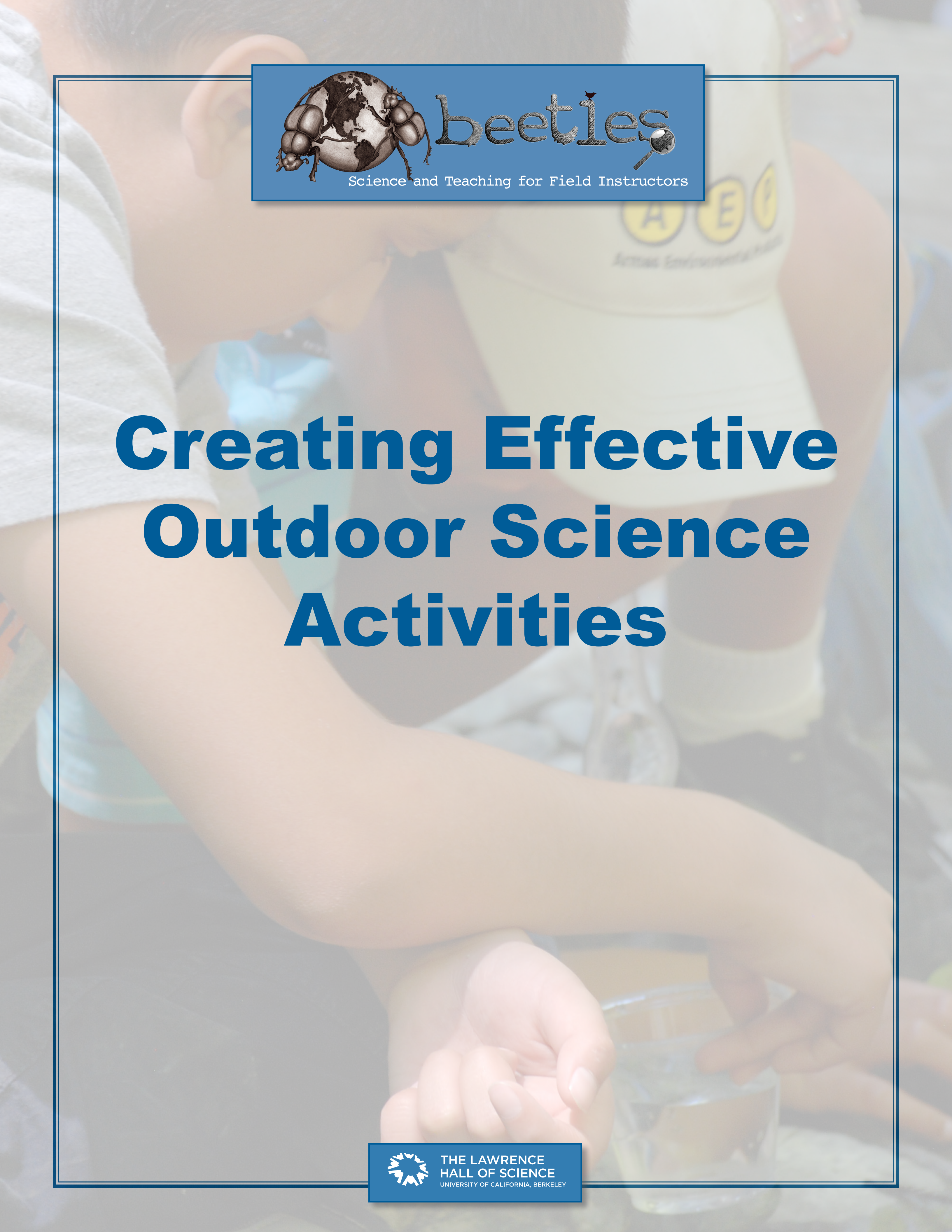

beetles

Science and Teaching for Field Instructors

Creating Effective Outdoor Science Activities

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

ABOUT BEETLES™

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

www.beetlesproject.org

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

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Letter to the Reader

Dear Reader,

Thanks for checking out this guide to creating effective outdoor science activities! Our goal at BEETLES is to help programs "get better at getting better at what they do." We hope to help programs that use science as a lens for connecting with nature take advantage of the rich resources available at their unique sites in order to offer high-quality learning experiences for students. The activities BEETLES has created are not site-specific, and have been designed to be used by most programs in most settings, but they are not intended to be the only activities a program should use.

While many BEETLES activities have been widely used and successfully applied at outdoor science programs across the country and internationally, we've heard over and over again that programs need more support in creating, evaluating, and revising activities that are unique to their site. Programs need activities that take advantage of the special stash of fossils they have, the huge amount of bald eagles, or that unique nearby grassland.

That's why we made this Guide! It's designed to help programs:

- Create effective new outdoor science activities for use by multiple instructors across a program.
- Adapt and revise existing activities.

There are other resources for activity design as well. Use whatever works best for you. This guide was made because outdoor science has specific opportunities and challenges that aren't always addressed by other resources. This document lays out a BEETLES approach to designing student-centered science activities focused on exploring and figuring out the intriguing mysteries of nature.

That's what this guide is, but there are a bunch of things that it's not, including:

- It's not a guide to designing nonscience activities (though we really appreciate the value of nonscience activities in outdoor education, and parts of this guide can work for that).
- It's not a guide to designing indoor activities (though we've done a lot of that too, and parts of this guide can be used in that way).
- It's also not a guide to designing curriculum (though it can be used as part of an approach to curriculum design).

We've created this guide to specifically share some thinking, approaches, opinions, and a process to design outdoor science activities, and to explain how you can adapt that process to your context to create high-quality student and nature-centered outdoor science learning experiences for your site.

This is not a guide to creating curricula. Curriculum is the whole collection of experiences students are engaged in by educators. Curriculum includes individual activities, but also involves other aspects, such as sequencing of activities. This is a guide to creating single activities, not curricula. Of course curriculum design is also important and a valuable pursuit, (especially if your program has long periods of time available to work with students). See BEETLES model theme hikes for some information about sequencing and structuring a series of activities.

This guide is based on many conversations with program leaders, education directors, and lead instructors like you! It also comes from many years of experience writing science activities and curriculum for classrooms, after-school programs, other informal settings, and especially the outdoors. We (Lawrence Hall of Science) also have extensive experience researching what works and what doesn't. BEETLES applies this research, teaching experience, and its successes, and failures to the process of creating effective outdoor science activities.

This guide can certainly be used by an individual instructor who is designing learning experiences for their students. But if your goal is to create activities that will be used by different instructors repeatedly across your program, we recommend that activities be developed by a small team of experienced instructors, curriculum specialists, and program directors. One of the biggest lessons we've learned over the years is that curriculum design and the creation of truly effective activities is not a 1-person job. A team effort can:

- Provide different perspectives, as well as a structure, for people to bounce around ideas.
- Allow one person to try out teaching an activity with students, while another observes and writes lots of notes about what happens so it can be discussed later.
- Help to make sure the activity will work for instructors of different styles, not just for the person who wrote it.

This guide is meant to be read by every member of that team. So if you're reading it on your own and plan to single-handedly and completely revise your program's entire curriculum, we urge you to go recruit a few others to join you.

Take this resource and figure out how to make it work best for you. Then don't forget to tell us how it went and show us what you created!

All our best,

The BEETLES Team

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Learn more about the Lawrence Hall of Science, UC Berkeley's public science center, at www.lawrencehallofscience.org/.

Check out the References section on page 44, as well as the sidebars throughout this document, to find the research and resources we use the most.

Are you an individual instructor designing activities to use with your students? You may want to check out the Appendices, and the following sections: "Chapter 4. Using Tools and Frameworks to Support Activity Design" on page 19, "Chapter 2. Designing Principles for Outdoor Science Activities" on page 14 and "Chapter 3. Avoiding Common Pitfalls" on page 16 to guide you. To get experience with a student-centered, nature-focused approach to teaching, you can try leading some BEETLES Focused Explorations (see our website at http://beetlesproject.org/resources/for-field-instructors/).

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Want to read a description of how the BEETLES team went from "Huh, lichen seems cool" to a full blown activity? Designing Lichen Exploration is a step-by-step description of the design of a field activity included in this guide. It's divided into three sections that are distributed in three chapters of this guide.

Chapter Overview

Chapter 1. *Focusing on Strengths of Outdoor Science Learning Experiences.* There are certain things outdoor science can do better than classroom science. Those should be your bread and butter, and where you should start when designing activities.

Chapter 2. *Designing Principles for Outdoor Science Activities.* These are things to include when designing student activities to make sure they are quality learning experiences that take full advantage of outdoor science education opportunities.

Chapter 3. *Avoiding Common Pitfalls.* These tips can help you avoid common mistakes that folks who are less experienced often make when designing activities.

Chapter 4. *Using Tools and Frameworks to Support Activity Design.* There are tools and frameworks that we've found are crucial when designing outdoor science activities, including the Learning Cycle and the Next Generation Science Standards (NGSS).

Chapter 5. *Planning Ahead and Setting Up for Success.* To be successful, you'll need to pick the right team, make sure the structure of your program and your clients will support your new activities, and plan how to test, revise, and write-up your activities.

Chapter 6. *Revising Existing Activities.* You can use this guide to revise existing activities (instead of creating new ones). This chapter includes an example of how a program took careful steps to successfully revise all their materials.

Chapter 7. *A Flexible Step-by-Step Process for Developing Student Activities.* This is a step-by-step process a development team can use to create new activities. It takes the information on the design process from the other chapters and puts it into practice.

Chapter 1. Focusing on Strengths of Outdoor Science Learning Experiences

Teaching **science outdoors** can be the "secret weapon" of science education. But for that to be true it **needs to include authentic exploration and deep thinking.** When this happens, **outdoor science can meet certain goals far better than classroom science experiences.** In a "rock star" classroom activity students might get a lot out of studying a bug in a cup. In the outdoors, students are surrounded by birds, rocks, streams, tracks, trees, and tons more interesting phenomena, including bugs doing their thing *in the context of the ecosystem*. In an outdoor learning environment, students can observe, poke, prod, and interact with things that can only be simulated, viewed through media, or sampled in a classroom. In this rich outdoor setting students can follow their curiosity into deeper inquiry, as they move between observation, questioning, and thinking in ways that mirror how scientists actually work. Outdoor science takes place in an authentic real-world context, and it lends itself toward more hands-on and physically active experiences, both of which increase student engagement.

Outdoor science programs can also have the advantage of spending more extended science time with students. **A week at a residential outdoor science program can be worth months of classroom instruction.** This is literally true! In a research report published in 2011, it was found that California elementary school students typically get less than 45 minutes of science instruction per week. That means that in one 4-hour, science-focused field experience, students can get the equivalent of 5 weeks of classroom science instruction, and all this in an authentic and highly stimulating environment! And if your program leads science experiences for multiple days, this can be the equivalent of *months* of science instruction. Because of other demands in the classroom, science often takes place in relatively short time chunks. Having consecutive, extended time blocks of science learning creates an opportunity for field instructors to take students deeper into inquiry about concepts by engaging them in scientific practices.

Strengths of outdoor science include:

- **Exploring and investigating interesting stuff.** The number and variety of critters and plants in even a small area outdoors offers an abundance of intriguing objects and processes to investigate.
- **Increased opportunities to engage students in science practices.** With authentic curiosity, and wonder, as well as rich and interesting parts of nature, students can ask questions, design investigations, construct explanations based on evidence, and engage in argument from evidence, all using their own first-hand observations.
- **Students' autonomy to follow their own interests and curiosity.** When given a balance of guidance and freedom through organized activities in nature students can be highly motivated to learn.

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Teaching outdoors can be a secret weapon for accomplishing a lot of other important things too, like character development and social-emotional learning. But that's another guide to write!

Of course, there are also many things that can be done better in a classroom than outdoors. The length of the school year allows for long-term investigations, and for teaching comprehensive science curriculum. The classroom is where students can wrestle with abstract concepts or global perspectives, using resources like maps and models of earthquakes, global temperatures, and ocean currents. A classroom setting is also great for projects that include research using books and online materials. Outdoor science is not a replacement for classroom science; rather, it is a magnificent complement to formal educational experiences.

For more information, see Dorph, Shields, P., Tiffany-Morales, et al. (2011) in the References section.

Check out research on the outcomes of outdoor science in the References. Specifically, take a look at Bognar (1998), Ernst & Monroe (2004), Farmer, Knapp, & Benton (2007), Palmberg & Kuru (2000), Shepard & Speelman (1986).

- **A mindset of discovering mysteries in the natural world can forever change students' relationship with nature.** Unraveling mysteries encountered outdoors leads to even more opportunities to engage in science practices—specifically, constructing explanations and arguing from evidence—and helps students to be more curious about the world around them.
- **Increased time allows for extended learning.** Outdoor science experiences are often longer than classroom experiences, allowing for more sustained focus, deeper and more connected learning, and the opportunity for exchange of ideas between students.
- **Understanding organisms and environmental processes in context.** Instead of isolated examples brought into the classroom, students can observe and investigate the relationships between all the interacting parts of an ecosystem. This supports more nuanced understanding of whatever part of nature students are studying, and helps make related concepts more clear.
- **Interacting directly with the natural world and developing a close relationship with nature.** It's clear that being outdoors and directly interacting with nature builds a connection to and appreciation for the natural world. That's big!
- **Instructors as enthusiastic and effective role models for inquiry.** Most field instructors love being in the outdoors, and can learn how to be curious about and investigate the natural world, then model and guide students to do the same. Whether students are watching antelope that are exotic to them, or ants that are common where they live, your program can provide interactions with field instructors that students can bond with and often view as mentors in the outdoors.
- **Students gain skills they can apply in their classrooms and outside in their own neighborhood.** If your instructors model and teach a scientific mindset of curiosity, students can become empowered to use the skills and attitudes developed at outdoor school when they go back home.

The quality of these kinds of experiences with high engagement in a real-world context, including student autonomy and a richness of resources, can be deeply impactful for students. When you combine the depth, quantity, and quality of learning possible in outdoor science, you can create transformative experiences for students in a relatively condensed amount of time. Students who have never had an interest in science before can see the subject and their relationship to it in a different way after a sustained experience in your program.

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To play to these strengths in outdoor science you also need to cultivate a "learning culture" among your staff. To do this, give them professional learning opportunities that develop their understanding of student and nature-centered pedagogy, and their capacities in key instructional skills like asking questions, leading discussions, and encouraging student observation. For more on how to cultivate a learning culture on staff, and how to use professional learning in your program, see the Guide for Program Leaders.

Check out research on the outcomes of outdoor science in the References section. Specifically, take a look at Bognar (1998), Ernst & Monroe (2004), Farmer, Knapp, & Benton (2007), Palmberg & Kuru (2000), and Shepard & Speelman (1986).

This can help you to make the argument that the money spent sending students to your program has a high return on investment. If done right, outdoor science is not a "luxury" that takes students away from valuable classroom time. It's an important complement to classroom learning that will significantly deepen students' science learning, environmental literacy, and help them to develop a close relationship with nature. So how do you play to these strengths? You do it by being thoughtful and strategic about what you teach in your program, and how you design your science activities.

Choosing What to Teach in the Outdoors versus in the Classroom

You can't teach everything in outdoor science programs, so it makes sense to play to your strengths. Ask yourself:

- "What can we do that can't be done or can't be done as well in a classroom?"
- "What makes learning experiences at our site extraordinary?"

The answer to those questions should be the focus of your program, and will help you take advantage of the outdoor learning opportunities we've outlined above. See Common Pitfalls (page 16) for examples of how outdoor science programs and instructors can sometimes stumble when trying to do things that don't play to these strengths. One of the best ways to avoid these pitfalls, and to make sure your program is rooted in the strengths of outdoor science education, is to **use nature realia to drive activity design.**

Using Nature Realia

The greatest resource we have as outdoor educators is the vast wealth of real stuff around us. The most effective way to take advantage of the unique setting of outdoor science education is to directly engage students with the stuff in nature that surrounds them while they are outdoors. But sometimes during field experiences students are out in nature, surrounded by natural stuff, and they aren't directly engaging with it. They're in nature, but not looking at, thinking about, or engaging with nature. Eek, what a missed opportunity!

You can make sure students are directly engaging with nature if your first step when designing an activity is choosing a part of nature at your site that is intriguing and present in large enough numbers for students to explore and investigate, then use this as the focus of the activity. In fact, most of our BEETLES activities began when one of us said, "Wow, there seems to be a whole lot of [lichen, spider webs, decomposing logs, bark beetle galleries] around here, and students sure do seem intrigued by it. Let's make an activity focused on it!" Students should be directly engaging with nature realia as much as possible during field experiences. Why, you ask?

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Schools and districts may sometimes pressure programs to teach specific facts or concepts, some of which may not play to the strengths of outdoor science. If you're trying to shift your program to take better advantage of what's possible in outdoor science, you'll need to make sure clients are aware of your rationale and how they can best support outdoor experiences in the classroom. You may need to maintain a focus on teaching traditional concepts in the short term, but you can gradually shift the priorities of classrooms and districts through careful messaging. See the Guide For Program Leaders for more on how programs have dealt with this.

***Realia* is a term for objects and** materials from everyday life, especially when used for instruction. By "nature realia," we mean some part of nature (such as leaves, galls, plants, animals, logs, stream features, rocks) that students can examine and interact with.

How does this happen that students may not directly engage with nature at outdoor science school? Sometimes it's because we are focused on concept-driven activity design—where we start out with a concept to teach, then try to figure out how to teach it on-site ("Chapter 3. Avoiding Common Pitfalls" on page 16). It's not that you should never create concept-driven activities for outdoor science—we certainly do sometimes—it's just that nature realia-driven activities are easier to create, and also more effective in engaging students directly with nature.

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See http://beetlesproject.org/ resources/for-field-instructors/ to download the *Spider Exploration* activity.

Phenomena-based instruction has been a recommended approach for designing curriculum to implement the Next Generation Science Standards. This approach shares many similar features with a nature realia approach, but there are important differences. The anchoring phenomena described in NGSS documents are events or processes that occur in real time and are directly observable. They happen in a specific place and at a specific time, which means they can be affected by context where they occur. For example, the reintroduction of wolves to Yellowstone, a mudslide, tree fall, a forest fire, bark beetle infestation, or a weather phenomena like fog forming and rolling in. These kinds of phenomena are worth exploring because they require students to understand and use several science concepts to explain what's going on. This is how anchoring phenomena can serve as a touchstone in the curriculum, in a way that compels students to learn new concepts and deepen their understanding, as well as to answer authentic questions and solve real-world problems.

