BACKGROUND INFORMATION FOR PRESENTERS

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

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

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

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

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

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

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

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

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

> *The overarching goal of our framework for K–12 science education is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (NRC Framework, 2012, p. 1)*