Using the NRC Framework to Engage Students in Learning Science in Informal Environments[i]

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The NRC Framework for K – 12 Science Education (2012) presents a coherent picture of the major scientific and engineering ideas, scientific practices, and cross cutting concepts that all learners need to develop an understanding of to live successful and productive lives as citizens in the 21st century or to pursue further study of science and engineering. It speaks to learners developing integrated understanding of core ideas of science by applying and using these ideas to explain phenomena and solve problems important to them. By integrated understanding I mean that a learner links together ideas in a web fashion that allows her/him to access information for problem solving and decision-making and to connect new ideas to his/her understanding. The framework includes ideas in engineering, as all students will need to understand the design world.

The Framework lists five major ideas that are essential to the design of assessments and learning environments: 1) limited number of core ideas of science, 2) cross-cutting concepts, 3) engaging students in scientific and engineering practices, 4) building integrated understanding as a developmental process, and 5) the coupling of scientific ideas and scientific and engineering practices to develop integrated understanding. What implications do these major ideas have for assessment in informal science setting? Below, I will discuss each of these ideas and discuss what they mean for assessment.

First, the Framework focuses on a limited number of core ideas of science and engineering that are essential to explain and predict a host of phenomena and solve problems. Core ideas are

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powerful in that they are central to the disciplines of science, provide explanations of phenomena, and serve as building blocks for learning within a discipline and in making connections to other ideas (Stevens, Sutherland, & Krajcik, 2009). This focus on core idea avoids the shallow coverage of a large number of topics typical of textbooks (Kesidou & Roseman, 2002; Roseman, Stern, & Koppal, 2010) and allows for students to develop integrated understanding that can be used to solve problems and make decisions.

The informal world of science education hopes to foster several important goals. Reflecting these goals, informal educators wish to assess several critical outcome areas including student motivation and interest in science. At the same time, the informal world does have interest in assessing student understanding of science content. In this case, science content refers to the core ideas of science. Working together and over time, the informal and formal worlds of science education can help learners build powerful and integrated understandings of the core ideas of science.

A second idea used in the Conceptual Framework is crosscutting concepts that consist of major scientific ideas that cut across disciplines but at the same time are essential to each of the disciplines. Systems, size, proportionality and scale, matter and energy, and patterns are examples of crosscutting concepts. At least in the formal world, many of these ideas have seldom been addressed and assessed, with the result that many students have weak understanding of them or do not see how they cut across disciplines. Many learners, for instance, don't see the connection of the energy involved in photosynthesis with the kinetic energy of a moving ball. Like core ideas, cross-cutting concepts are essential to problem-solving and decision making. Core ideas are specific to a discipline, whereas cross-cutting ideas, as suggested by the name, cut across disciplines, therefore are interdisciplinary in nature. To the extent that informal science providers seek to develop content understanding, assessments also should focus on core-ideas and cross-cutting concepts.

Third, the Framework emphasizes that learning about science and engineering involves the use of scientific and engineering practices to engage students in doing science and engineering design. Scientific and engineering practices consist of the multiple ways in which science explores and understands the world, including: 1. Asking questions (for science) and defining problems (for engineering), 2. Developing and using models, 3. Planning and carrying out investigations, 4. Analyzing and interpreting data, 5. Using mathematics and computational thinking, 6. Constructing explanations (for science) and designing solutions (for engineering), 7. Engaging in argument from evidence, and 8. Obtaining, evaluating, and communicating information (NRC, 2012).

Fourth, the framework presents learning as an ongoing developmental process. A developmental perspective purposefully builds upon and links with students' current understanding to form richer and more connected ideas over time (NRC, 2007). A developmental approach guides the development of students' knowledge toward a more sophisticated and integrated understanding of scientific ideas (NRC, 2007; & Corcoran, Mosher, Rogat, 2009). However, growth in understanding is not developmentally inevitable, but depends upon instruction and key learning experiences (including assessments), in both formal and informal environments, to support students in developing more sophisticated and integrated understanding across time (Corcoran, Mosher, Rogat, 2009). This notion of developmental processes has been referred to as a learning progression in the science education literature. If we have learned anything in the last several years, it is the importance of coherently building and assessing ideas over time to help learners form integrated understandings (Roseman, Stern, & Koppal, 2010).