Using nature realia to drive your activities can help with:

- **Cutting through the "green blur" when students observe nature.** We can help students get beyond this tendency to view nature as a vague whole, by focusing on specific parts or organisms in nature. It's hard to understand or investigate something we see as just a blur, or haven't paid close attention to, but by investigating spider webs through a focused *Spider Exploration* activity, students get an awareness and "ecosystem literacy" about spiders. Afterwards they tend to notice spider webs everywhere. The more of these kinds of experiences with different parts of nature, the greater a student's total ecosystem literacy, and the greater their curiosity and engagement about nature in general.
- **Helping students develop relationships with individual parts of nature, and nature as a whole.** If students engage in multiple activities focused on different parts of nature, they develop a relationship with nature as a whole. We've seen students, experienced ecologists, and seasoned naturalists struggle to leave a leaf or a tree behind, because they've "fallen in love" with it a little bit after an extended activity focused on the organism. For students who have never spent much time outside, this can be a particularly impactful experience.
- **Laying the groundwork to develop a strong, inclusive community of learners.** Grounding activities in nature realia is also a way to promote equity and inclusion in a group of learners. When students gain expertise through their own first-hand observations, everyone in the group can be an "expert," engage in discussion, and learn from each other. If an activity focuses only on abstract concepts or prior knowledge, the students who might not have developed an identity around science will be less likely to engage or feel they have something to contribute to the group's understanding. Time exploring nature realia shifts the experience from being about who knows more about science to begin with, towards a process of group discovery where everyone has a voice. Creating a community of learners centered around realia is a tried-and-true strategy for supporting academic language development and provides access for students with limited experiences outside the classroom or in other learning settings.

Make nature realia a program-wide focus. Figure out what at your site is intriguing, plentiful, and easy to investigate, and use it as a launching pad for creating activities. Doing this gives you a solid direction in the activity design process that makes sure that you're taking advantage of the strengths of outdoor science and of your program. Plus, it's just plain easier to create nature realia-driven activities than it is to create concept-driven activities. That's why the tools in this guide are specifically geared towards this kind of activity design, and do not directly address developing concept-driven activities.

If your program does need to create concept-driven activities, it still works well to use some tools we reference in this guide (like those connected to the Learning Cycle, and the Next Generation Science Standards). **Do your best to find ways to ground concepts in direct experience by choosing concepts that are connected to things students can observe, or concepts that students can figure out through engaging with nature.** If you don't start the activity invention process with nature realia, try to add it in later, by making sure that students are directly engaging with some type of nature realia during the activity. As models for designing concept-driven activities, consider using BEETLES concept-focused activities, such as *Decomposition Mission, Related & Different*, or *Structures & Behaviors*.

Charismatic Fauna and Emblematic Features

Some programs create activities that focus on a specific creature or a geographical feature that is important to the area. It makes sense to use local features as a starting point; swamps are amazing, and students in programs in areas with swamps should get the chance to explore and learn about them!

But some of these charismatic fauna and emblematic features can be easier for students to engage with than others. For example, one program developed a dolphin activity, because students could sometimes get a glimpse of them offshore. Through conversations at a Leadership Institute, the program leaders realized that it was essentially a classroom activity presented outdoors. They decided to shelve that activity and instead developed activities that focused on organisms and features in the area that instructors and students could find and explore more directly and more extensively.

If there are charismatic fauna (like dolphins) that students might occasionally catch a glimpse of and that students have GOT to see, it's worth developing a short (5 or 10 minute) learning cycle mini-activity an instructor can lead with students about it. When developing a longer activity, it's best to choose organisms or features that students can observe for a longer period of time.

Just don't leave out the parts of nature that might be less head-turning at first, but are fascinating, present in large numbers, and worthy of students' attention. Things like invertebrates, other small creatures, tiny plants, creeks, or leaves might seem ordinary to your instructors because they see them every day, but they can be new and fascinating for your students. Focusing on these parts of nature helps students slow down, get down, and learn to find wonder in exploring the ordinary. If students spend time during an activity observing leaves, lichen, ants, spiders, dirt, or some other commonly encountered aspect of nature, they can develop a relationship with something they might be able to find when they return home, and again and again in the future. This is usually not the case when students are observing something that is special to the site.

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Outdoor science activity design often gets into trouble when the designer(s) start out with a concept they want to teach. Sometimes, the concept is abstract and not related to what students can observe and figure out on the site. As an instructor tries to figure out how to teach it, they may slide into creating games or simulations that are relatively unrelated to the surroundings, and that don't engage students with nature (for more on educational games, see "Using Games Well" on page 18). Prioritizing nature realia-driven activity design doesn't mean not teaching concepts! Starting with nature realia, then figuring out which concepts can be taught through it, is a way to make sure you're focusing on concepts students can learn through engaging with nature at your site.

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Finding Nature Realia in Unexpected Places

When BEETLES staff were leading a professional learning session at an outdoor science school, we assigned small groups to put a circle of string somewhere, and spend time investigating what was in the circle. One group chose to focus on a lawn used by students for running around during breaks. We wondered why they chose the lawn when there were all kinds of interesting forest options that were much less impacted by humans. We were pleasantly delighted when they found lots of larvae under the surface of the lawn. Lightbulbs went off in their heads as they realized they had seen ducks feeding on this lawn for years, but hadn't known that these larvae were what the ducks were eating. Investigating this humble little patch of lawn helped them understand a food chain that was an interesting, yet previously unrecognized, feature of their site.

Designing *Lichen Exploration* is a step-by-step description of an example of activity design. It's a real life example of the process described in this guide. It has been divided into 3 sections spread throughout the guide to illustrate different parts of the process.

Designing *Lichen Exploration*: An Activity Development Example, Part 1

So what does this all look like in practice? In this section, we describe our design process for the BEETLES activity *Lichen Exploration*. Read through it to see specific examples of each phase of the activity design process. Since we don't run programs of our own, and are a team of people dedicated largely to creating tools and activities, parts of the process will be a little different from yours. While it roughly follows the sequence laid out in this guide, this section is intentionally not broken up exactly into the steps outlined above, because sometimes parts of a couple of steps are happening all at once. We hope it will be helpful to read as an example of what the activity design process can look like.

A Place to Begin: Finding Nature Realia

To start, we wanted to find something in nature that was interesting to students, and was present in large enough number that students could observe it. We found lichen fascinating ourselves, and noticed in lots of outdoor experiences that students would often pick it up and wonder about it. But we noticed most instructors we observed didn't seem to know what to do with lichen beyond telling the Freddie Fungus/Alice Algae story. So we decided to design an activity that would take students deeper with lichen. We also liked that lichen can be found in both rural and urban areas, so we figured that if we could help students become "lichen literate" they'd be able to continue their explorations back at their neighborhood and school, which is another of our goals.

Further Exploration, Research, and Identifying Learning Goals

We began intentionally exploring lichen ourselves. We paid attention to it everywhere we went. We got down on our knees with hand lenses and checked it out. When we did, we realized that we *had* to get students to do that, because we were so excited to discover that lichen looks like little alien

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worlds when seen through a hand lens. As we explored, we started to use Crosscutting Concepts to deepen our thinking. We looked at patterns of lichen growth, paying attention to where lichen grew, and where it didn't. We asked questions about lichen, looked at its structures, and thought about how different types of lichen might function differently.

Then we did some research of lichen online to see what we could find out. We learned that although there are thousands of species of lichen, there are between three to four basic "types" of lichen. These types of lichen seemed very manageable for students to identify, so by using free photos from online, we made a prototype identification key. After learning that the fourth type is often confused with another type, and many folks simplify it to three, we chose to include just the three types on our key. During our research we also learned that lichen often grows in the same succession pattern, with crusty lichen colonizing a surface first, followed by leafy lichen, and then shrubby lichen (and then moss!). We started looking for examples of this in nature, and found it to be observable in many places. We were hopeful that students would be able to observe it too. We also learned that while most people think of lichen as a mutualistic relationship (so did we!), it can actually involve three different types of symbiotic relationships.

We identified some learning outcomes for students, including students will:

- Observe differences between different types of lichen.
- Learn that lichen is actually a symbiotic relationship between two organisms, a fungus and a lichen.
- Learn to use a simple field guide to identify three types of lichen, and observe examples of lichen succession.

See Appendix I: Lichen Concept Map.

(continued on page 23: Designing Lichen Exploration*: An Activity Development Example, Part 2, Applying the Learning Cycle to the* Lichen Exploration *Activity)*

Chapter Summary:

- Outdoor science programs can offer significant quantity and quality of learning experiences that are different from classroom learning, and are highly valuable for students.
- These programs should be structured learning experiences that focus on the strengths of outdoor science learning and take advantage of the unique opportunities at your site.
- To ground activity design and to make sure students are engaging directly with nature, the outdoor science program should use nature realia, including "ordinary" stuff.

Chapter 2. Designing Principles for Outdoor Science Activities

At BEETLES we use five design principles when we create student activities—the first two are "nature-centered," the next three are "student-centered". Sticking to these principles helps us to make sure the quality of our learning experiences is high and helps us take full advantage of outdoor science education settings.

In BEETLES activities students will:

- **Engage directly with nature.** It's not enough for students to just be in nature. They need to make their own first-hand, extended observations of the details of nature; they need to establish intimacy with organisms, objects, and processes in nature. They need to develop an ongoing relationship with nature through direct engagement, while growing lifelong curiosity and inquiry skills that they take away with them.
- **Think like a scientist.** Students need to observe, ask questions, develop explanations, and understand the importance of evidence. Students learn science most effectively when they engage in the same practices scientists engage in. Scientific habits of mind are important to help students grow into responsible decision-makers. (*A Framework for K-12 Science Education*, and the *Next Generation Science Standards* can provide much-needed guidance in this area).
- **Learn through discussions.** Students need to make sense of their experiences by putting their ideas into words and comparing their ideas to those of others.
- **Experience instruction based on how people learn.** Students learn best when learning experiences are designed based on the Learning Cycle, a highly effective and flexible model for designing high-quality, student-centered instruction that helps make sure activities are constructivist.
- **Share and make connections to their lived experiences and cultural identities.** Students learn in the context of their cumulative life experiences, family histories, and cultural identities, including race, socioeconomic status, and gender identity. Quality instruction affirms individual's cultures and lived experiences. Educators should show cultural curiosity and humility, recognizing the many ways students' lives, experiences, and values may be different from their own and making space for students to share diverse perspectives.

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We will continue to reference the Next Generation Science Standards (NGSS) a lot throughout this guide. The NGSS represent a significant shift in teaching and learning—a shift from memorizing and recalling facts to a focus on thinking, meaning making, and deep conceptual understanding. Read more on the BEETLES website (http://beetlesproject.org/resources/for-program-leaders/ngss/) and the NGSS website (nextgenscience.org).

See Talk Science Primer (listed in the References) for information on the importance of talk for learning, as well as strategies for creating a culture of productive discussion in a group.

The Learning Cycle is a model for designing instruction that is consistent with research about how people learn. The Learning Cycle includes the following phases of learning: 1) Invitation (students become engaged with and access prior knowledge), 2) Exploration (students explore, become curious, and begin making sense), 3) Concept Invention (students invent concepts for themselves, with and without guidance), 4) Application (learners apply what they've learned to a different context), and 5) Reflection (learners think back on how their ideas have changed, and what helped them change). The Learning Cycle was originally described in the 1960s by Robert Karplus, a University of California, Berkeley, researcher who was an early leader of the Lawrence Hall of Science! It was revised and re-published in the 1990s by Roger Bybee as the "The 5 E Model." See the BEETLES "Teaching and Learning" Professional Learning Session for more information.

Designing activities with these research-based principles in mind can help you position your program as extraordinary, focusing on what you can do best and marketing your strengths to schools, parents, and other stakeholders.

It has also been helpful for BEETLES to keep in mind the following essential features that are related to the five principles:

- **Students use skills of observation and curiosity to figure things out and reflect on how those skills can be used to explore nature.**
- **Activity write-ups are educative.** As instructors read a write-up they're not just learning steps to follow. The activity guides are meant to help instructors learn about the art of instruction while learning how to teach a particular activity.
- **Any instructor can pick up the activity write-up and lead it the way it is written.** That means the activity does not rely on a specific person's personality, but on a well-designed structure that works for everyone, not just the person who designed it. This helps make sure that people with different styles or background knowledge (on science content, teaching approaches, etc.) and skills can pick it up and use it effectively.
- **The pedagogy is sound, and is communicated through the write-up.** Instructors need to understand why an activity is designed the way it is. This helps make sure that if instructors make any adjustments to the activity, they will be well-informed decisions about how to change the activity.

No doubt, your program has other features to add to this list. For example, there might be specific needs and expectations of your clients you need to address. Before starting on activity design, make sure all your design principles and essential features are clear to your team.

Designing activities that meet all these needs is complex, and you need planning, a strong team, and a testing and revision process. These are discussed in the next chapter.

Chapter Summary:

- BEETLES uses five design principles to help focus activities on the strengths of outdoor science learning experiences: Engage directly with nature, Think like a scientist (aligned with NGSS), Learn through discussions, Experience instruction based on how people learn and by using the Learning Cycle instructional model and constructivist approaches, and Learn through instruction that affirms their lived experiences and cultural identities.
- Other essential features for BEETLES activities are to involve students using skills of observation and curiosity to figure things out and to reflect sound pedagogy. And the activities are written to be educative and successfully used by any instructor.

NOTES

See "Marketing Your Program's New Activities" on page 36 for ideas on how to help your clients understand and value your approach to outdoor science.

For more about the importance of educative curriculum, check out Ball & Cohen (1996) or Davis & Krajcik (2005) in the References section.

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Chapter 3. Avoiding Common Pitfalls

After many years of creating activities and consulting with individuals and programs as they design activities, we've identified some common pitfalls that can lead to less effective activities. Having a focus on nature realia, and using frameworks like the Learning Cycle and connecting to the NGSS, can help your activity design team avoid many of these design-process-related mistakes.

Starting out with an abstract concept to teach. Instructors often begin designing a lesson by thinking about a fairly abstract conceptual goal for students, such as understanding adaptations, plate tectonics, photosynthesis, evolution, or energy transfer. Starting with an abstract concept that's hard to observe directly in nature (like photosynthesis) often results in lessons based on games or other simulations, with no (or little) direct exploration of nature. Often, instructors choose a concept they have recently learned about at an adult level and are excited to teach, even if it may not be appropriate for where their students are at. They may dismiss as boring or too basic, other topics that would be more appropriate for students. Abstract concepts are probably better taught in a classroom than outdoors, so students have multiple opportunities and a variety of ways to build their understanding. Using nature realia to drive outdoor activity design helps avoid this pitfall.

Check out the National Research Council's report *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century* for more on the importance of deep learning, which includes opportunities for students to apply their understanding to new contexts.

Trying to teach too much, too fast. Sometimes instructors (particularly beginning instructors) will try to cram too many concepts into a single activity. This tends to come hand-in-hand with the misguided belief that, "if I explain it to students, they'll know it." Deep learning of a meaningful concept requires multiple opportunities for learners to engage with the concept, and is probably not going to happen during a single activity, no matter how cool and engaging it is. Packing multiple concepts into one activity can actually make learning more challenging for students. It's better to choose one worthwhile concept, and do it really well. If it's a challenging and important concept (e.g., adaptations or decomposition), then it's probably worth addressing the concept in more than one activity.

Including too many transitions. Leading a group through multiple transitions to get through different parts of an activity can be hard for instructors—and for students! Having to get the groups' attention in the middle of an activity, gather them in one spot, deliver a new set of instructions, then send them back out to work can lead to behavior-management issues and/or lack of engagement with students. It can also be hard on a learner to be interrupted when they've become engaged in a task, particularly if it was hard for them to get interested and focused in the first place. When an activity has lots of transitions, it's sometimes because an instructor has tried to fit too much into a teaching session and has multiple steps for each concept they're trying to teach. A format that tends to work well (but which is not always possible) is for an activity to start off with an engaging and efficient introduction, give students a substantial block of time to dig into a task in pairs, then finish up with an engaging debrief as a whole group. An activity structured into these three main "chunks" minimizes the number of times the instructor has to get students' attention or shift them from the task they're doing.

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Confusing memorization with learning. Memorization of facts is useful and has its place in education, but if a student can recite a fact it's not necessarily a sign of full understanding. Some instructors think that if their students can repeat a definition, they really "got it." Memorization can be quick and easy, but deep learning takes time. For deep learning, students need to discuss ideas with other students, as well as the instructor, and ideally, engage with concepts using multiple perspectives. When creating activities, plan for this kind of learning instead of just having students memorize a fact. The NGSS are less about "facts" and more about deep understanding—the focus is now on quality versus quantity.

Not giving enough opportunities for students to discover information themselves. Be thoughtful about when and how you introduce content (information) to students. Whenever possible in the activity, students should engage with nature and with each other in order to develop understanding of concepts and the world around them. If there is key information that will help students to better understand a concept or could lead them to look at the topic of the activity in a different way—and students aren't likely to learn this information just by observing, discussing ideas with their peers, or engaging in a science practice—then you should find some way for students to get that information. Ideally, students can gather information through something like a field guide, book, or another evidence-based resource. It's important for students to learn how to gather information from different sources, and much more empowering for them if they gain and apply the information themselves. For the BEETLES activities *Case of the Disappearing Log* and *Bark Beetles*, we couldn't find any "student-friendly" resources that concisely showed information relevant to what we wanted students to figure out, so we created these resources ourselves (*Decomposing Log Key, Evidence Cards, Suspect Cards*). At times, of course, it's effective to just tell students some information, but we can't assume that students will remember or understand anything that they're told unless we have them apply it to figuring something out. Students should be engaged with nature and each other for the majority of an activity, and you should minimize when they're passively listening to an instructor.

Relying on educational games. Games are fun and can be energizing, but the learning that takes place during a game is often overestimated. Most students arrive at programs already knowing what *Camouflage* is, and probably won't be expanding their knowledge much through playing a *Camouflage* game. But a rousing game of *Camouflage* can get students who are uncomfortable outdoors enthusiastically flinging their bodies into bushes filled with spider webs, dirt, and other little critters. The right game at the right time can recharge a group that has become lethargic, or give an ansty group the opportunity to "blow off" their energy. Games can be used well in outdoor education (see sidebar below), but they are often overrelied on to teach concepts and to make learning "fun," to the exclusion of letting students actually engage with nature. Playing a game in nature is not the same as directly engaging with nature. For example, while the instructor may be thinking that their students are learning about predator-prey interactions during a game, the students are probably thinking, "I'm playing tag!"

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Some instructors use games when they underestimate students' abilities to engage with nature, to make observations, to talk, draw, or write about what they see (i.e. "they'll be bored if I don't keep them entertained, so I'd better do a game instead of having them observe"). When activities use tools and approaches that tap into students' natural inclinations towards curiosity, exploration, and trying to figure things out, you don't need gimmicks to keep them engaged.

Using Games Well

Some in the outdoor education world argue that if an activity can be done in a supermarket parking lot, then it's not taking full advantage of being outdoors in nature, so it shouldn't be used in outdoor science school. We agree that the bulk of student time in outdoor science instruction should be spent directly engaging with nature, exploring, and discussing those discoveries and ideas with others. But it's also true that sometimes students can use a break during which they use their bodies more than their brains. So games, adventure hiking, or just plain running around can be a great way to give students that kind of break.

