of steps, with no room for creativity and inspiration. In fact, many scientists recognize that creative thinking is one of the most important skills they have — whether that creativity is used to come up with an alternative hypothesis, to devise a new way of testing an idea, or to look at old data in a new light. Creativity is critical to science.

Scientific analysis often involves jumping back and forth among different modes of reasoning and creative thinking! What's important about scientific reasoning is not what all the different modes of reasoning are called, but the fact that the process relies on careful, logical consideration of how evidence supports or does not support an idea, of how different scientific ideas are related to one another, and of what sorts of things we can expect to observe if a particular idea is true.

The scientific community values individuals who think of creative explanations that turn out to be correct — but it also values scientists who are able to think of creative ways to test a new idea (even if the test ends up contradicting the idea) and who spot the fatal flaw in a particular argument or test. Creativity is involved in all aspects of science whether it is developing new questions, techniques, explanations or hypotheses. Anyone can have an idea in science, it is non-discriminating and it is not sentimental.

Misconception: "Science facts and explanations are the truth." vs. "Science facts and explanations are no more trustworthy than other sources."

The scientific enterprise is a union of science, mathematics, and technology, as well as logic and imagination. Science assumes that the world around us is understandable, and that the basic rules that exist in one part of the universe can be applied to others. Like many other systems of thought, science is a quest for truth, yet scientists recognize that they can never completely arrive at the truth.

Scientific knowledge is only our current best approximation based on all available evidence. In science, no explanations are considered "proven." All explanations are open to replacement or refinement, if warranted by new evidence. Yet most scientific knowledge is durable, growing stronger and more refined over time.

When newspapers make statements like, "most scientists agree that human activity is the culprit behind global warming," it's easy to imagine that scientists hold an annual caucus and vote for their favorite hypotheses. Of course, that's not how it works. Scientific ideas are judged not by their popularity, but on the strength of the evidence supporting or contradicting them. A hypothesis or theory comes to be accepted (usually over the course of several years — or decades!) once it has garnered many lines of supporting evidence and has stood up to the scrutiny of the scientific community. A hypothesis accepted by "most scientists," may not be "liked" or have positive repercussions, but it is one that science has judged likely to be accurate based on the evidence.

Misconception: Scientific ideas are absolute and unchanging.

"Because science textbooks change very little from year to year, it's easy to imagine that scientific ideas don't change. It's true that some scientific ideas are so well established and supported by so many lines of evidence, they are unlikely to be completely overturned. However, even these established ideas are subject to modification based on new evidence and perspectives." Understanding Science, University of California Museum of Paleontology: undsci.berkeley.edu. This openness to new observations and interpretations is what makes science a fascinating topic of curiosity for children and adults!

Since much of what is taught in introductory science courses is knowledge that was constructed in the 19th and 20th centuries, it's easy to think that science is finished — that we've already discovered most of what there is to know about the natural world. This is far from accurate. Science is ongoing, and there is much more to learn about the world. In science, making a key discovery often leads to many new questions ripe for investigation. Scientists are constantly elaborating, refining, and revising established scientific ideas based on new evidence and perspectives.

Misconception: "Science kills wonder & curiosity during outdoor education experiences."

When science is taught only as information that is delivered to learners, it may be true that students can become disinterested. When science is taught only as a linear scientific method to follow, it may also be a turn-off to certain students.. But when science is taught as discovering mysteries everywhere in nature, and trying to figure them out, it's far from boring or dry. When field science is experienced as making careful observations, asking questions, constructing explanations from evidence, and discussing those ideas, it can ignite wonder and curiosity, and can be a powerful vehicle for engaging students directly with nature.

A Quote from the NRC Framework:

"A rich science education has the potential to capture students' sense of wonder about the world and to spark their desire to continue learning about science throughout their lives. Research suggests that personal interest, experience, and enthusiasm—critical to children's learning of science at school or other settings—may also be linked to later educational and career choices. Thus, in order for students to develop a sustained attraction to science and for them to appreciate the many ways in which it is pertinent to their daily lives, classroom learning experiences in science need to connect with their own interests and experiences.

"The actual doing of science or engineering can also pique students' curiosity, capture their interest, and motivate their continued study; the insights thus gained help them recognize that the work of scientists and engineers is a creative endeavor—one that has deeply affected the world they live in."

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University of California Museum of Paleontology (UCMP), Understanding Science website: http://undsci.berkeley.edu/

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