The informal world needs to take this developmental view into account to help build integrated understanding in learners. The developmental view may be especially appropriate for informal learning experiences, since these experiences may be brief or sporadic, but the learning could potentially accumulate over time. Developing clear guides as to the level of understanding we hope learners will develop and providing instructional experiences (whether formal or informal) to help students obtain these various levels is a critical aspect of educational research. As such, developing learning progressions that would allow us to track where students are with respect to core ideas, cross-cutting concepts and scientific practices is an important research activity for the informal world. Within the informal assessment realm, because of the variety of people who visit informal settings, the assessments will need to accommodate a range of levels. However, assessments that blend core ideas with practices such as constructing models, communicating ideas, and presenting scientific explanations, can accommodate a range of appropriate responses.

Fifth, the framework emphasizes that learning about science and engineering involves the coupling or linking of scientific ideas with scientific and engineering practices to build integrated understanding. Convincing evidence exists that suggests that understanding a scientific idea is inextricably linked to the context in which the student develops the understanding (NRC, 2007). As such, the Framework stresses the importance of linking scientific and engineering practices with the scientific ideas both for instructional and assessment purposes. Just as science is both a body of knowledge and the process whereby that body of knowledge is developed, the learning of science is similar: you cannot learn a scientific idea without using it with scientific practices and the converse also holds: you can’t learn a practice separate from the scientific idea. If we want learners to be able to apply the scientific idea, then they need to engage with that idea utilizing a particular scientific practice and if we want students to learn the scientific practice, then we need to use the practice to engage with the scientific idea. In other words, they go hand-in-hand – you can't learn one without doing the other.

From an instructional and an assessment perspective the blending of scientific ideas with scientific and engineering practices has important assessment implications. It implies that you can't assess a student's understanding devoid of a practice and that you can't assess the practice devoid of the understanding. The assessment task needs to measures the learner's understanding of both the scientific idea and the scientific or engineering practice.

Developing assessment strategies to measure practices blended with scientific ideas

How do you write assessments that blend scientific ideas with scientific practices? In my own work with the Investigating and Questioning Our World through Science and Technology (IQWST) (Krajcik, Reiser, Sutherland & Fortus, 2012), we have found that creating what we call "learning performances" is a critical first step in guiding the overall design of assessment and development of assessment items. Learning performances provide a clear learning goal, showing how students should apply the understanding they are developing. We have used the following process for developing learning performances and assessments (Krajcik, McNeil & Reiser, 2008, Shin, Stevens & Krajcik, 2010): 1) identify and elaborate specific aspects of the core idea, 2) unpack the scientific and engineering practice, 3) construct the learning performance, 4) identify the evidence you will need to measure students' understanding as displayed in the learning performance, 5) Write the assessment task and 6) external review. Because of limited space, I will only focus on the construction of learning performances and their use in writing assessments.

Creating learning performances:

Learning performances specify what students should be able to do with a scientific idea. In essence, they articulate the cognitive tasks that students should accomplish with the scientific idea. You can think of a learning performance as a cross between the scientific idea and the scientific or engineering practice. The learning performance clarifies how the scientific idea is used to reason about a scientific phenomenon. Figure 1 is an example of how to construct a learning performance. It combines the scientific learning goal (atoms and molecules are in perpetual motion) with a scientific practice learning goal (i.e. modeling) to develop a learning performance that blends or combines the idea and practice together.

Figure 1: Developing Learning Performance

Scientific Idea crossed with	Scientific practice makes	Learning performance
Atoms and molecules are perpetually in motion. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.	Models are often used to think about processes that happen… too quickly, or on too small a scale to observe directly… (AAAS, 1993, 11B: 1, 6-8)	Students create models of a gas at the molecular level showing how an odor can be smelled from across the room.