A well-designed and well-led game can also give students a different perspective or lens on a process in nature that they can't directly observe, and can deepen students' understanding of something they've explored. Environmental education games tend to be metaphors for processes that take place in nature, but for a game to actually add to student understanding, students need to be primarily exploring and observing nature, and any game must have a thoughtful introduction and debrief before and after. Often, students are able to understand the concept within the context of the game, but are unable to apply it to the real world context. The debrief should guide students in applying the metaphor to the real world of nature. Games used for the goal of deepening student understanding of a concept should be used sparingly, and never to the exclusion of direct engagement with nature.

Playing a game right off the bat when you meet a group of students can be a great way to set a tone of fun and lightheartedness, and help deal with some of the awkwardness you can get when meeting a group for the first time.

Games can also be used for the worthy goal of having fun and giving your students a break from thinking, or to change up the energy of a group. Students get recess and breaks at school, and we encourage instructors (and program leaders) to give themselves permission to play a game just for the game's sake, without necessarily having an educational goal.

Chapter Summary:

- Activities that don't directly engage students with nature often come from activities that started with a concept, rather than starting with nature realia.
- Other common pitfalls in outdoor science activity design are trying to teach too much, too fast; including too many transitions; confusing memorization with learning; not giving enough opportunities for students to discover information themselves and overreliance on educational games.

Chapter 4. Using Tools and Frameworks to Support Activity Design

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There are key tools and frameworks we use when we create new activities that help us make sure we're sticking to our design principles. **Of all the tools and frameworks out there, we think the most useful for designing student-centered, nature-centered outdoor science activities are the Learning Cycle and the Next Generation Science Standards (NGSS).** The Learning Cycle is a model for structuring and sequencing activities that is based on research about how people learn best. The NGSS, and specifically the framework the standards were based on, offer sound approaches to empower students to think, explore, and make sense of their discoveries like scientists, as well as tools that help take student thinking deeper.

We strongly suggest that anyone you want involved in activity design gets to experience the BEETLES *Teaching & Learning* professional learning session in full. It's funny that the Learning Cycle, or The 5 E's as it's sometimes called, is almost everywhere in school districts around the country, and most teachers know about it, but it's often not reflected in instruction. How is it that so many have heard of it, but don't use it? Probably because they didn't learn about it experientially (as it's presented in *Teaching & Learning*), and because applying it to instruction can be a little tricky and is good to do in collaboration with others.

The Learning Cycle Instructional Model

The Learning Cycle should be the best friend of activity designers. It's a model for instruction designed to make sure learning experiences include what we know about how people learn. It can be thought of as a way to structure lessons that takes into account the way people naturally learn. Applying the Learning Cycle to instruction can be a little tricky, so it's helpful to have some support, such as from your activity design team. But it's so worth any struggle involved, because grappling with these ideas helps to develop skills in activity design, and will lead to creating more effective activities.

For more on the Learning Cycle, see the BEETLES PL Session *Teaching & Learning*, and it's handouts: The Learning Cycle Explained and Questions about the Learning Cycle. Also see "Appendix E. Learning Cycle Template for Activity Design" on page 75.

Shortcut to Designing a Nature Realia and Learning Cycle–Based Activity

The BEETLES Exploration Routine *Discovery Swap* is designed to be a flexible structure that makes creating a Learning Cycle-based activity easy. An instructor can choose anything in nature (stream macroinvertebrates, plants, leaves, bird feathers, or rock types) to be the focal point within the structure of the activity. The activity is a full Learning Cycle, and includes questions and strategies for engaging students in science practices, and introducing content throughout. That's why the simplest way we know of to design a new Learning Cycle–based activity is to insert the nature realia topic of your choice into the structure of Discovery Swap, add students, and voilà!

See http://beetlesproject.org/resources/for-field-instructors/discovery-swap-2/ to download this activity.

Using the Next Generation Science Standards (NGSS) and the Science Framework

We are thrilled that, in the era of NGSS, we now have documents and an educational movement in science that are based on evidence about what actually works and can be useful guides for improving teaching practices! The NGSS and the document they are based on, *A Framework for K-12 Science Education*, are not just something new that we have to do—they are thoughtful documents providing worthwhile guidance that can be extremely relevant for outdoor science. One of the basic ideas behind the NGSS is that students should be figuring things out for themselves. This is deep stuff! Although not all states in the U.S. have officially adopted NGSS, many states *have*

Want to know more about NGSS and its connections to environmental education? See our website: http://beetlesproject.org/resources/for-program-leaders/ngss/.

Not in a state or situation that uses the NGSS? Take a look at the Standards anyway. No matter what requirements you need to follow, using some aspects of the NGSS to design activities will lead to deeper and stickier learning for students.

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incorporated ideas from the framework and content from the Standards into their standards, even if they don't call it "NGSS."

Many previous versions of science standards were essentially lists of facts that students were supposed to "know." T**he NGSS go way beyond that, spelling out that students should be engaging in Science and Engineering Practices (what scientists and engineers do) and applying Crosscutting Concepts (thinking tools scientists use) in order to deepen their understanding of Disciplinary Core Ideas (science knowledge).** The NGSS and the *Framework* push educators toward using phenomena-based "three dimensional" instruction, which includes the Science and Engineering Practices, Crosscutting Concepts and Disciplinary Core Ideas all woven together into in-depth experiences that lead to a fuller and more relevant understanding of science. In other words, students are expected to be thinking and figuring things out for themselves—doing what scientists do—while also learning what science knows and applying this knowledge to real-world questions and problems. BEETLES has developed some key resources to help understand and apply each of the NGSS dimensions.

Science and Engineering Practices (SEPs)

See "Appendix D. NGSS: Applying Science Practices in Outdoor Science" on page 66

Science Practices are what scientists do. Science and engineering practices are where we think outdoor science educators should start with NGSS.

For more information, see Appendix F of the Next Generation Science Standards at nextgenscience.org/get-to-know/.

The vast availability of interesting stuff to investigate in the outdoors provides the opportunity for a thoughtful program to really rock the science practices by directly engaging students in many of these behaviors, particularly: **Asking Questions, Constructing Explanations, and Engaging in Argument from Evidence.** Any activity will probably involve more than one science practice, but it's not a good idea to try to cram them all into one activity. Focus on just a few of these practices in your program, and choose one in particular to focus on explicitly in a single activity.

Crosscutting Concepts (CCCs)

See "Appendix B. NGSS: Applying Crosscutting Concepts in Outdoor Science" on page 48

Crosscutting Concepts might look confusing at first. They're thinking tools that can be used across disciplines to look at any subject, to gain a different perspective, or to lead to different questions or ideas. The Crosscutting Concepts of **Patterns, Cause and Effect, and Structure and Function** are particularly rich for outdoor science.

For an more in-depth reading about the Crosscutting Concepts and how they can be developed over different grades, see the NGSS Appendix G, Crosscutting Concepts (nextgenscience.org/get-to-know).

Disciplinary Core Ideas (DCIs)

The **factual or conceptual content of science** can be found within the **Disciplinary Core Ideas** of the NGSS. DCIs are conceptual understandings that are important for students to know, and might be described as, "what science knows." There is so much conceptual and factual knowledge science has agreed upon that you just can't teach it all! In the past some efforts have been launched that have been criticized for trying to teach too much, leading to science instruction that has been described as "a mile wide and an inch deep." With so much to "cover," educators have sometimes been pressured to move quickly through material without students really understanding it. It has sometimes led to science instruction that is based more on memorization than on understanding. This has also been reflected in the ways assessment has been done, with memorizable tidbits that can easily be tested as the focus. One of the goals of NGSS has been to narrow it down to fewer, really important core ideas of science to focus on, and to spend significant time on them. These core ideas have been mapped out to build student understanding through the grades, paying attention to what is most developmentally appropriate for students to learn at each grade.

Some programs make the common mistake of only focusing on alignment with the DCIs. They may seem easier to connect to because they look more like the lists of facts that the more regressive standards have emphasized in the past. Use DCIs appropriately. As mentioned before, it's better not to teach these in isolation; rather, they should be *combined* and *intertwined* with Science Practices and Crosscutting Concepts in student-centered activities where students are figuring stuff out about the natural world.

NGSS Performance Expectations (PEs):

The PEs were intended as examples of the kinds of things students should be able to do—after engaging in multiple learning experiences or long-term instructional units—to show their understanding of important Disciplinary Core Ideas and Science Practices, as well as their ability to apply the Crosscutting Concepts. The NGSS performance expectations do not describe what instructors should be teaching. In other words, they are not meant to determine the curriculum. As examples of what students should be able to do after extended instruction on a topic, they are designed to provide guidance about how to assess students. If educators treat them like previous science standards and try to "teach to the standard," they will miss much of the important skills and understandings as described in the *Framework*. Any single activity can only provide foundational experiences to build toward this type of performance. It is definitely worth it for outdoor science educators to explore the PEs of the NGSS, because many of them include ideas related to environmental education goals. Table 1, on the following page, shows an example of how many experiences are needed to support a single PE.

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See "Appendix C. NGSS: Applying Disciplinary Core Ideas (DCIs) in Outdoor Science" on page 56

To begin incorporating or aligning with the DCIs, we suggest reading the NGSS, Appendix E, Disciplinary Core Idea Progressions (nextgenscience.org/get-to-know).

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Table 1. Experiences to Support a Single Performance Expectation

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

Experiences Needed:	NGSS Dimension:	Related BEETLES Activities:
Gathering evidence from observations and testing	**Science Practice:** Planning and carrying out investigations	*Exploratory Investigation*
Exploring the living and nonliving things in ecosystems, and how they are connected	**Science Practice:** Constructing explanations	*What Lives Here?, Decomposition Mission Discovery Swap*
Making models of ecosystems, mapping out connections between living and nonliving things	**Science Practice:** Developing and using models **Crosscutting Concept:** Systems and system models	*What Lives Here? Decomposition Mission*
Using models of ecosystems to predict what might happen to populations of organisms if some parts were to change	**Science Practice:** Developing and using models **Crosscutting Concept:** Systems and system models **Disciplinary Core Idea: LS2.C: Ecosystem Dynamics, Functioning, and Resilience** *Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.*	*What Lives Here?*
Guiding students to understand how to make explanations from evidence, how to discuss ideas scientifically, and how to use these to construct scientific arguments	**Science practices**: Constructing explanations Engaging in argument from evidence	*NSI: Nature Scene Investigators Case of the Disappearing Log Bark Beetle Investigations Discovery Swap*

You can further develop your team's understanding of the NGSS by suggesting they read selected chapters from *A Framework for K-12 Science Education*. (All documents related to the NGSS are downloadable for free online). Particularly helpful are *Chapter 2: Guiding Assumptions and Organization of the Framework, Chapter 3: Dimension 1: Science and Engineering Practices,* and *Chapter 4: Dimension 2: Crosscutting Concepts.* Because the *Framework* is the document the NGSS were based on, it is much more detailed in describing the rationale for the teaching approaches and conceptual understanding the Standards are advocating for. And it's a pretty clearly written and engaging text for instructors to read, as opposed to leafing through the Standards charts.

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See free PDF download of the *Framework* at http://www.nap.edu/catalog.php?record_id=13165

Designing *Lichen Exploration*: An Activity Development Example, Part 2

Applying the Learning Cycle and Other Lenses to the *Lichen Exploration* Activity

(continued from Designing Lichen Exploration*: An Activity Development Example, Part 1, page 12)*

Given what we'd figured out in our own observations of lichen, and what we'd learned through our research, we outlined a plan for the activity using phases of the Learning Cycle to take students through an experience of exploring lichen and learning a little about it. Here's what we mapped out:

- **Invitation.** Students discuss questions: "Have you ever seen anything like this before?" "What does it remind you of?" "Is it a plant, fungi, or something else?" "How does it get the matter and energy it needs to live?" After a lot of debate within our team, we decided to not introduce the term "lichen" till after students had become more curious about it, but figured that if a student brought up the term, we'd introduce it right then.
- **Exploration.** Pairs explore lichen in an area, using hand lenses and noticing different kinds. Instructor co-explores with students, asking them questions about what they see, prompting them to take their comparisons between different lichen groups deeper, and supporting any students who have become disengaged.

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- **Concept Invention.** Students gather after exploring and we ask them what they discovered. This is when we decided to introduce the term, "lichen," by saying it and writing it on a whiteboard, and then using it a lot during the rest of the activity. This is also where we decided to introduce the idea of lichen and fungi being in a symbiotic relationship. Introducing all three kinds of symbiotic relationships seemed confusing for students just learning about lichen, so we decided to just call it "symbiotic," and included a note to instructors with more information they could use with advanced groups. Then we planned to introduce students to the identification key, and later to the concept of lichen succession.
- **Application.** We challenge them to use the key to identify different types of lichen and to look for examples of lichen succession. Afterwards, we gather them to discuss what they've found.
- **Reflection.** To help students reflect on their learning, we have them *Walk & Talk* using the following prompts: What are you still curious about? What do you wonder about lichen? What did you do today that helped you learn about lichens? Describe to your partner how you might tell a younger brother or sister what you learned about lichen..

Making Connections to NGSS

As we designed the activity with the Learning Cycle, we looked for opportunities for students to engage in science practices to develop understanding about lichen. We thought it was a good opportunity for students to engage in the Scientific Practice of Constructing Explanations as they tried to use evidence to figure out if lichen is a plant, a fungus, or whatever. We also thought we might ask students to work to explain where lichen grows and why, which would also be making use of the Crosscutting Concept of Patterns. We decided that the activity would support some understanding of the DCI LS2.A Interdependent Relationships in Ecosystems, which focuses on how organisms can only live where they can get their needs met, and we decided to add in more opportunities for students to think about what affects where lichen lives.

Using Other Lenses to Review the Activity

We went through to make sure we were including enough opportunities for students to explore and to discuss ideas in small and large groups. We also made sure that there was an opportunity at the beginning for students to access their prior knowledge, and opportunities for students to make their thinking visible to the instructor.

(continued on page 32: Designing Lichen Exploration*: An Activity Development Example, Part 3, Piloting, Testing, Revising, and Writing Up the Activity:* Lichen Exploration*)*

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Chapter Summary:

- Frameworks and tools are helpful (if not essential) to successful activity design.
- The Learning Cycle is the most useful model for figuring out how to sequence and structure a learning experience to mirror how people learn naturally.
- The Next Generation Science Standards strive for deep, comprehensive student experiences through three dimensional learning: students should be engaging in practices of science and applying crosscutting concepts as they deepen their understanding of disciplinary core ideas. Students should be doing a lot of figuring things out themselves.
- There are many resources in this Guide that can help your instructors develop their understanding of the Learning Cycle and the NGSS before the activity design process, as well as some resources that will help them figure out how to apply these models as they are designing activities.

Chapter 5. Planning Ahead and Setting Up for Success

Before starting the process of designing activities for a program, there are two main areas of planning you need to do:

1. Choosing and preparing a team to take on the activity design, and building their expertise to get them ready.
2. Making a plan for how the new activity will be tested, revised, and written up.

Choosing & Preparing the Team

We've said it already but we'll say it again: You should have a team (not an individual) to design activities for your program. The team should include your most experienced instructors and others who know a lot about:

- Student-centered pedagogy
- Nature-centered instruction
- Natural history and science
- Equity, inclusion, and culturally responsive teaching
- Your program goals and constraints

But a group of competent folks doesn't guarantee a great team. Your team will also need to work well together and be willing to seek out different perspectives. There are many different flavors of successful working groups, but there are some key ingredients to pay attention to. Google recently did research on what makes effective teams. What they came up with might seem obvious to some, but it's worth thinking about:

- Participants get about the same amount of time to speak.
- Participants pay attention to and are sensitive to the feelings and needs of others in the group.

These help establish what psychologists call "psychological safety," which is when team members feel that the team is safe enough for interpersonal risk-taking. When they feel there is psychological safety, team members feel accepted and respected, comfortable being themselves, and that they can share ideas without fear of ridicule or other negative consequences.

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Culturally responsive teaching involves setting up a learner-centered environment in which each student's unique cultural background and strengths are valued, recognized as a kind of expertise, and are taken into account as an instructor creates learning experiences. It seeks to increase student achievement and feeling of well-being about their cultural place in the learning context, and the world.
Want a great book to help staff become more culturally responsive instructors? Check out Zarretta Hammond's book *Culturally Responsive Teaching and the Brain.*

For more information about safety in expressing ideas, see: https://www.nytimes.com/2016/02/28/magazine/what-google-learned-from-its-quest-to-build-the-perfect-team.html?_r=0

For further reading about how work environments influence psychological conditions, see Kahn (1990) in the References list.

Building a Productive Learning Culture

Encouraging a learning culture within your program can help lay the foundation for safety in sharing ideas, if it includes:

- Trying out new things during instruction.
- Having permission to fail.
- Engaging in ongoing discussion about different approaches to instructional situations.

One way to establish this culture is to have group members share, early on in the teaching season, what they see as their strengths and how they prefer to work in teams and receive feedback. Other factors that help groups work well are:

- Having agreed upon norms for how to act in community.
- Clear channels for giving and receiving feedback.
- Transparent policies on how decisions are made.
- Distinct roles within the organization.
- Clear expectations about what each person is to achieve, and by when.

Norms like "work toward a deeper understanding," "disagree with the idea, not the person," or "step up, step back" make the key aspects of creating a culture of collaboration more visible, empowering your activity design team to intentionally develop an environment of healthy collaboration in which every voice is heard. If you don't take the time to set up norms and discuss how to make a positive collaborative process up front, the process could be sidetracked by whoever is most vocal during discussions.

An important aspect of collaborative/iterative curriculum design is not getting too attached to an idea. Decisions should be based on how well an activity does with students, not how awesome the idea seems in theory. Another critical step is getting feedback from others outside of the core development team when needed—when there's disagreement about the best approach, an outside voice can help to bring in some new perspective and settle any disagreements. Finally, giving clear expectations on the work that needs to be done, the timeframe, and decision-making process can help provide clarity and encourage efficiency among members of your team.

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For more on building this kind of culture with staff, see the Building a Culture of Reflection section of the *Guide for Program Leaders*. Also check out research on learning culture, reflective practice, and professional learning communities in the References list.

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Activity Design as Professional Learning

Activity design can be a great learning experience for individual instructors, and we think every instructor should try their hand at it at some point. Many programs give their instructors the opportunity to design one or more activities they use with students as a form of professional learning. This can be great for instructors because it supports their autonomy and gives them the valuable learning opportunity that comes from designing their own materials.

To best support novice instructors' professional development, they should start by teaching tried and true activities that have already been carefully planned, tested, and written up. As they try to teach these activities as closely as they can to how they are written, they can get a feel for well-designed instruction and effective teaching strategies. Once they have experienced success with these activities, they'll be ready for some professional learning on pedagogy: the art and science of instruction. They can apply what they learn by dissecting and discussing one of the well-designed activities they've learned, using the design principles to think through what makes the activity strong, before trying to create their own activities. It can be a great learning assignment for novice instructors to work (ideally with a partner) on designing one or two activities for their own use, as long as they are given lots of back and forth with someone more experienced to guide them. When using activity design as part of professional learning, it's important to stress that the guided process of trying out teaching ideas, reflecting on instruction, and revising activities is more important than the end product.

In some programs, instructors are in charge of designing all the student experiences they lead. In others, the program is pretty much set, and instructors are expected to teach established lessons. Most programs are somewhere in between those two extremes. Some instructors think it's fun to get creative and design a student activity from scratch. For others, not so much. Activity/curriculum design is a different (but very related) skill set from teaching, and some instructors will be better at it than others. While an individual instructor might create an activity that works well for them, they are unlikely to design an activity that is effective with all instructors unless it's developed by a team of experienced instructors who have a deep understanding of pedagogy and best practices. If every instructor designs their own learning experiences, students may experience a huge range in the effectiveness and quality of the instruction. Solid activities that work for more than one instructor—which is the focus of this guide—take a lot of thoughtful development, bouncing ideas around, testing, thinking about the activity through different lenses, rewriting, and retesting –this takes time and effort!

Using BEETLES Professional Learning Sessions to Build Staff Expertise and Competence

The more time you take building your staff's expertise and understanding of outdoor science education pedagogy, and the more thoughtfully you approach each topic, the more effective your design team will be. BEETLES resources can be used very effectively to help staff share a common understanding of best practices in teaching and learning. An effective entry point can be to have members of the team lead BEETLES *Focused Explorations* and *Exploration Routines* to get a feel for student and nature-centered teaching. Experiencing activities based on these design principles will help staff think about the strategies, sequencing, questions, and other aspects of those activities they can use in activities they design themselves.

Each BEETLES Professional Learning (PL) session helps build a different aspect of staff teaching and activity design capacities. We strongly recommend using the BEETLES PL Sessions *Teaching & Learning* and *Constructing Understanding* with your entire activity design team, both of which are focused on how people learn. The experiences and information shared in *Teaching & Learning* is pretty much imperative for activity designers. A sequence including all BEETLES PL sessions would be ideal to prepare your team, but most programs don't have time for that and need to pick and choose a bit. Meet with your leadership team to discuss strengths and weaknesses of your current education staff in order to decide which other sessions would be most valuable. Once you have a sense of what they need to be prepared and engage in the design process, then you can plan when to tackle the activity design effort. See the *Guide for Program Leaders* Chapter 1: Creating a Professional Learning System for more on sequencing PL sessions. Table 2 shows important perspectives for activity developers, as well as the BEETLES professional learning sessions that address them.

NOTES

About *Guide for Program Leaders.* Be thoughtful and forward thinking in your use of BEETLES Professional Learning Sessions. It's less helpful to your staff to use PL sessions sporadically, or to shortcut them, than to present them fully and strategically, and offering time for instructors to apply what they learned in the session to their own instruction afterwards. The BEETLES *Guide for Program Leaders* has much more information for program leaders interested in designing an approach to professional learning..

What are Focused Explorations? They are BEETLES activities that were designed to focus on one kind of nature realia, and they model the types of approaches and strategies that are most successful and backed by research in activity design. Specifically, they are the activities: *Lichen Exploration, Spider Exploration, Bark Beetle Exploration,* and *Case of the Disappearing Log.* The members of your activity design team should lead these activities a few times before the process begins; doing so will help them become better at designing activities based on nature realia.

These resources can be found on the Resources for Program Leaders section of the BEETLES website: http://beetlesproject.org/resources/for-program-leaders/

NOTES

Table 2. Goals and resources for activity developers

Goals for Building Staff Activity Design Capacities	Professional Learning Sessions	Related Instructor Resources
Using the Learning Cycle as an instructional design model	*Teaching & Learning*	Learning Cycle Template Applying the Learning Cycle Lens to Outdoor Instruction The Learning Cycle Explained
Understanding meaning making in science	*Constructing Understanding*	What Research Tells Us about How People Learn
Understanding how to phrase effective questions, and the effects of different types of questions on students	*Questioning Strategies*	BFF Questions Questions and the Learning Cycle Broad Questions/Narrow Questions Research on Instructor Questions
Awareness of different roles for instructors, and how those roles affect instruction	*Questioning Strategies*	Goals and Prompts for Encouraging Exploration
Learning about effective ways of engaging students with nature	*Evidence & Explanations* *Making Observations*	Ecosystem Literacies and Exploration Guides
Understanding science as a discipline, and how to teach students a scientific mindset	*Evidence & Explanations* *Nature & Practices of Science*	Teaching Science Practices Outside Evidence and Explanations in Science
Appreciating the value of discussions in learning, and how instructors can effectively implement productive discussions in science	*Promoting Discussion*	Discussion Strategy Videos Encouraging Student Discussion and Productive Talk
Using student journals to increase the effectiveness of instruction	*Field Journaling with Students*	Model Field Journal
Learning how assessment can be incorporated into instruction to increase effectiveness	*Assessing for Learning*	Assessing for Learning Should Be Indistinguishable from Good Teaching
Understanding important content related to adaptations and evolution	*Adaptation & Evolution*	Adaptations Theme Hike
Understanding important content related to matter and energy in ecosystems	*Matter & Energy in Ecosystems*	Ecosystems, Matter, and Energy Theme Hike

Preparing All Staff to Teach Designed Activities

Whether you're doing a major revision to your curriculum or just introducing some additional activities, you'll want to make sure all your instructors are prepared to use the new materials. The way you introduce programmatic changes can significantly affect whether your staff (and clients) will maintain an open attitude or be resistant to new activities and approaches. For guidance on this topic, see the section on Building a Culture of Reflection in the *Guide for Program Leaders*. Also see How We Adapted Existing Activities, page 34 of this guide.

To develop the teaching skills needed to implement new activities, have instructors try out different BEETLES student activities, emphasizing that they should teach them as they are written. Make sure to provide opportunities for staff to reflect on the teaching strategies they used and think about their effects on students. Instructors should pay attention to the structure of the activities, the types of questions asked, and especially, what the students are doing and learning. There should be ongoing opportunities for staff discussion of these important teaching topics, as well as time to express their successes and challenges encountered when using new approaches.

Once your newly designed activities are ready to teach with students, plan how you'll roll them out. When and where will they be taught? What logistical supports might be needed for new activities, such as equipment or adjusting the timing of programming? How will you get your staff excited about teaching them, and help to fold them into your program? Who will train instructors on leading new activities, and when will they do this? How will you introduce new activities to your clients, and generate excitement, instead of resistance, to changes in your program?

Creating a Systematic Process for Testing, Revision and Documentation

Testing out new activities with students is critical for lots of reasons. Leading an activity and revising it a couple of times can tell you a lot: What seems like absolute genius on paper often doesn't work out that way when you try it. There are also lots of ideas and ways of saying things that tend to come out when you're teaching that you probably wouldn't think of while sitting and writing at your computer. Some of those in-the-moment ideas and ways of saying things, can end up being vast improvements over your original plan. If you can get several instructors involved in testing out activities, you're more likely to end up with an activity that can be led successfully by different kinds of instructors and with a wide range of students. It's easy for an individual activity designer to create an activity that works for them as a teacher, but other instructors with different approaches might not feel comfortable teaching it as written.

It makes sense, before you're in the midst of an activity-design process, to plan how you will test, get feedback on, and revise the activity, and how to repeat the process till you end up with the best possible product (see "Chapter 7. A Flexible Step-by-Step Process for Developing Student Activities" on page 37 *Step 6: Write and test draft for a step-by-step process*).

NOTES

We refer to these kinds of conversations and the culture they inspire as a "learning culture." Read more in the *Guide for Program Leaders* on the BEETLES website.

NOTES

Designing *Lichen Exploration*: An Activity Development Example, Part 3

Piloting, Testing, Revising, and Writing Up the Activity: Lichen Exploration

(continued from Designing Lichen Exploration*: An Activity Development Example, Part 2, page page 23)*

After making a rough write-up, we piloted the *Lichen* activity on a hike with students, and it went well.

We had the following takeaways from the pilot:

- Students loved the keys, but we realized that some of them were looking for lichens that exactly matched the picture on the key, and especially had trouble identifying "leafy" lichen. So we added a statement to the introduction of the keys about how "leafy" lichen might not look exactly like a leaf, or exactly like the photo, but is just generally *kind* of "leafy."
- It didn't go very well to introduce lichen succession right after introducing the key, and to have students use the key and look for succession at the same time. It seemed like too much at once. So we decided next time to introduce the key, and then have students go out and use it to identify types of lichen. We decided we'd gather them again, debrief the types they had identified, and *then* introduce the idea of lichen succession send students out to look for evidence of lichen succession. This added another concept invention and application phase to the structure of the activity.
- After the activity, students started pointing out lichen growing on a gate, in trees, and even along the edges of a road. They tried to figure out if more lichen grew on dead trees and branches than on living, and found evidence to support that idea. Because lichen is photosynthetic, they thought it wouldn't live in dark places, so they looked for it in those places, and the evidence they found supported that explanation. The application after the activity was so rich, we decided to add another Application phase at the end of the Learning Cycle that involved students looking for patterns of where lichen grows and doesn't grow, and making explanations for the patterns they observed. So now the Learning Cycle for the activity became: Invitation-Exploration-Concept Invention-Application-Concept Invention-Application-Reflection-Application.

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We made these revisions to the activity, made a very thorough write-up of it, including teaching notes, some introductory points about finding the right setting, and necessary materials, and specific wording of key questions, phrases, and instructions. Then we field tested it with other program instructors.

During the field test, we also realized that we hadn't made use of the Crosscutting Concept of Patterns as explicitly or intentionally as it could be, so we looked at the activity through that lens. This focus inspired us to add steps to the activity that would highlight for students when they were using patterns as a thinking tool. We explicitly introduced the idea of patterns just before they went out using the keys, and challenged them to pay attention to any patterns related to where and on what surfaces lichen grows.

Since we had significantly changed the activity since our initial pilot, we decided to teach the revised activity ourselves, one last time with a different group of students. This group was behaviorally more challenging than the first, but it still worked, which was a good sign. The changes seemed to have improved the activity, but we wanted to again make sure it worked for more people than just us. So we did a final field test to make sure the revised version of the activity worked for other instructors as well. After about 10 instructors from different programs across the country tested *Lichen Exploration* with no problems, we polished the write-up more, added an instructor support section that included more science background and more connections to NGSS, and published it.

And then we rested (ha!).

Chapter Summary:

Plan the logistics for your activity-design process ahead of time:

- Choose and build the expertise of a team in student-centered instruction, nature-centered instruction, culturally responsive teaching, NGSS, and your program by using *Teaching & Learning* and other BEETLES PL sessions to help prepare them,
- Establish a learning culture among staff, using norms and other strategies, to create a safe environment for doing the hard work of designing curriculum together.
- Make sure your program will be ready to implement the new/revised activities, including updating messaging to clients and making sure your other staff are open and ready to teach new activities.
- Plan your system for testing and revising activities, making sure there will be time for a few rounds of testing, revision, and writing up the activity.

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Jill and Becca's story has been documented more thoroughly on our website. See http://beetlesproject.org/ymca-camp-seymour/ for a more complete account, including a side-by-side comparison of one activity before and after revision.

Chapter 6. Revising Existing Activities

Some well-established programs with extensive offerings may decide to adapt existing teaching materials instead of creating new ones from scratch. Much of the information in this document can be used to guide that process. For instance, the revision process should also involve a team of experienced people, and it's still important to center your activities around something intriguing in nature that is present at your site (and possibly, tossing out an activity if it doesn't fit that). You can begin by having a few of your most experienced and knowledgeable instructors read through the existing teaching materials, while using the Design Principles, Learning Cycle Model, NGSS guidelines, and other criteria to inform the types of changes you might want to make. An important goal could be to create more student/nature-centered experiences and to ensure that activities take advantage of the strengths of teaching outdoor science at your site. Once potential changes and improvements are identified by your experienced staff, then the activity revision process can be shared by teams of instructors, guided by the recommendations derived from this closer look at the activities. A direct example of this kind of process is described in the box below.

How We Adapted Existing Activities

by Jill Begin, Assistant Director, and Becca Gjertson, Director at Outdoor Environmental Education Camp Seymour, Gig Harbor, Washington

Jill and Becca were excited about implementing BEETLES, but were in a quandary. They had a set program for their instructors to use with students. If they started off their new season with BEETLES Professional Learning Sessions, they were worried that their instructors would get excited about teaching in new ways, but could be frustrated by having to teach the existing activities that didn't reflect these new approaches. They also thought that their instructors would be better able to help improve the activities after experiencing some of the Professional Learning Sessions. What to do? Chicken or egg?

At the last minute, they decided to restrain their eagerness to get started, and hold off on the professional learning at the start of the season. Meanwhile, Jill made time to teach BEETLES activities with students to get some first-hand experience. She then chose a few of their student activities, and wrote out her general recommendations for how each one should be improved. During their next big training, they did launch a few BEETLES Professional Learning Sessions with their staff, and got the staff revved up about teaching. Then they divided into teams, each in charge of updating an activity while working off of Jill's notes. The small groups wrote their revisions over 1 to 2 days, while consulting with Jill. They made sure every activity began with making observations and exploration, and marketed this to their teachers as a selling point. They took out the 20-minutes of talking about the topic that had been at the beginning of each activity. They shifted the lessons to be about building understanding of a few select things and having students use this understanding to evaluate a claim.

Then they piloted the new lessons and revised them based on feedback. They chose who they thought would be the best person to pilot the activity, and had them keep teaching it many times, before training another staff person on it. As each staff member had a chance to test a new lesson, they would come back very excited after the experience, and this inspired the rest of the staff to become enthusiastic about teaching it. "I just taught the best class of my life," was what one leader said he heard from one of their instructors. They followed this process to slowly work their way through revisions, activity-by-activity, as they revamped their program.

Jill and Becca's approach at Camp Seymour to revising their instructional materials is insightful. They were strategic about making changes, not impulsive. It was a long-term approach that took into account the needs of instructors. Whatever the conditions in your program, a careful, gradual approach is more likely to succeed than a rushed one. They didn't put the revision fully in the hands of all instructors, but included them meaningfully in the revision process with a lot of structure and guidance. Senior staff taught some BEETLES activities first to get the feel of nature-centered, student-centered instruction, then made overall suggestions for revisions to Camp Seymour activities that were next implemented by less experienced staff. They also made sure staff who were responsible for changes to their activities had some professional learning experiences around best practices in teaching. The method the leaders used included testing ideas and activities, modifying their professional learning, and communicating with their clients about their process.

They took the time to make sure they built instructor buy-in to making changes. There was very little resistance to adopting the new materials in this case, because the staff was involved in the revision process, was trusted to be a part of an exciting shift in teaching for the program, and had ownership over the way the lessons turned out. They got buy-in from teachers, as well, by communicating about the kinds of changes they were making, and framing this as an asset. And it sure didn't hurt that they all agreed the revised activities ended up being more successful and engaging with students.

Marketing Your Program's New Activities

Outdoor science instruction is an important and critical supplement to classroom science experiences, especially with the rise and adoption of the Next Generation Science Standards. By being well-informed about the NGSS you can convince your clients—classroom teachers who bring their classes to your program—that what you have to offer is what they want! For instance, you might try explaining that your program focuses on helping students engage in science practices and applying big ideas of science as they learn, that it focuses on teaching students "stuff they can't google," or sparks students' passion for science through an authentic experience at your program.

Because classroom science instruction is typically very limited, a 3-hour field trip can be approximately equivalent to one month of classroom science instruction. But that doesn't mean outdoor science instruction can take on everything in the science standards. If you spend some time thinking about the parts of the NGSS that your program can do better than what can be taught in a classroom setting, then you can emphasize these things with teachers. It's also good to be realistic and take care not to oversell your program by stating that your program will address everything they need to teach in science. In just a few hours outside, students can develop some understanding of a concept, but are unlikely to comprehend a big idea in science or fully engage in all the practices of science.

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Sometimes classroom teachers who have brought their classes to a program in previous years react negatively to changes in activities, saying things like "Where's the photosynthesis activity? Why isn't the instructor telling the students facts they should learn?" It can be helpful to guide teachers to notice how your program and activities have been enriched so they aren't just focused on missing what used to be there. If you make a "look for" sheet that directs their attention towards teaching techniques that define NGSS and that support your program's student learning goals, you're more likely to have happy customers. These sheets can include prompts with space for the teacher to record their observations during your program's lesson. The prompts can be general (e.g., "When did students make explanations from evidence?" "When were connections made between what they were doing and what scientists do?") or specific to the activity (e.g., "Look for moments when students noticed and described patterns in nature"; "Look for when students made possible explanations for causes of patterns." "When were the students practicing skills of respectful discussions, such as listening to each other, using appropriate language of uncertainty, using respectful language with each other, building on each others' ideas, citing evidence, and citing sources?" "How did students use their observations of spider webs to develop understanding of how spiders survive in their habitat?").

NOTES

Even if your state has not adopted the Next Generation Science Standards, the Framework for K-12 Science Education (from which the NGSS standards were derived) represents the current best thinking in science education.

Marketing Your Program's New Activities

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Sometimes there's an expectation from teachers, schools, or districts that you'll teach full comprehension of a concept, so they can "check off" the standard. Temper this by framing clearly what you do expect to accomplish, such as changing the objectives of activities from notions like "Students will learn the definition of adaptation" to "Students will practice looking for patterns among organisms and make explanations about their structures and how they might function." Use the Next Generation Science Standards and other recent publications in science education to support the idea that meeting the standards (and science in general) is about much more than just memorizing facts, and clearly state the value of your program.

Chapter Summary:

- When revising existing program activities, you need thoughtful planning, a strategy, patience, and staff buy-in.
- Using the BEETLES tools for designing activities as a lens to evaluate existing lessons can inform improvements.
- Whether you're revising existing activities or creating new ones, take note of Camp Seymour's approach to restructuring programmatic activities.

NOTES

Chapter 7. A Flexible Step-by-Step Process for Developing Student Activities

OK! You did it! You've read about the unique qualities of outdoor science, design principles and frameworks, and how to set yourself up for a successful activity design process by developing a team and a long-term logistical plan.

Once you're ready to design activities, what follows is a possible workflow beginning with choosing the nature realia to focus on, and finishing with a writeup of a revised activity so it can be consistently used in your program. Although this is presented in a step-by-step format, activity design tends to be a lot messier than that, with some back and forth between the steps. You can use this general flow as a guide, but be ready to be flexible and repeat steps when necessary.