Writing the assessment task: A learning performance with specificity guides the developer in writing assessment tasks and also guides what should happen in the formal or informal learning experience. Assessment tasks should engage students in applying both their content and scientific practice to create the desired product. The learning performance should provide a guide for creating the assessment tasks. For instance, using the learning performance written above, an assessment task could be written to ask a student to explain why they can smell fragrances of different flowers. This activity could be part of an outdoor learning experience, in which learners might be asked to close their eyes, take a deep breath and explain how is it that the smell can travel from a flower to the nose. As another example, a learning performance on earth science and evolution could focus constructing evidence-based explanations on the extinction of various species, including dinosaurs. A corresponding assessment item would focus on the evidence that exists for why the dinosaurs became extinct. Students could visit an exhibit, such as the exhibit at NY Museum of Natural History, to collect data to support possible explanations.

A valuable aspect of assessment items that stem from blending scientific practices with core ideas is that students need to do a performance to show what they know. This takes assessment design away from the construction of multiple-choice tests to assessments in which students need to construct products or artifacts that show what they have learned. Another valuable aspect of this type of assessment for the informal world is that the learner will demonstrate more sophistication both in terms of the practice and the scientific idea as he/she learns more and has new learning experiences.

The Challenges and Benefits of Constructing Assessments for Informal Learning Environments

Informal science learning environments typically provide short and isolated experiences, making it challenging to separate what students learned from engagement in the informal environment from other factors that influence learning. A second unique aspect of informal environments is that learners have different goals for visiting informal learning environments and as a result informal learning environments provide many options for visitors. By their very nature, informal environments have choices built into them to accommodate the various goals that people have for visiting. A third unique aspect of informal environments is that individuals with a range of ages, experiences, and backgrounds often visit and take part in these environments. Although these three unique aspects of informal learning environments bring challenges to assessing what visitors or participants learn during informal learning experiences, the use of carefully constructed learning performances along with learning progressions can help alleviate these challenges.

Let me provide an example of how the challenges can provide opportunities for assessment. The first challenge is to develop assessments that measure student learning if the learners who come to informal environments have a range of different experiences. Let's say students are visiting a museum that has an exhibit on the evolution of Homo sapiens. One learning outcome we might want to measure is how well visitors can analyze and interpret changes in fossil records to make claims and provide evidence for how life changed on earth. If informal assessment experts constructed a learning performance that blends analyzing and interpreting data with core ideas from natural selection (from the Framework document, NRC 2011), this could provide individuals from a variety of backgrounds and experiences an opportunity to analyze data and make claims support by evidence. The learning performance might read: Collect and analyze data on various fossil records to make claims supported by evidence about how life has changed on earth. As learners enter the exhibit they could be given a tablet that prompts them to make tentative claims and recall any evidence they might know (of course, this would be done with various scaffolds). As they went through the exhibit, the learners would retain their tablets and at various points be asked to modify their claims based on new evidence and ideas they gather from the exhibit. At the end of the exhibit, the learners/participants would be asked to write a claim and state their evidence. Their claims with their evidence would be uploaded to the "cloud" and could then be analyzed to see what the visitors learned at various points of the exhibit, by examining whether their claims and the evidence they provided changed at these various points. If we had learning progressions associated with natural selection, we could then see how far along the learning progression a learner might have progressed as a result of going through the exhibit. The benefit of such an assessment is that it would make the exhibit much more interactive, helping learners to focus on the important aspects of the exhibit. It is also important to note that learners' claims could be co-constructed with other learners/visitors, providing a collaborative nature to the models they collect. Although this example needs to be elaborated, it does illustrate that using learning performances, learning progressions, and technology tools provides opportunities to measure learners' understandings of core ideas and scientific practices in informal science settings and represents an approach that would alleviate the challenge of assessing a range of learners who visit informal settings. This example does entail visiting an exhibit that goes beyond just a five minute exposure, but we also know that learning outcomes seldom occur in such short visits. As such, this example assumes that informal science educators have a goal of helping learners or visitors to learn core ideas and scientific practices. Also notice that this particular example entails important an important idea about the nature of science – claims change with new evidence. Although this example is from a museum setting, we could also dream up other examples from outdoor science learning centers.