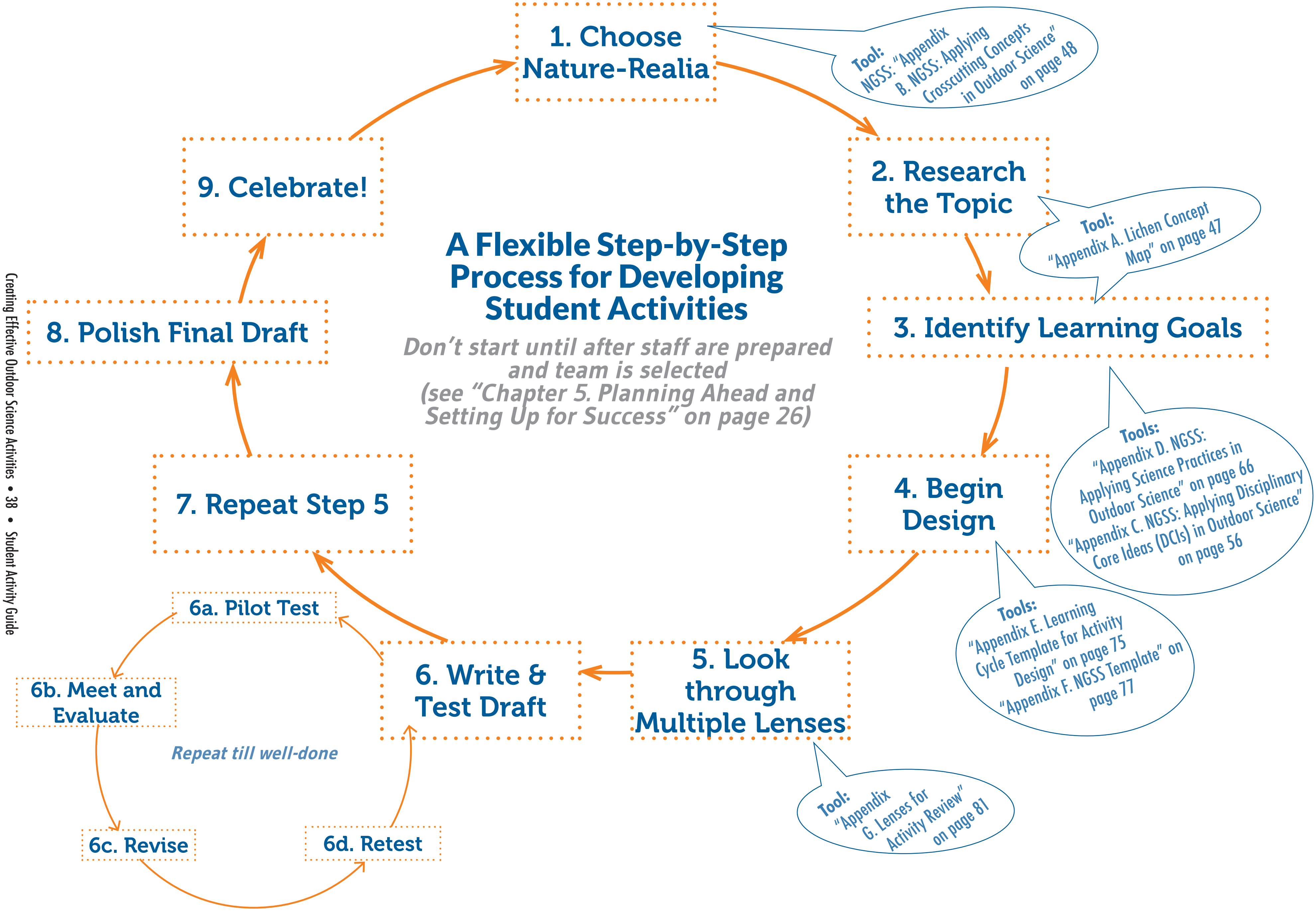
There are six planning tools to be used during this process that are included in the Appendices. You also need a central document to write down notes. Two of these planning tools are templates, with space to write down notes about the activity. Use these for guidance, whether or not you choose to use them for recording.

Print these out to use at different stages, as shown on the diagram on page 38:

- **"Appendix B. NGSS: Applying Crosscutting Concepts in Outdoor Science"** on page 48. *Suggestions on how to effectively use NGSS Crosscutting Concepts in outdoor science.*
- **"Appendix C. NGSS: Applying Disciplinary Core Ideas (DCIs) in Outdoor Science"** on page 56. *Suggestions on how to effectively use Disciplinary Core Ideas in outdoor science.*
- **"Appendix D. NGSS: Applying Science Practices in Outdoor Science"** on page 66. *Suggestions on how to effectively use NGSS Science Practices in outdoor science.*
- **"Appendix E. Learning Cycle Template for Activity Design"** on page 75. *A place to begin writing out steps to an activity, broken down into phases of the Learning Cycle, to help make sure each is included.*
- **"Appendix F. NGSS Template"** on page 77. *Questions about NGSS Science Practices, Crosscutting Concepts and Disciplinary Core Ideas. A place to help make sure you are thoughtfully addressing each. Includes space to write how you will address each.*
- **"Appendix G. Lenses for Activity Review"** on page 81. *A sheet to use as you check to make sure your activity is addressing each of the following: Student and Nature-centered Design, Supporting English Language Learners, Equity and Inclusion, Assessment, and Accuracy of Science Content.*

A Flexible Step-by-Step Process for Developing Student Activities

Don't start until after staff are prepared and team is selected (see "Chapter 5. Planning Ahead and Setting Up for Success" on page 26)



A Flexible Step-by-Step Process

Step 1: Choose Nature Realia. Remember, it's stuff that's *intriguing, plentiful, easily observable, and present enough for students to investigate.*

NOTES

Print planning tool.
"Appendix B. NGSS: Applying Crosscutting Concepts in Outdoor Science" on page 48

Explore your site for nature realia to be the focus of your activity. To find nature realia, we recommend that your activity design team (or your whole staff) poke around your site, including getting on hands and knees, seeing what's there and what's interesting. When you find something intriguing, make observations, ask questions, see what you can learn about it, and think about the kinds of observations and questions students might come up with.

As you're exploring, also:

A. Try using different Crosscutting Concepts to shift perspectives and see where they take you, such as:

- **Patterns.** Are there patterns to where it's found and where it isn't? Patterns in behavior?
- **Cause and Effect.** Try explaining what you see. What may have caused what you're seeing?
- **Structure and Function.** What purpose might an organism's structures serve to help it survive?

B. Think about whether this aspect of nature will be present and plentiful enough at different times in your program's season to be worth designing an activity around it.

C. Write your observations in a format you'll be able to keep adding ideas to. We suggest using a concept map (see "Appendix A. Lichen Concept Map" on page 47 as an example,) to show your observations, questions, thoughts, and what you find out during the next steps of the process.

During any part of this process, you might choose to "abandon ship" if you realize the part of nature you're looking at might not work for students (i.e., isn't around in large enough number at all times the lesson would need to be taught, isn't actually that interesting to kids, etc.), Finding the "right" nature realia to center your activity is important; it helps a lot when students are excited to explore!

Play around with observing a few different parts of nature (environmental features and organisms) until you find something that seems like it's interesting enough to engage students, and plentiful enough that students can easily find it.

Step 2: Research the Topic. Go a little deeper in your observations to help you better define the focus of the activity, and to help you come up with learning outcomes.

The goal of this step is to do more focused observations once you have found a part of nature that you think will work (i.e., is plentiful, observable, and interesting). Some of this deeper observation should happen in the field (using field guides and staff members of sources of information), but the research could take place in an office if you'd like to use online resources.

A. Use Crosscutting Concept(s) again and add observations and thoughts you have to your concept map.

B. Do research using other sources (e.g., ideas from staff members who are knowledgeable about the part of nature you're focused on, field guides, or online resources) to see what else you can find out about this aspect of nature.

C. Add any interesting information from your research to your concept map, and make note of which ideas students could observe directly, investigate further, or use to deepen their relationship with nature. You may learn some really cool concepts related to what you're observing, but find that they're just not accessible or relevant for students. It's best to focus on a concept that's intriguing and that students can observe or gather evidence to explain. In the design process of *Lichen Exploration* we found the concept of lichen succession is intriguing and observable, so we put it in the lesson. There were many other interesting, but less observable concepts that were left out.

Step 3: Identify Learning Goals. Use what you observed and what you found out in your research to pick learning goals that will focus the first draft of the activity (knowing that these may change).

A. Revisit your concept map. See what kinds of observations, information, and questions you've written down, and mark any you think students could observe, investigate, or figure out through discussion with peers.

B. Check out the grade level Disciplinary Core Ideas to see if there are any broader science concepts connected to what students could observe and learn when engaging in the nature realia you chose. If you're designing an activity to be used with more than one grade level, look at DCIs for all of them. The goal is not necessarily to find a perfect DCI match for each grade level—since there is value in a 5th grader having a quality outdoor experience with a concept that's addressed in 4th grade, and/or getting an early experience with a middle school concept—as long as these concepts are developmentally appropriate.

C. Choose one (or two) concepts you think students could figure out through discussion, observations, and using some simple source of information. If you have to choose between different directions for learning, think about what might lead to understanding of their surroundings as a whole, or whether it might fit in well with other parts of your program. Decide which direction seems better when combined with an NGSS Science Practice or a Crosscutting Concept that works well.

D. Research common misconceptions about the concepts and/or parts of nature you're investigating in the activity. Look into websites that list and describe common misconceptions for different ages. Brainstorm ideas for what students might observe in nature, or what they might discuss with an instructor or peer, to help them move toward a more accurate understanding.

Step 4: Begin Design. Begin designing the activity, using the Learning Cycle and the Next Generation Science Standards (NGSS) to guide you.

A. Use the Learning Cycle Template for Activity Design (page 75) as your team starts designing the activity together. Discuss each phase, what the students and instructor will be doing, and how that matches the Learning Cycle phase and supports learning goals. First write your ideas for each phase in draft form, then expand to include more details.

B. Use the NGSS documents (See Appendices). For "three-dimensional instruction," decide how students will engage in science practices and apply Crosscutting Concepts to develop understanding of disciplinary core ideas (or other concepts) and reach learning

NOTES

Print planning tool:
"Appendix C. NGSS: Applying Disciplinary Core Ideas (DCIs) in Outdoor Science" on page 56

Check out examples of learning goals in each of the BEETLES student activities.

In our design process, we've often found that the things we were already having students focus on were fairly easy to relate to a Disciplinary Core Idea (or two). We've also often found that once we figured out the DCI, this would further guide the direction of our activity and the kinds of information we'd work into the activity for students to think about.

As you do research during this phase, keep in mind the quality of the sources of information. There are many examples of misconceptions being passed around by field instructors for years. You want to make sure your information is accurate so you don't end up launching another misconception into the field.

Print planning tools:
"Appendix D. NGSS: Applying Science Practices in Outdoor Science" on page 66.
"Appendix E. Learning Cycle Template for Activity Design" on page 75
"Appendix F. NGSS Template" on page 77

For more on Crosscutting Concepts (CCCs), see the CrossCutSymbols website at http://crosscutsymbols.weebly.com/ for questions related to each CCC.

outcomes. Use the NGSS Template to check and write out how you are including each dimension.

C. Check to see that you have each of the Learning Cycle phases in your activity: Invitation, Exploration, Concept Invention, Application, and Reflection. But don't be too rigid with the 5 steps. Parts of the phases tend to bleed into each other somewhat. If there's a lot of rich content in the activity, you might want to repeat some of the phases during the activity. For example, a common successful application of the Learning Cycle is Invitation, Exploration, Concept Invention, Application, Concept Invention, Application, Reflection.

D. As you sequence the phases of the activity, make sure each phase of the Learning Cycle supports your learning goals. Use Science Practices as the driving force for how students develop their understanding of learning goals, and apply Crosscutting Concepts to deepen their thinking and to help them connect their learning to other contexts.

Step 5: Look Through Multiple Lenses. After the basics of the activity are laid out, look at it through different lenses included on the Lenses for Activity Review tool, then make changes and add notes accordingly.

It's hard to keep everything in mind when designing an activity, so it's good to take time to look at it through different lenses, making adjustments as needed. Make sure each important aspect is in the structure, language, and content of the activity.

Step 6: Write and Test Draft. First one to two members of your team create a rough write-up for your pilot test. Write up the lesson in a form clear enough to be used when teaching it for the first time. Include phrasing of key questions or ideas, but don't worry about making the write-up slick or totally complete yet. You'll need to find out if the activity works before doing a full write-up. It's not unusual after a pilot to decide to radically change the write-up or even to start over completely. Ideally, the person who is teaching it for the first time should create the write-up for piloting, since it will need to make sense to them.

Step 6a: Pilot Test. As described in the section "Setting Yourself Up for Success," test the activity with students. Choose who would be best from your team to try it out first. Your pilot instructor should be someone who "gets" the activity, and who will be able to run it most successfully. If possible, have someone observe the pilot test of the activity. Preferably, this would be another member of the design team. The observer should write down much of what is said by the instructor and students, as well as what they observe students doing during the activity. They should also record time points in the margins of their notes fairly regularly, so you have a record of how long each part of the activity takes. These kinds of notes are super useful in the design process. Decide as a team what other signs of quality instruction the observer should look for (as ideas, see the handout *Goals and Instructor Moves for Productive Discussion* from the *Promoting Discussion* Professional Learning Session).

Step 6b: Meet and Evaluate. The design team meets, discusses how it went in the pilot test, and what could be done to make the activity work better next

NOTES

Going back and forth between templates and planning tools. During this phase of activity design, you might bounce back and forth between the two templates a bit. For example, you might reach the Concept Invention phase of the Learning Cycle and decide that students will make some explanations about the causes of the similarities and differences they observed when they were checking out nature realia. Then you might look at the NGSS Template to guide your thinking about how students would engage with that practice to deepen their understanding of the nature realia. Next, you might want some examples of how students could engage in constructing explanations in outdoor science, so you'd glance at the handout Teaching Science Practices in Outdoor Science to jump-start your thinking. Then you'd bounce back to the Learning Cycle Template to plan the next phase of the activity.

Print planning tool:
"Appendix G. Lenses for Activity Review" on page 81

Check to make sure you're not making any of the following common Learning Cycle mistakes:

- **Introducing concepts and** vocabulary before Invitation and Exploration.
- **Skimping on or skipping one or** more phases of the Learning Cycle, most commonly: Application, Reflection, or Concept Invention after Exploration.
- **Relying mostly on one phase of** the Learning Cycle, such as Exploration or Concept Invention.

time. If the activity works right away, great! Then you can focus on fine-tuning. If it doesn't, revise it. If it doesn't work at all, then ditch it and go back to the drawing board!

Step 6c: Revise. One to two team members should rewrite the activity, making the changes recommended by the design team. If they get stuck, they can go back to other members of the design team to troubleshoot. If still stuck, get advice outside the design team with a respected member of staff who has experience with design.

Step 6d: Retest. Try it with students again (and again and again) until it is consistently successful with students. One of the two instructors who taught or observed the activity initially should teach the new version to another group of students, then make any necessary changes based on how it goes. Once you've had some success with the activity, ask other instructors to try it out, get their feedback, and revise the lesson accordingly.

At this stage, it's also important to start thinking about where the activity might happen during the arc of a student's experience in your program, and make any adjustments to the activity so it fits in with activities that come before and after it. You might also discover that you need to design new activities to go before or after the newly designed activity.

Repeat Steps 6a–6d till Well-Done. Keep testing, evaluating, revising, and retesting until you're satisfied with the activity (for now at least). These steps (6a–6d) should be repeated until the activity works well when led by a couple of different instructors.

Step 7: Repeat Step 5. When in the thick of designing and testing an activity it's easy to forget about all the criteria you want included. Now that you have a strong idea of what your activity will look like, use the Lenses for Activity Review planning tool again and have a discussion with your activity design team about how you are addressing each lens in the activity. Make sure that any revisions to the activity didn't remove these important aspects.

Step 8: Polish Final Draft. Do a thorough write-up of the activity. Thorough write-ups will help make sure your activities last over years or seasons, and that the quality and spirit of the activity will be passed along, even after lead staff may have moved on. A write-up should be detailed enough that someone could pick it up, read it, and lead it successfully without necessarily having talked to one of the designers of the activities (though it's best if they can consult with a mentor about it).

It should also include reasoning behind choices you've made. The write-up should be much more than a paragraph-long summary of what students do. It should include references to the Learning Cycle, specific wording of key questions and concepts, clear instructions for what students do in transitions between parts of the activity, options to use with different audiences, and notes about how to successfully lead the activity based on feedback during the design process.

NOTES

It's helpful to have a systematic way to collect feedback from instructors. Surveys or recorded conversations guided by specific questions about the overall effectiveness of the activity, the responsiveness of students during different phases of the activity, any adjustments made during teaching, and specific things that worked well/didn't work well can help focus an activity tester's feedback and ideas. Giving each instructor who tested the activity the same questions to respond to will also make sure the feedback you get will actually show differences in various instructor's experiences.

It's not uncommon for someone to come along after the authors of the activity are gone, see the write-up and decide to "improve it," but without an understanding about it's development, so they actually end up making it less effective. Often this happens when someone without much understanding of teaching and learning adjusts activities so they include more of the instructor directly explaining things.

NOTES

Thanks for reading! What you're doing is meaningful work, both for the students, and also for developing your own professional chops.

Specifically, make sure the write-up includes:

- Introductory notes about any preparation needed and the best setting for the activity.
- Moments of "metacognition" (thinking about your thinking), such as when students are engaging in a Science Practice or applying a Crosscutting Concept, and then reflecting on how using these skills influenced their thinking.
- Teaching notes about specific strategies for engaging different audiences in the activity, any lessons learned through testing, strategies and rationale for promoting equity and inclusion, and any other information that will help the activity to continually be led effectively.
- Learning goals: Write out a few bullet points of what exactly you want every child who does this activity to do and learn. Keep these realistic for all learners.
- Useful content background for the instructor.

Step 9: Celebrate! Pat yourselves on the back, crack the beverage of your choice, and do a little dance. You did it! Then go out and do it again.

NOTES

References

Atkin, J. M., & Karplus, R. (1962). Discovery or invention. *The Science Teacher, 29*(2), 121–143.

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher, 25*(9), 6–14.

Bogner, F. X. (1998). The influence of short-term outdoor ecology education on long-term variables of environmental perspective. *The Journal of Environmental Education, 29*(4), 17–29.

Bybee, R. M. (1997). *Achieving scientific literacy: From purposes to practices.* Portsmouth, NH: Heinemann.

Cochran-Smith, M., & Lytle, S. L. (1999). Chapter 8: Relationships of knowledge and practice: Teacher learning in communities. *Review of Research in Education, 24*(1), 249–305.

Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession.* Washington, DC: National Staff Development Council.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3–14.

Dorph, R., Shields, P., Tiffany-Morales, J., Hartry, A., & McCaffrey, T. (2011). High hopes—few opportunities: The status of elementary science education in California. *Strengthening Science Education in California.* Center for the Future of Teaching and Learning at WestEd.

DuFour, R., & Eaker, R. (1998). *Professional learning communities at work™: Best practices for enhancing student achievement.* Bloomington, IN: Solution Tree Press.

Duhigg, C. (2016, February 25). What Google learned from its quest to build the perfect team. *The New York Times Magazine.*

Ernst, J., & Monroe M. (2004). The effects of environment-based education on students' critical thinking skills and disposition toward critical thinking. *Environmental Education Research, 10*(4), 507–522.

Farmer, J., Knapp, D., & Benton, G. M. (2007). An elementary school environmental education field trip: Long-term effects on ecological and environmental knowledge and attitude development. *The Journal of Environmental Education, 38*(3), 33–42.

Hammond, Z. (2014). *Culturally responsive teaching and the brain: Promoting authentic engagement and rigor among culturally and linguistically diverse students.* Thousand Oaks, CA: Corwin Press.

NOTES

Hord, S. M. (1997). *Professional learning communities: Communities of continuous inquiry and improvement.* Austin, TX: Southwest Educational Development Laboratory.

Kahn, W. A. (1990). Psychological conditions of personal engagement and disengagement at work. *Academy of Management Journal, 33*(4), 692–724.

Lemke, J. L. (1990). *Talking science: Language, learning, and values.* Westport, CT: Ablex Publishing.

Lieberman, G. A., & Hoody, L. L. (1998). *Closing the achievement gap.* State Education and Environment Roundtable Report.

Loughran, J. J. (2002). Effective reflective practice: In search of meaning in learning about teaching. *Journal of Teacher Education, 53*(1), 33–43.

Michaels, S., & O'Connor, C. (2012). *Talk science primer.* Cambridge, MA: TERC.

National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits.* Washington, DC: National Academies Press.

National Research Council. (2010). *Surrounded by science: Learning science in informal environments.* Washington, DC: National Academies Press.

National Research Council. (2011). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press.

National Research Council. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century.* Washington, DC: The National Academies Press.

Newberry, T., & Holtan, G. (2005). *The ardent birder: On the craft of birdwatching.* New York City, NY: Random House LLC.

Norris, K. (1998). *Mountain time: Reflections on the wild world and our place in it.* Oakland, CA: University of California, Natural Reserve System.

Osborne, J., (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*(23), 463–466.

Palmberg, I. E., & Kuru, J. (2000). Outdoor activities as a basis for environmental responsibility. *The Journal of Environmental Education, 31*(4), 32–36.

Shepard, C. L., & Speelman, L. R. (1986). Affecting environmental attitudes through outdoor education. *The Journal of Environmental Education, 17*(2), 20–23.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Educational Change, 7*(4), 221–258.

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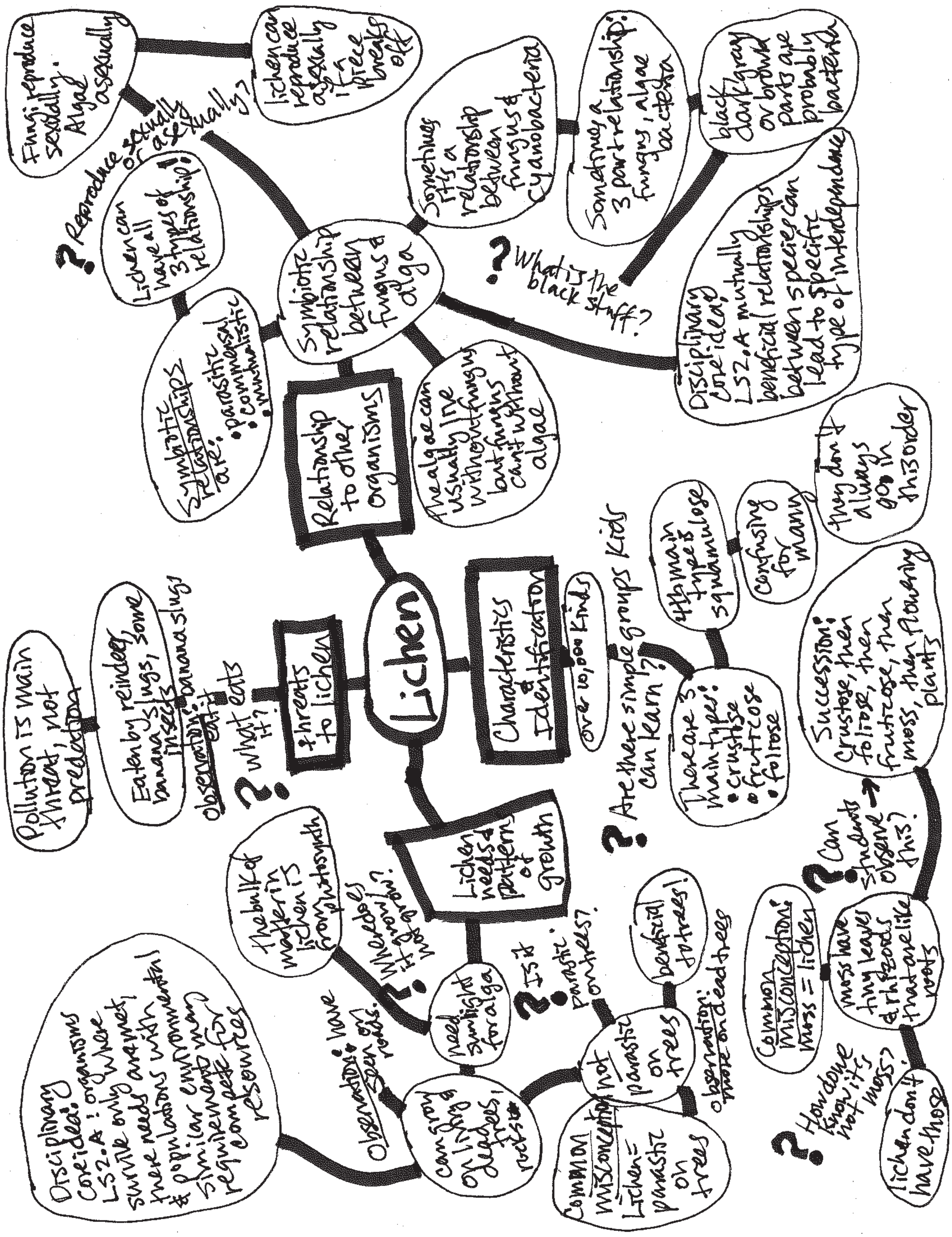
Appendices

Appendix A. Lichen Concept Map



Appendix B. NGSS: Applying Crosscutting Concepts in Outdoor Science

The *Fra*mework for K-12 Science Education (See free PDF download at http://www.nap.edu/catalog.php?record_id=13165) is a progressive vision for science education produced by top scientists and educators appointed by the National Research Council, which served as the basis for developing the Next Generation Science Standards (NGSS). It represents the most current, research-based ideas about how to teach science. At its core are the following guiding principles: (1) children are born investigators and have the capacity to reason in sophisticated ways, (2) focusing on core ideas and practices helps build a more wide-ranging understanding of science, (3) deep understanding develops over time and through making connections, (4) science learning involves both knowledge and practice, (5) connecting to student interests and experience helps to sustain their curiosity and wonder, and (6) all students should have opportunities to learn about and engage in science.

The *Framework* describes three dimensions that make up the how and what in science to be taught by the end of high school: (1) Science and Engineering Practices, (2) Crosscutting Concepts, and (3) Disciplinary Core Ideas. These dimensions should be woven together while teaching, so students can develop a more coherent understanding of science that reflects its interconnections in the real world. The *Framework* as a whole is quite educative and thoughtfully written—definitely worth reading and revisiting as instructors are exploring new ways of teaching science.

Crosscutting Concepts

Crosscutting concepts are "big ideas" that are applicable to and can be used as thinking tools across disciplines. For example, the idea that an object's structure is directly related to its function is true in the natural and human-designed world, for structures at the cellular level, and all the way up to the largest living and nonliving things in the universe. It is an idea used by engineers in the design process, biologists when thinking about how structures help organisms survive, and all other disciplines of science.

Outdoor science programs are well-situated to help students apply Crosscutting Concepts in meaningful ways. In the field, students have sustained contact with different aspects of nature, and can use these "big ideas" over time to deepen their understanding of key ideas and different aspects of nature.

Since the advantage of using Crosscutting Concepts is applying useful thinking tools across disciplines, it is especially important that students use them more than once, and in multiple kinds of situations (ideally, a couple times in the course of one activity, and in subsequent activities related to different topics). In addition to using Crosscutting Concepts while you are exploring nature, look for short opportunities for students to apply the "big idea" in a different context (e.g., after Structure and Function focused activities, have students look at a building, make observations about some structure like the shape or texture of the roof, or placement of windows, then discuss how that functions).

In addition to *using* the Crosscutting Concept, it's also important for students to recognize and value Crosscutting Concepts as thinking tools. Students should reflect on how using Crosscutting Concepts help them deepen their thinking. Point out to students when they use a Crosscutting Concept during an activity or while they are exploring nature. Ask them how it changed their thinking, and how they might apply it in another situation. Ultimately, a goal of science learning is that students begin to use Crosscutting Concepts without being prompted by an instructor.

As part of the Next Generation Science Standards, students will be asked to apply Crosscutting Concepts throughout the duration of their schooling and science education, so we recommend focusing on one or two particularly useful Crosscutting Concepts that can be used in outdoor learning experiences. The Crosscutting Concepts of Patterns, Cause and Effect, and Structure and Function are well suited to use in outdoor settings. A useful approach is to organize an entire day's "hike" or a sequence of activities around one Crosscutting Concept (see BEETLES Theme Hikes for an example of what this can look like).

This document focuses on how field instructors can use these Crosscutting Concepts to deepen students' thinking during outdoor science experiences. Each Crosscutting Concept includes a brief description, and examples of how it might be applied during field instruction, as well as in specific BEETLES activities. Use this handout to jump-start your thinking on how to incorporate them into your teaching.

	Description of Crosscutting Concept & Student Abilities	Field Examples & Teaching Notes
1. Patterns	Patterns can be found everywhere and noticing patterns can lead to interesting questions about how and why they occur. This is an important lens for scientific investigations—and often how an investigation of a process or phenomena begins. Once you've identified a pattern, it often leads you to thinking about Cause and Effect, so that you can explain what is causing the pattern. *Abilities we can help students develop in outdoor science:* • Recognize and observe patterns in nature. • Identify similarities and differences between objects and parts of nature. • Observe patterns and develop questions based on observations. • Use patterns to identify possible cause and effect relationships. Useful Questions (excerpted from CrossCutSymbols website © 2013 Peter A'Hearn/CrossCutSymbols) • What is the evidence for this pattern? • Do similarities and differences reveal a pattern? • Is this pattern real or imagined? (People sometimes see patterns where there isn't one.) • What predictions can I make based on this pattern? Can I test them? • Is there a cause for this pattern? • How does this pattern compare to other patterns I have learned about?	*General Approach:* Prompt students to notice patterns wherever you take them and whatever they are studying. For example, students might be exploring a grassy hillside and notice a pattern to where the grass grows and where it doesn't; or when catching macroinvertebrates in a stream you might notice a pattern in their coloration, with many of them being brown. You might notice a pattern of streamlined shapes of underwater organisms. *Specific BEETLES activities:* In *I Notice, I Wonder, It Reminds Me Of,* students practice their observation skills and look for patterns in what they observe. In *Lichen Exploration,* students look for patterns of lichen growth, then think about what factors might have caused the patterns they observed. In *Bird Language Exploration,* students listen to different types of bird calls, group them based on similarities, and discuss what each call might mean. In *Spider Investigation,* students look for patterns in the kinds of webs that grow in different plant communities.

Note: *Patterns* is one of the Crosscutting Concepts BEETLES has identified as being particularly suited to outdoor science learning situations.
Many essential scientific thinking processes begin with identifying patterns, including grouping organisms or other parts of nature based on common features, generating questions about why patterns occur. The outdoors are a great place for students to develop the skill of looking for patterns, and an inherently intriguing place for them to start to explain possible causes behind what they observe. A focus on patterns is also a natural lead in to thinking about cause and effect, and noticing patterns of where organisms occur, shapes of rocks in different stream beds, or the occurrence of herbivory in certain areas, reveals underlying processes that relate to many of the key ideas taught at outdoor schools.

<table>
<tr><th></th><th>Description of Crosscutting Concept & Student Abilities</th><th>Field Examples & Teaching Notes</th></tr>
<tr><td>2. Cause and Effect</td><td>When scientists make explanations for how or why something happens, they are thinking about the connection between cause and effect. Much of what we can observe of the natural world are the “effects” of many potential “causes.” Understanding cause and effect relationships leads to a deeper understanding of the world, which is helpful in making predictions and scientific explanations about what might happen as a result of similar conditions in the future.

Abilities we can help students develop in outdoor science:
• Observe and identify cause and effect relationships.
• Try to figure out and explain what caused observable things in nature.
• Discuss possible effects of different actions or events.
• Make predictions about possible effects of different actions or events in the environment.
• Distinguish between causation and correlation.

Useful Questions (excerpted from CrossCutSymbols website © 2013 Peter A’Hearn/CrossCutSymbols)

• What evidence is there for a cause and effect relationship? • How can this cause and effect relationship be tested? • What are other possible causes? • Is there more than one cause? • Is the cause and effect relationship real or imagined? • How is this cause and effect relationship similar to and different than others I have learned about?</td><td>General Approach: When students notice patterns, or intriguing “nature mysteries,” ask them to generate possible explanations for what might have caused what they’re looking at. Or prompt students to make predictions about what might happen in the future based on what they’re observing in the moment.

For example, you might ask questions like: What might be causing those holes? How did these bones end up here? What might be causing the trees to be dying around here? What might be effects on the ecosystem if the foxes in this area died off? What might be effects to this stream if we planted more trees along the edges?

Specific BEETLES activities:

In Bark Beetle Exploration, students notice features of bark beetle galleries and make explanations about what beetle behaviors might have caused each feature. Later, they predict possible effects of different management strategies of bark beetle outbreaks.

In Case of the Disappearing Log, students look for evidence of how a log might be changing, then think about what things might have caused the features (effects) they observe.

In NSI: Nature Scene Investigators, students observe features of a “mystery object” and come up with possible explanations for what might have caused them.</td></tr>
</table>

Note: *Cause and Effect* is one of the Crosscutting Concepts BEETLES has identified as being particularly suited to outdoor science learning situations.
Looking at cause and effect relationships is one of the main goals of science. It’s also incredibly easy to do outdoors, since almost anything students lay eyes on (rocks in a certain area, patterns of mud after a rainstorm, the shape of a stream bank, holes in leaves, weathering patterns, tracks, etc.) is essentially an “effect” of one (or more likely, many) causes. Helping students to look at nature as a collection of mysteries to be explored can help them to apply this Crosscutting Concept. It is also applicable in many topics that are common focuses of outdoor science schools, such as interdependent relationships in ecosystems. Cause and Effect is also useful in building environmental literacy, since it pertains to predicting possible effects on systems if conditions change, which is a thinking process essential to creating management strategies.

	Description of Crosscutting Concept & Student Abilities	Field Examples & Teaching Notes
3. Structure and Function	The idea that Structure and Function complement each other is a useful tool for explaining things in science. In the designed world and in any natural system, the shape and material of a structure is related to what it does, and vice versa. Students might observe an organism's structures, and make possible explanations for how each one helps the organism survive in a specific environment. In other words, students look at structures and think about how they might function. *Abilities we can help students develop in outdoor science:* • Observe structures of animals, plants, nonliving things, and human-made objects in detail. • Think about how the specific characteristics of a structure help it to function. Useful Questions (excerpted from CrossCutSymbols website © 2013 Peter A'Hearn/CrossCutSymbols) • How does the function depend on the structure? • How does the structure support the function? • Are there other structures that can serve the same function? • How does this relationship between structure and function compare to others that I have learned about?	*General Approach:* As students observe organisms, prompt them to focus on its structures, and discuss how those structures might function in the context of living in the environment. For example, if students spot a deer, ask them, "What are some specific characteristics of the deer's structures? What specific things can we say about the color, texture, shape, etc. of its different body parts? How might those help it to survive in its habitat?" *Specific BEETLES activities:* In *Discovery Swap*, students consider an environment where organisms live and discuss what kinds of structures might function to help an organism survive there. Later, they observe organisms' structures and make possible explanations for how the structures function. In *Structures and Behaviors,* students catch organisms, observe their structures, and think about how the structures might function. In *Adaptation Intro- Live!,* students observe an organism, and think about whether its structures and behaviors are adaptations or not. In *Blend In, Stand Out,* students observe the colors and patterns of organisms, and think about how those characteristics function to help the organism blend in to or stand out from its surroundings.

Note: *Structure and Function* is one of the Crosscutting Concepts BEETLES has identified as being particularly suited to outdoor science learning situations.
A critical aspect of figuring out how structures function is seeing them in context, so the outdoors are an ideal location for students to study organisms' structures and think about how those structures function to help organisms survive. Seeing a deer, fish, or other organism in its habitat leads students to think more accurately about how its structures specifically function in its environment, and is an opportunity that's not usually available in most classrooms.
Focusing on this Crosscutting Concept can be a way to build foundational understanding for more complex content, like Adaptations and Natural Selection.

	Description of Crosscutting Concept & Student Abilities	Field Examples & Teaching Notes
4. Energy and Matter	Tracking the transfer of matter and energy into, out of, and within a system enables scientists to learn about the relationship between the various elements that make up and drive all kinds of systems. For example, thinking about how matter moves through a system can help students gain a deeper understanding of relationships between living and nonliving parts of an ecosystem. *Abilities we can help students develop at outdoor science school:* • Track the cycling of matter among living and nonliving parts of an ecosystem. • Explain how matter is never destroyed even when it seems to disappear, and help students to see examples of this in their surroundings. • Specifically, help students recognize how matter cycles between forms that are visible (e.g., a log) and invisible (e.g., carbon dioxide gas). • Discuss how energy flows among living and nonliving parts of an ecosystem. Useful Questions (excerpted from CrossCutSymbols website © 2013 Peter A'Hearn/CrossCutSymbols) • How are energy and matter related in this system? • Where does the energy for this system come from? Where does it go? • How does matter in this system change? How does it enter and exit the system? • Is the role of energy and matter in this system similar to other systems I have learned about? How is it different?	*General Approach:* When students discuss relationships between various living and/or non-living parts of an ecosystem or observe evidence of an interaction between parts, prompt them to think about how matter or energy is transferred via those relationships and interactions. For example, if students find scat on the trail, ask them, "Where did the matter that makes up this scat come from?" Challenge them to trace the matter back to the food of the animal who's scat it is, or even farther, to think about where the matter that makes up that food might have come from. Also ask them, "What might happen to the matter that makes up the scat over time? Where will it go?" *Specific BEETLES activities:* In *Food, Build, Do, Waste,* students trace matter as it cycles through organisms, and think about the flow of energy between the organism and other parts of the ecosystem. In *Case of the Disappearing Log,* students think about where the matter in a decomposing log is now. In *Decomposition Mission,* students observe decomposition, think about it as a process, and discuss how matter cycles within an ecosystem.