Another challenge of assessing in informal environments is providing choice, as individual learners come to museums or other informal settings with different goals. As such, when learners take part in informal science environments, they want to have choice. This choice factor is one of the strengths of informal environments, but also a challenge if we want to measure learning outcomes. How can we design assessments when learners are free to choose what to focus on? First, it is important to realize that all informal environments limit participant choice to some extent, because each is a particular learning environment – a museum exhibit focuses on a particular idea and an outdoor learning exhibit might focus on habitats or local fauna. For instance, in a museum, the exhibit could focus on minerals, how an organism develops through its life span, a history of the evolution of the solar system, how musical instruments produce different sounds, or the history of a geological region to name a few. Although each exhibit offers choice about where and how long to focus within the exhibit, each is limited by context. As such, we could develop a variety of learning performances associated with each exhibit. Different learners might focus on different learning performances, but we could track their involvement. For instance, learners could be asked to write a question they want to answer as a result of visiting the exhibit and given a tablet to record their question. If a visitor doesn't have a question, scaffolds could be use to prompt these questions. For instance, sentence starters could be used. These questions could be mapped back to the learning performance. Participants could also be asked to gather data associated with answering their questions. The evidence could come in a variety of forms from students taking photos, audio recording a comment, making a drawing or writing a comment. As the end of the exhibit, the participant could be asked to answer their initial question and support the response by using their evidence. Such an approach to assessment could accommodate learners with different goals, providing them choice on what they focus on as they engage in the activities of the exhibit.

Interestingly enough, such an approach is not out of reach. Professor Christopher Quintana and colleagues at the University of Michigan are designing such a tool in which learners, before visiting the informal environment – a museum or field trip to their local stream – pose questions and then during the visit to the informal environment collect data to answer their questions using an ipad, (Zydeco Project, Quintana, 2010).   This approach, in which learners ask their own questions that relate to the exhibit, maintains a key strength of informal science learning—participant choice--while at the same time provide a way of assessing learning.

Although it is likely that, in such an approach, some participants will pose unanticipated questions that might not map back to one of the learning performances developed, those participants' learning can still be tracked through the use of the tablets--especially their use of evidence to answer questions and how their ideas change over time. Moreover, these unanticipated questions might be used to frame new learning performances, building the pool of learning performances and how learning might respond over time.

Potential of the Assessment Strategy for Informal Systems

The United States science curriculum has suffered from being disconnected and presenting too many ideas at too superficial level, often leaving students with disconnected ideas that cannot be used to solve problems and understand phenomena they encounter in their everyday world. By focusing scientific ideas (core ideas and cross-cutting concepts) blended with scientific and engineering practices to construct learning performances and resulting assessments, informal and formal science education have a great opportunity to help build integrated understanding. Because fewer scientific ideas are presented and developed across K – 12-science curriculum and blended with the use of scientific practices, there now exists an opportunity to build curriculum and assessments in a coherent manner. The informal world and formal world need to work together to make this vision a reality. As I have argued, informal science educators who are interesting in building integrated understand can do so by focusing on core and cross-cutting scientific ideas blended together with scientific practices to form learning performances that can guide development of assessments and various exhibits. I want to acknowledge that, particularly within the informal world, the boundary between instruction and assessment is very permeable and transparent. But this is a positive aspect of the informal world. Assessment and instruction need to work together toward common goals for student learning.

I recognize that the informal world of science education seeks many outcomes including raising interest and engagement in science. One of those outcomes is also student learning. However, assessing what students learn by engaging in the informal world of science education does bring challenges, but these challenges also bring opportunities and push our creativity. As I have tried to outline, learning performances can be constructed that can map back to learners with a variety of experiences and we can also construct a variety of learning performances to accommodate the various goals learners/visitors bring to the informal environment.

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