	Description of Crosscutting Concept & Student Abilities	Field Examples & Teaching Notes
5. Systems and Systems Models	The world is complex! Using a system model provides a simpler, more contained unit of study (e.g., discussing just the organisms and features of one ecosystem, as opposed to thinking about every single ecosystem on the planet). Defining the artificial boundaries of a system and studying the interactions between parts of the system, as well as the flows into and out of the system, can help scientists understand and make predictions about how changes to one part of a system may affect other parts of the system, the system's overall processes, or other systems. *Abilities we can help students develop at outdoor science school:* • Describe a system in terms of its components and their interactions. • Understand a system is a group of related parts that make up a whole. • Define the boundaries of a system. • Identify flows into and out of a system. • Predict how changes to one part of a system will affect another part of the system. Useful Questions (excerpted and adapted from CrossCutSymbols website © 2013 Peter A'Hearn/CrossCutSymbols) • What are the boundaries of this system? • What other systems affect this system? How? • What parts make up this system? How do they interact? • What are the advantages to thinking about this as a system? • In what ways is this system like others I have learned about? How is it different?	*General Approach:* As students investigate organisms, prompt them to define the boundaries of the system in which the organisms live, identify parts of the system, and think about how the organisms they are focused on interact with the other parts of the system. Challenge older students to identify systems at different scales, and to identfy flows into and out of the system. For example, if students are observing macroinvertebrates from a pond, ask them to identify other living and nonliving parts of the pond ecosystem, and to discuss how those parts interact with the invertebrates. For a challenge, ask them, "How are things outside of the pond system affecting the pond? How is the pond system affecting things outside of it? If we thought of the pond as one part of a bigger system of interacting parts, what are other parts of that system?" *Specific BEETLES activities:* In *Discovery Swap,* students could define the area they are looking at as a system, identify the boundaries of the system, label its parts, and describe the interactions between the parts of the system. In *Interview an Organism*, students identify living and nonliving parts of the system in which an organism they are observing lives. They think about how their organism interacts with those parts of the system and how it would be impacted if various parts of the system changed. In *What Lives Here,* students make an interaction web based on organisms they have found in an area, then use those webs to make predictions about what might happen if certain conditions (like the presence of certain living or nonliving factors) changed).

	Description of Crosscutting Concept & Student Abilities	Field Examples & Teaching Notes
6. Stability and Change	If scientists understand how stable a system (or organism, or object) is, when it will change, and what causes it to change, they can make predictions about cause and effect relationships in nature. The lens of stability and change can also be an important tool for understanding flows of matter and energy into, out of, and within a system. Some systems may seem stable at one scale but may be changing at another scale (e.g., the bank of a river that seems stable at shorter timescales, but erodes noticeably over longer timescales; a log that seems stable at one scale but shows evidence of decomposition when you zoom in to a smaller scale). When you prompt students to think about stability and change, make sure you are asking them to focus on observing things at a scale at which you can actually observe changes, and/or encourage them to extrapolate what changes might happen over a longer period of time. *Abilities we can help students develop at outdoor science school:* • Understand what causes stability and change within a natural system they are observing. • Ask questions about what causes a system to change. • Look for evidence of change within a system, and think about the rate of change. • Understand how one change may lead to another within systems. Useful Questions (excerpted and adapted from CrossCutSymbols website © 2013 Peter A'Hearn/CrossCutSymbols) • What causes change in this system? • What causes stability in this system? • Are there feedbacks that make this system more or less stable? • If the system is stable, how long is this system likely to remain stable? • If the system is stable, what would cause it to change? • If the system is changing, what would make it become stable? • How does stability and change in this system compare with other systems I have learned about?	*General Approach:* As students explore and investigate cause and effect relationships or evidence of changes in an ecosystem, prompt them to think about the factors that may affect the stability of the system (or object) they are investigating. Encourage them to make predictions about the changes that might occur at different timescales. For example, if students are discussing a decomposing log, ask them to find evidence that the log is changing. Prompt them to think about how much the log might change over an hour, a day, a month, or a year. Challenge students to consider whether the decomposition of the log may cause changes to their parts of the ecosystem. *Specific BEETLES activities:* In *Fire Discussion*, students seek to understand the how the stability of a forest ecosystem is impacted by wildfires, and would be affected by different fire management strategies. In *Bark Beetle Exploration*, students seek to understand how the stability of a forest ecosystem is impacted by bark beetle outbreaks, and would be affected by different environmental management strategies. In *Stream Mysteries*, students observe a stream, learn about how currents and streams work, then think about what the stream might have looked like in the past, and make predictions about how it will change in the future.

	Description of Crosscutting Concept & Student Abilities	Field Examples & Teaching Notes
7. Scale, Proportion, and Quantity	Scientists rely on a foundational understanding of scale, proportion, and quantity when they make observations about nature. Understanding and attending to scale is a crucial step towards making sense of any system's process and any structure's function. In outdoor science contexts, this Crosscutting Concept is especially applicable when looking at the night sky, and thinking about the relative sizes and scales of different observable objects. *Abilities we can help students develop at outdoor science school:* • Observe the scale of objects and phenomena in nature. • Compare the relative scale of different objects and phenomena in nature. • Use standard units to make measurements of objects and phenomena in nature. Useful Questions (excerpted and adapted from CrossCutSymbols website © 2013 Peter A'Hearn/CrossCutSymbols) • How does this interaction affect the global scale? • How does this system look at a smaller and larger scales? • What is new and what is the same? • How does this scale relate to you? How much bigger or smaller is it than what you are used to experiencing? • How can we study nature at this scale? • How can we accurately measure this at this scale?	*General Approach:* When students observe objects or phenomena in nature, guide them to pay attention to scale of the things they are observing. Encourage them to think about what the scale of an object can tell them about possible structure-function relationships, and what the scale of an event can reveal about cause and effect relationships. For example, you might ask questions like: How many? How long? How tall? How fast? How big? Which environment had more _____ and why do you think so? What does the size of this structure tell you about its function? What do you think happened first and how do you know? *Specific BEETLES activities:* In *How Big and How Far*, students measure how tall a student looks when observed from different distances to realize that perspective affects how large objects seem. They apply this idea of relative size to understand the scale of objects in the night sky. In *Night Sky Scavenger Hunt*, students think about the mind-boggling scales of objects in the night sky. They discuss the relative sizes of and distances to various objects. In *Spider Investigation*, students collect data on and compare the number of spider webs in two different plant communities.

Appendix C. NGSS: Applying Disciplinary Core Ideas (DCIs) in Outdoor Science

DCIs are conceptual science understandings that are important for students to know, and they might be described as, "what science knows." This handout is for helping activity designers make realistic and accurate connections to the Next Generation Science Standards (NGSS) DCIs. It includes a selection of life science, earth science, and engineering design DCIs that are closely related to concepts and experiences common in outdoor science programs that have the potential to be investigated through nature-centered activities. Left out here are DCIs that are certainly important but difficult to learn about through direct nature studies, and are probably best taught in a classroom. Outdoor science is at its best when it plays to the strength of learning through direct engagement with nature, not when it involves too many models and simulations of things students can't directly experience outdoors. That's why parts of the DCIs included here should be skipped, because they would be difficult to teach through direct engagement with nature, and should not be the focus of outdoor science. This appendix is not a comprehensive list of all DCIs, but is a list of DCI topics and ideas that might be useful for most outdoor science programs to think about to guide their instruction, and that might be possible to teach outdoors.

For more details about understanding the Disciplinary Core Ideas, see Chapter 6: Disciplinary Core Ideas—Life Sciences, Chapter 7: Disciplinary Core Ideas—Earth and Space Sciences, and Chapter 8: Engineering, Technology and Applications of Science in *A Framework for K-12 Science Education*. For information about specific grade-level performance expectations, see the NGSS, and look within the color-coded orange boxes for the DCIs associated with each grade-level performance expectation.

When choosing DCIs to focus on, it's important to recognize that these are complex ideas that can't be thoroughly taught and understood in one outdoor science experience, no matter how engaging it is! It's also important to be realistic in stating expectations for students —for instance, it shouldn't be claimed that your program can completely address all the ideas contained in a single DCI or a performance expectation.

For example, the BEETLES *Ecosystems, Matter and Energy Theme Hike* is a series of activities that can be used with 5th-grade students focused on developing some foundational understanding of the DCI: LS2.*A Interdependent Relationships in Ecosystems*, but it's not possible to completely address any DCI in one outdoor experience.
Note: This same hike also addresses parts of other DCIs, like LS2.B *Cycles of Matter and Energy Transfer in Ecosystems*. How do matter and energy move through an ecosystem?

Example of how a DCI can be addressed through a field experience.

LS2.A Interdependent Relationships in Ecosystems. How do organisms interact with the living and nonliving environments to obtain matter and energy?

By the end of grade 5:

The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Either way, they are "consumers." Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil for plants to use. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.

The hike begins with a *Walk & Talk* where students share ideas about connections between organisms, and they discuss systems in general. Then they explore and observe their surroundings using the *I Notice, I Wonder, It Reminds Me Of* routine. In the *What Lives Here?* activity they identify and record evidence of different plants, as well as other living and nonliving things in the ecosystem, making a model of the ecosystem that shows connections. They keep adding to this model throughout the hike. Next they explore a decomposing log to learn about other interdependent relationships and decomposition in *The Case of the Disappearing Log.* Then they discuss matter cycles and energy flow in the ecosystem using the *Food, Build, Do, Waste* activity. They use the ecosystem models they've been adding to throughout the hike to have a discussion about interdependence and how introducing new parts (like introduced species) or losing parts of the ecosystem affects the balance of the ecosystem. Finally, they reflect on what they've learned in a *Walk & Talk*.

This may seem like a lot of activities for teaching about one DCI, but this example shows how complex DCIs can be, and how you need a lot of time and extended experiences to address them with students—in this case a 6-hour long hike! And although the 6 activities in this theme hike can do a lot to develop middle school students' understanding of parts of this DCI, all of these parts can't be addressed in one experience! For a more complete understanding, students will need additional experiences with these concepts throughout their K-12 education. The role of your program and your site is to give them active outdoor learning experiences with some of these science concepts, that allow students to observe and think about real world examples in the context of working ecosystems. This is why we recommend focusing on DCIs that are about processes or concepts students can actually observe directly (or observe the effects of) in the outdoors and at your site. The following is a list of DCIs that can have feasibly observed effects in the outdoors, and that might lead to interesting investigations through outdoor nature-centered, science experiences.

Life Science Core Ideas (text taken directly from *A Framework for K-12 Science Education,* Chapter 6)		
Core Idea LS1: From Molecules to Organisms: Structures and Processes. *How do organisms live, grow, respond to their environment and reproduce?*		
LS1.A: Structure and Function. *How do the structures of organisms enable life's functions?*		
By the end of grade 2: All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive, grow, and produce more plants.	*By the end of grade 5:* Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (Boundary: Stress at this grade level is on understanding the macroscale systems and their function, not microscopic processes.)	*Note: In grades 6–8 students are expected to learn about microscopic structures and processes and how they function in the cells of living organisms. LS1.A is not included for middle school here, because these kinds of investigations require special equipment and are not directly observable nor particularly nature-centered.*
LS1.B: Growth and Development of Organisms. *How do organisms grow and develop?*		
By the end of grade 2: Plants and animals have predictable characteristics at different stages of development. Plants and animals grow and change. Adult plants and animals can have young. In many kinds of animals, parents and the offspring themselves engage in behaviors that help the offspring to survive.	*By the end of grade 5: Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles that include being born (sprouting in plants), growing, developing into adults, reproducing, and eventually dying.*	*By the end of grade 8:* Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. Animals engage in characteristic behaviors that increase the odds of reproduction. Plants reproduce in a variety of ways, sometimes depending on animal
LS1.C Organization for Matter and Energy Flow in Organisms. *How do organisms use the matter and energy they need to live and grow?*		

By the end of grade 2: All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow.	*By the end of grade 5:* Animals and plants alike generally need to take in air and water, animals must take in food, and plants need light and minerals; anaerobic life, such as bacteria in the gut, functions without air. Food provides animals with the materials they need for body repair and growth and is digested to release the energy they need to maintain body warmth and for motion. Plants acquire their material for growth chiefly from air and water and process matter they have formed to maintain their internal conditions (e.g., at night)	*By the end of grade 8:* Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. Animals obtain food from eating plants or eating other animals. Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. In most animals and plants (also in fungi & aquatic organisms), oxygen reacts with carbon containing molecules (sugars) to provide energy and produce carbon dioxide; anaerobic bacteria achieve their energy needs in other chemical processes that do not require oxygen.
Core Idea LS2: Ecosystems: Interactions, Energy and Dynamics. *How and why do organisms interact with their environment and what are the effects of those interactions?*		
LS2.A Interdependent Relationships in Ecosystems. *How do organisms interact with the living and non-living environments to obtain matter and energy?*		
By the end of grade 2: Animals depend on their surroundings to get what they need, including food, water, shelter, and a favorable temperature. Animals depend on plants or other animals for food. They use their senses to find food and water, and they use their body parts to gather, catch, eat, and chew the food. Plants depend on air, water, minerals (in the soil), and light to grow. Animals can move around, but plants cannot, and they often depend on animals for pollination or to move their seeds around. Different plants survive better in different settings because they have varied needs for water, minerals, and sunlight.	*By the end of grade 5:* The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Either way, they are "consumers." Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil for plants to use. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.	*By the end of grade 8:* Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

LS2.B Cycles of Matter and Energy Transfer in Ecosystems. *How do matter and energy move through an ecosystem?*		
By the end of grade 2: Organisms obtain the materials they need to grow and survive from the environment. Many of these materials come from organisms and are used again by other organisms.	*By the end of grade 5:* Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, water, and minerals from the environment and release waste matter (gas, liquid, or solid) back into the environment.	*By the end of grade 8:* Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms (matter) that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.
LS2.C Ecosystem Dynamics, Functioning and Resilience. *What happens to ecosystems when the environment changes?*		
By the end of grade 2: The places where plants and animals live often change, sometimes slowly and sometimes rapidly. When animals and plants get too hot or too cold, they may die. If they cannot find enough food, water, or air, they may die.	*By the end of grade 5:* When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.	*By the end of grade 8:* Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations. Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.
LS2.D Social Interactions and Group Behavior. *How do organisms interact in groups so as to benefit individuals?*		
By the end of grade 2: Being part of a group helps animals obtain food, defend themselves, and cope with changes. Groups may serve different functions and vary dramatically in size.	*By the end of grade 5:* Groups can be collections of equal individuals, hierarchies with dominant members, small families, groups of single or mixed gender, or groups composed of individuals similar in age. Some groups are stable over long periods of time; others are fluid, with members moving in and out. Some groups assign specialized tasks to each member; in others, all members perform the same or a similar range of functions.	*By the end of grade 8:* Groups may form because of genetic relatedness, physical proximity, or other recognition mechanisms (which may be species specific). They engage in a variety of signaling behaviors to maintain the group's integrity or to warn of threats. Groups often dissolve if they no longer function to meet individuals' needs, if dominant members lose their place, or if other key members are removed from the group through death, predation, or exclusion by other members.

Core Idea LS4: Biological Evolution: Unity and Diversity. *How can there be so many similarities among organisms yet so many different kinds of plants, animals and microorganisms? How does biodiversity affect humans?*		
LS4.B Natural Selection. *How does genetic variation among organisms affect survival and reproduction?*		
By the end of grade 2: (not addressed at this grade level)	*By the end of grade 5:* Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing.	*By the end of grade 8:* Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection. It leads to the predominance of certain traits in a population and the suppression of others. {In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed onto offspring.} *Note: This artificial selection is only observable if you have domesticated plants or animals at your site.*
LS4.C Adaptation. How does the environment *influence populations of organisms over multiple generations?*		
By the end of grade 2: Living things can survive only where their needs are met. If some places are too hot or too cold or have too little water or food, plants and animals may not be able to live there.	*By the end of grade 5:* Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful. For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.	*By the end of grade 8:* Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. {In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to become separate species.} *Note: The process of speciation is not easily observable though there may be evidence of its occurrence at your site.*
LS4.D Biodiversity and Humans. *What is biodiversity, how do humans affect it, and how does it affect humans?*		
By the end of grade 2: There are many different kinds of living things in any area, and they exist in different places on land and in water.	*By the end of grade 5:* Scientists have identified and classified many plants and animals. Populations of organisms live in a variety of habitats, and change in those habitats affects the organisms living there. Humans, like all other organisms, obtain living and nonliving resources from their environments.	*By the end of grade 8:* Biodiversity is the wide range of existing life forms that have adapted to the variety of conditions on Earth, from terrestrial to marine ecosystems. Biodiversity includes genetic variation within a species, in addition to species variation in different habitats and ecosystem types (e.g., forests, grasslands, wetlands). Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

Earth and Space Science Core Ideas (text taken directly from *A Framework for K-12 Science Education,* Chapter 7)		
Core Idea ESS1: Earth's Place in the Universe. *What is the universe, and what is Earth's place in it?*		
ESS1.A: The Universe and its Stars. *What is the universe, and what goes on in stars?*		
By the end of grade 2: Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. At night one can see the light coming from many stars with the naked eye, but telescopes make it possible to see many more and to observe them and the moon and planets in greater detail.	*By the end of grade 5:* The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their size and distance from Earth.	*By the end of grade 8:* Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. The universe began with a period of extreme and rapid expansion known as the Big Bang. Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. *Note: Understanding and explaining the motion of the Moon and planets in the solar system can be challenging for students (and adults) even with the use of models designed to help learners address misconceptions. See BEETLES Night Sky Activities.*
ESS1.B: Earth and the Solar System. *What are predictable patterns caused by Earth's movement in the solar system?*		
By the end of grade 2: Seasonal patterns of sunrise and sunset can be observed, described, and predicted.	*By the end of grade 5:* The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily and seasonal changes in the length and direction of shadows; phases of the moon; and different positions of the sun, moon, and stars at different times of the day, month, and year. Some objects in the solar system can be seen with the naked eye. Planets in the night sky change positions and are not always visible from Earth as they orbit the sun. Stars appear in patterns called constellations, which can be used for navigation and appear to move together across the sky because of Earth's rotation.	*By the end of grade 8:* The solar system consists of the Sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. This model of the solar system can explain tides, eclipses of the sun and the moon, and the motion of the planets in the sky relative to the stars. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. *Note: Understanding and explaining the motion of the Moon and planets in the solar system, as well as the seasons, can be challenging for students (and adults) even with the use of models designed to help learners address misconceptions.*

Core Idea ESS2: Earth's Systems. *How and why is Earth constantly changing?*

ESS2.A: Earth Materials and Systems. *How do Earth's major systems interact?*

By the end of grade 2: Wind and water can change the shape of the land. The resulting landforms, together with the materials on the land, provide homes for living things.	*By the end of grade 5:* Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. Rainfall helps shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. Human activities affect Earth's systems and their interactions at its surface. *Note: Much of these core ideas are not directly observable, though some evidence of the processes described can be found.*	*By the end of grade 8:* All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. *Note: Much of these core ideas are not directly observable, though some evidence of the processes described can be found.*

ESS2.C: The Roles of Water in Earth's Surface Processes. *How do the properties and movements of water shape Earth's surface and affect its systems?*

By the end of grade 2: Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. It carries soil and rocks from one place to another and determines the variety of life forms that can live in a particular location.	*By the end of grade 5:* Water is found almost everywhere on Earth: as vapor; as fog or clouds in the atmosphere; as rain or snow falling from clouds; as ice, snow, and running water on land and in the ocean; and as groundwater beneath the surface. The downhill movement of water as it flows to the ocean shapes the appearance of the land. Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.	*By the end of grade 8:* Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation as well as downhill flows on land. The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. Global movements of water and its changes in form are propelled by sunlight and gravity. Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. *Note: Much of what is described in these water processes is fairly abstract, and having students memorize or chant the steps of the water cycle does not necessarily help to build understanding of what drives the process.*

ESS2.D: Weather and Climate. *What regulates weather and climate?*		
By the end of grade 2: Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.	*By the end of grade 5*: Weather is the minute-by-minute to day-by-day variation of the atmosphere's condition on a local scale. Scientists record the patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. Climate describes the ranges of an area's typical weather conditions and the extent to which those conditions vary over years to centuries.	*By the end of grade 8:* Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Because these patterns are so complex, weather can be predicted only probabilistically. {The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. Greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping it habitable.} *Note: The effects of the ocean and atmosphere on weather and climate can be directly observed, but the explanations described here require the use of models and/or additional investigative experiences.*
ESS2.E: Biogeology. *How do living organisms alter Earth's processes and structures?*		
By the end of grade 2: Plants and animals (including humans) depend on the land, water, and air to live and grow. They in turn can change their environment (e.g., the shape of land, the flow of water).	*By the end of grade 5:* Living things affect the physical characteristics of their regions (e.g., plants' roots hold soil in place, beaver shelters and human-built dams alter the flow of water, plants' respiration affects the air). Many types of rocks and minerals are formed from the remains of organisms or are altered by their activities.	*Note: In grades 6–8 students are expected to learn about how changes in geology have influenced evolution of life on Earth. These kinds of investigations require an understanding of deep time and are not directly observable nor particularly nature-centered.*
Core Idea ESS3: Earth and Human Activity. *How do Earth's surface processes and human activities affect each other?*		
ESS3.A: Natural Resources. How do humans depend on Earth's resources?		
By the end of grade 2: Living things need water, air, and resources from the land, and they try to live in places that have the things they need. Humans use natural resources for everything they do: for example, they use soil and water to grow food, wood to burn to provide heat or to build shelters, and materials such as iron or copper extracted from Earth to make cooking pans.	*By the end of grade 5:* All materials, energy, and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not.	*By the end of grade 8:* Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geological processes (link to ESS2.B). Renewable energy resources, and the technologies to exploit them, are being rapidly developed.

ESS3.C: Human Impacts on Earth Systems. *How do humans change the planet?*		
By the end of grade 2: Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things—for example, by reducing trash through reuse and recycling.	*By the end of grade 5:* Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. For example, they are treating sewage, reducing the amounts of materials they use, and regulating sources of pollution such as emissions from factories and power plants or the runoff from agricultural activities.	*By the end of grade 8:* Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of many other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.
ESS3.D: Global Climate Change. *How do people model and predict the effects of human activities on Earth's climate?*		
	By the end of grade 5: If Earth's global mean temperature continues to rise, the lives of humans and other organisms will be affected in many different ways.	*By the end of grade 8:* Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Engineering, Technology and the Applications of Science Core Ideas
(text taken directly from *A Framework for K-12 Science Education,* Chapter 8)

Note: Solving environmental issues can be considered an engineering design problem. Providing students with some of experiences described in this core idea, and discussing how the process can be applied to addressing problems and creating solutions, can help students to see that engineering is not just about building things.

Core Idea ETS1: Engineering Design. *zzz*

ETS1.A: Defining and Delimiting an Engineering Problem. *What are the criteria and constraints of a successful solution?*		
By the end of grade 2: A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. Asking questions, making observations, and gathering information are helpful in thinking about problems. Before beginning to design a solution, it is important to clearly understand the problem.	*By the end of grade 5:* Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.	*By the end of grade 8:* The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (e.g., familiarity with the local climate may rule out certain plants for the school garden).

ETS1.B: Developing Possible Solutions. What is the process for developing potential design solutions?		
By the end of grade 2: Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. To design something complicated, one may need to break the problem into parts and attend to each part separately but must then bring the parts together to test the overall plan.	By the end of grade 5: Research on a problem should be carried out—for example, through Internet searches, market research, or field observations—before beginning to design a solution. An often productive way to generate ideas is for people to work together to brainstorm, test, and refine possible solutions. Testing a solution involves investigating how well it performs under a range of likely conditions. Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. There are many types of models, ranging from simple physical models to computer models. They can be used to investigate how a design might work, communicate the design to others, and compare different designs.	By the end of grade 8: A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. In any case, it is important to be able to communicate and explain solutions to others. Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the model based on peer and leader (e.g., teacher) feedback.

Appendix D. NGSS: Applying Science Practices in Outdoor Science

The *Framework for K-12 Science Education ((See free PDF download at http://www.nap.edu/catalog.php?record_id=13165)* is a progressive vision for science education produced by top scientists and educators appointed by the National Research Council, which served as the basis for developing the Next Generation Science Standards (NGSS). It represents the most current, research-based ideas about how to teach science. At its core are the following guiding principles: (1) children are born investigators and have the capacity to reason in sophisticated ways, (2) focusing on core ideas and practices helps build a more wide-ranging understanding of science, (3) deep understanding develops over time and through making connections, (4) science learning involves both knowledge and practice, (5) connecting to student interests and experience helps to sustain their curiosity and wonder, and (6) all students should have opportunities to learn about and engage in science. The *Framework* describes three dimensions that make up the how and what in science to be taught by the end of high school: (1) Science and Engineering Practices, (2) Crosscutting Concepts, and (3) Disciplinary Core Ideas. These dimensions should be woven together while teaching, so students can develop a more coherent understanding of science that reflects its interconnections in the real world. The *Framework* as a whole is quite educative and thoughtfully written—definitely worth reading and revisiting as instructors are exploring new ways of teaching science.

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

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

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

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

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

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

	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. All models are inaccurate in some way(s), otherwise they'd be the "real thing." Modeling tools are used to develop questions, predictions, and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and make it possible to go beyond the observable and imagine a world not yet seen. *Modeling abilities that we can help students develop at outdoor science school:* • Making drawings or diagrams to represent events or systems. • Using a drawing/model as the basis of an explanation, or to make predictions. • Using different types of models to represent phenomena. • Discussing the limitations of models and suggesting ways they could be made more accurate.	*General Approach:* Food webs, food chains, nutrient cycles, and food/energy pyramids are all different models that can be used to explain some aspect of ecosystems that can't be directly experienced. For example, use a food web to predict what might happen to the ecosystem if wolves were re-introduced, or use both a food web and a nutrient cycle to represent interactions that occur in an ecosystem. Whenever students are exposed to any kind of model, they should be encouraged to come up with things that are inaccurate about the model, and ways the model might be made more accurate. NOTE: If you have students play a predator-prey game, that doesn't necessarily mean that they're doing modeling. Some outdoor science simulation games might be considered models, but only if they are used to make predictions, or if they are used by students to make explanations. It's also important that the model is evaluated for both its accuracies and inaccuracies. *Specific BEETLES activities:* In the *Moon Balls* activity, students use a model of the Sun, Earth, and Moon to explain (and test their explanations for) the phases of the Moon. In the activity, *Food, Build, Do, Waste*, students make a chart that is a model of the inputs and out-puts in the system of a living organism.

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

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

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

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

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

	Description of Practice & Student Abilities	Field Examples & Teaching Notes
8. Obtain, Evaluate, and Communicate Information	Scientists need to be able to communicate clearly and persuasively about the ideas and methods they investigate. Reading, interpreting, discussing, and producing text (all forms of communication) take up the majority of a scientist's working time. Exposure to the language of science is particularly important for students who hear less academic language outside of school than others, or who don't speak English as their first language. Even students who can decode text well may struggle with comprehending informational texts in science. All students need exposure to and guidance about different forms of nonfiction texts, including field guides, diagrams, graphs, etc. Using field journals is an authentic way of providing the opportunity for students to communicate through writing and drawing. *Science text & communication abilities we can help students develop at outdoor science school:* • Reading and using appropriate scientific text, including field guides, diagrams, words, tables, and graphs to communicate their understanding or to ask questions. • Creating scientific text, including writing, drawing, and making diagrams in field journals. • Citing and evaluating sources of information, e.g., *"My source is the Sponge Bob 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 take note of how certain they are based on the source of their information. *Specific BEETLES activities:* During *Discovery Swap*, students draw and record observations and questions about an organism, generating science "text." They also use science text in the form of a key to identify their organism, and a booklet with information on their organism. During a "Cool Organism Convention," they discuss their findings, questions, & ideas with others. During an *NSI* activity, students name the sources for the information they share with the group.

Appendix E. Learning Cycle Template for Activity Design

Nature realia:

Big idea(s) and learning goals:

Once you've selected the nature realia and established learning goals, use this template to map out what students will do at each phase of the learning cycle to deepen their learning. At every phase, ask yourself, "And why would students need to do that?" to make sure the activity is helping students reach the learning goals.

INVITATION

Engage students and activate prior knowledge: *How will you get students engaged with the topic? How will you get students to access their prior knowledge about the nature realia or key concepts? How will you find out what students already know/don't know?* Use strategies like *Turn & Talk*, *Walk & Talk*, or writing to help students show their thinking.

Helpful Prompts:

a. What are some things you've heard about ____?
b. What are some positive experiences you've had with ____?
c. Imagine what it would be like to be a ____?
d. Look around. How many ____ (leaves, squirrels, whatever) can you see from here? What do they remind you of?
e. What do you know about ____?

EXPLORATION

Exploring ideas and nature: *What are questions you can ask to inspire students to explore the part or process of nature? What are questions you can ask that will help them make observations relevant to the concepts you want them to understand better?* This often looks like students making observations in small teams, independent of the instructor.

Helpful Prompts:

a. Go observe as many different types of ____ as you can find, and make comparisons between them.
b. Go observe ____. What can you notice about their structures?
c. Go observe ____. Where are they? Where aren't they?

CONCEPT INVENTION

Making meaning and deepening understanding: *How will you help students make meaning of what they found during their explorations? What content might you introduce to help them deepen their thinking? What misconceptions might come up during the lesson, and how might you help students address them?* This can look like students discussing explanations, accessing information through a resource, or (only occasionally) listening to an instructor.

Helpful Prompts:

a. What are some possible explanations for ____?
b. Why might ____ be similar to or different from ____?
c. How might some of the structures you observed help the organism survive in its habitat?

APPLICATION

Apply learning in a new context: *How will you help students apply the concepts they were thinking about during Concept Invention?* This could include discussions about how the part or process of nature in the activity might occur under different conditions; predictions of what could happen in the future; thinking maps; peer to peer discussion; using a field guide or resource and discuss what students learned, etc.

Helpful Application Questions/Activities:

a. What might happen to this organism if [name a condition] changed?
b. What might happen is if____ was missing from this process?
c. We've learned about 3 different categories of this organism, see if you can identify them in the area.

REFLECTION

Reflecting on learning: *How will you help students reflect on what they learned, and how they learned it?* This can be students discussing what they've learned in pairs, like in Walk & Talk or Turn & Talk. Ideally students will spend time alone reflecting too, like during a Sit Spot and/or doing journal writing. Students have a tendency to just report out facts they've learned, so push them to share skills, abilities, ways of thinking about the world, etc.

Helpful Reflection Questions

a. What helped you to learn today?
b. What surprised you? What made your thinking change?
c. How well did we work together as a team? What could we have done better?
d. What skills did you get better at today?
e. How might you help a younger sibling or friend learn about ____?

Appendix F. NGSS Template

Science and Engineering Practice(s)

For students to fully engage with a practice, it's important they not only use it, but recognize it as a transferable skill. So it's important to point out to students how what they're doing relates to the nature and practices of science. For example, if students are constructing explanations, an instructor might say: "As a group, we just tried to find the best possible explanation given the available evidence. That's what science is all about, but on a much bigger scale." You'll likely use more than one practice during an activity, but we suggest you put special emphasis on one, so students get to reflect on how it helped them learn, and how they might use it in the future.

For ideas on how students might engage in in Science Practices to deepen understanding of nature realia or concepts, see the handout Teaching Science Practices in Outdoor Science Schools, Appendix D.

Chosen Science Practice:

- What do students do to engage in the practice?
- How will engaging with the practice deepen students' understanding of the nature realia, topic, or main ideas? At what phase(s) of the learning cycle will students engage in the practice, and what will it look like?
- What will the instructor do to support students engaging in the practice(s)?
- How does the instructor model the practice(s)?
- What kinds of prior experiences or knowledge would students need to engage in the science practice(s)?
- How do students reflect on the practice(s)—why it's important, how it helps them learn about the world, and how they could use it in other scenarios? How will you know students have engaged in the practice(s)?

Crosscutting Concepts

As with Science Practices, it's important to make the use of Crosscutting Concepts explicit for students by framing them as thinking tools that help deepen understanding. An instructor might say "A lot of what science is about is thinking about Cause and Effect. That might mean looking at something and trying to figure out what caused it to be the way it is, or making predictions about possible effects of some kind of action." Though students might use a few Crosscutting Concepts during an activity, it can be useful to just highlight one explicitly.

For ideas on how students might apply Crosscutting Concepts in order to deepen their thinking about nature realia or content, see the handout Crosscutting Concepts in Outdoor Science Schools, Appendix B.

Chosen Crosscutting Concept:

- How will applying this Crosscutting Concept deepen students' understanding of the nature realia, topic, or main ideas?
- At what phase(s) of the learning cycle will students apply the Crosscutting Concept, and what will it look like?
- What will the instructor do to support students in applying the Crosscutting Concept?
- How will students reflect on the Crosscutting Concept—why it's important, how it helps them learn about the world, and how they could use it in other scenarios?
- How will you know students have applied the Crosscutting Concept successfully?

Disciplinary Core Ideas

Each DCI is complex. Students will not build thorough understanding of a DCI through one activity. During one learning experience students might build some foundational understanding of one aspect of a DCI, and ideally, students would engage in multiple activities focused on the same content. Students need time to struggle with a DCI, and do some discussing and meaning-making around it in multiple contexts. A mere *mention* of the content in a DCI by an instructor during an activity will not lead to student understanding.

Chosen Disciplinary Core Ideas:

- How will students build understanding of this DCI?
- What will students do at different phases of the learning cycle to deepen their understanding of this DCI?
- How will engaging with nature realia help students to better understand this DCI?
- What will the instructor do to support students in deepening their understanding of the DCI?
- How will you know students have successfully developed understanding of this DCI?
- What subsequent learning experiences or activities would be required for students to fully understand this DCI?

Three-Dimensional Learning

NGSS 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) Disciplinary Core Ideas. 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.

- What does “Three-Dimensional Learning” look like in this activity? Or how are students engaging in Science Practices and applying Crosscutting Concepts in order to develop understanding of Disciplinary Core Ideas?
- How are you making the science practices and Crosscuting Concepts explicit for students?
- How will this activity connect to NGSS in other learning experiences within the program? In other words, what are other opportunities in your program students will have to engage in these Science Practices, apply
  Crosscutting Concepts, or learn about subjects related to this Disciplinary Core Idea?
- How will you sequence this activity with other activities?)

Appendix G. Lenses for Activity Review

It's hard to keep every critical factor in mind when designing an activity, so it's important to take the time to methodically look through the activity using different lenses, and make adjustments as needed. Use the questions and suggestions highlighted for each feature to examine your activity and make sure each of these aspects of a well-designed lesson is reflected in the structure, language, and content of the activity.

Student and nature-centered design: How are student ideas and direct observations of nature at the center of this activity?

- Do students have a chance to engage directly with nature?
- Are students actively struggling with ideas during the activity?
- Are they making connections and figuring things out?
- Does your activity involve the right amount of challenge for students (enough to make it engaging, but not too much to make it frustrating)?
- Are there opportunities for students to do meaning-making throughout the whole experience?
- Are there opportunities for students to discuss ideas, both with peers and with the instructor?

Supporting English Language Learners. What strategies will you use during the activity to engage and support English Language Learners? We recommend:

- Using, pointing to, or holding objects when referring to them.
- Including visuals, such as written directions or questions and photos, when there is not a physical representation of something you're talking about to point to.
- Introducing only a few hard words, defining them clearly, and using them repeatedly.
- Providing key vocabulary, definitions, and questions in both written and oral form.
- Including opportunities for students to speak in their home language, imperfect English, or nonverbally.
- Phrasing questions in more than one way, and asking students to say them in their own words.
- Providing lots of opportunities for pair talk.
- Modeling how to participate in a discussion before conducting one.
- Using optional sentence starters.

Equity and inclusion. In what ways will you promote equity and inclusion for all students in this activity? We recommend:

- Offering different ways for students to participate, such as different formats for sharing ideas (pair talk, talk while engaged in a task, nonverbal communication, drawing, writing, small group work, whole group talk, etc.).
- Having students make connections between what they're learning and their prior knowledge and experiences.
- Making connections between the topic and relevance to students' lives back home.
- Providing a chance for students to follow their own curiosity.
- Shifting the direction of the activity to better suit individual groups of students.

- Accommodating students who may be uncomfortable outdoors.
- Sharing norms with students that will help make the learning environment feel safe.
- Providing a common experience that everyone has access to and can learn from.
- Creating opportunities for students to share and debrief their experiences.
- Making sure some students don't dominate discussions, and that other voices can be heard—include opportunities for students who prefer more quiet participation to do that.
- Mixing up teams to create a more positive learning community.
- Sharing your discussion and inclusion goals with students.
- Providing additional support with developing academic language.
- Making adjustments to allow differently-abled students to participate fully.

For more suggestions on how to design culturally relevant curriculum that promotes equity and inclusion, see Youth Outside's Guide to Cultural Relevancy, found here: http://www.youthoutside.org/about/resources.

Assessment opportunities. In what ways are students demonstrating understanding of the main concepts of the activity?As yourself:

- How will the instructor figure out what students are thinking, and what they know/don't know during the activity?
- Are students making their thinking visible to instructors and each other (through discussions, journaling, or other forms of communication) at critical phases of the activity?
- Is there a task at the end of the activity where students can show what they've learned?
- Are there reminders in the write-up for instructors to recognize assessment opportunities, to listen when their students are talking, and to adjust their instruction appropriately?

We recommend the following assessment evidence to collect from student observations and work:

- Successfully engaging in the highlighted science practices.
- Making careful observations, recording accurate information, and communicating observations.
- Following journal prompts and other written responses.
- Distinguishing testable questions from nontestable questions.
- Distinguishing between observations and explanations.
- Actively participating in a productive discussion about the topic.
- Applying what they learned or other evidence of achieving the learning goals.

Accuracy of science content. These questions can help you gauge if the science content is appropriate for your students:

- Is the science content accurate, and is it appropriate for students' grade level?
- What are possible misconceptions that might come up? Are there opportunities for students to see evidence that contradicts misconceptions, and for them to confront and alter their misconceptions?
- Are there opportunities for students to reflect on and develop an understanding of the nature of science (e.g., steps pointing out to students when they are engaging in practices, or reminding them to use tentative language when making explanations)?