**Designing a learning sequence**

The approach of NGSS centers on sense-making of phenomena. So, each cycle of learning should begin with one or more phenomena that provokes questions. Then, students should be given tasks that require them to engage in the appropriate science and engineering practices to build their understanding, through inquiry, so that they are then able to complete some version of the performance assessment. Common core dialogue, reading and writing prompts help students make sense of what they’re learning, and should be specifically and intentionally incorporated into learning.

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| **Targeted concept** | **Learning Tasks around Phenomena** | **Evidence of learning (how will students show/demonstrate what they are learning?)** | **My reflection on the task after implementing. Where do I need to insert or remove scaffolding** |
| Pieces of matter can come off other matter, such as wind and water ‘rubbing’ off particles of rock to make sand.  Earth features, such as canyons, cliffs and other rock structures are therefore due to a ‘subtractive’ process of taking away particles, not an additive one where particles are piled on top of each. | 1. Students will physically observe and investigate a piece of sandstone, and a bit of sand, and then create a diagram of how they think wind and water effects stone, and how sand is formed. Students do this both in a group, and then individually into a notebook or onto paper.   Teacher questions include: what do you think happens to the rock to make the sand? Did the sand or rock come first? How could the sand be turned back into the rock?   1. Students view images of unique rock structures, choose one in a group and try to figure out how it got to be that way.   Teacher questions similar to those for the first task. | Students’ diagrams, best done on visible surfaces such as chart paper or dry erase boards, will provide an initial idea for how students are thinking about this.  As students collaborate on this model, they will be informally exchanging ideas. You want them to be able to do this without feeling much pressure to defend them, so that ideas can change and be modified fluidly.  For the second task, some students tried to simulate the formation by building, using an additive model to prove it could be done. They ran into interesting challenging that left them puzzled. | When I first did this, I was not prepared for how many students (about 30%, about 10) would think that matter particles would just add to each other to make rocks and rock structures, rather than rocks breaking off from larger pieces of solid material, and erosion creating interesting sculptures.  The model for these students changed slowly, and I learned to ask more explicit questions about what role they thought gravity played, and how matter might add up this way. Only when they experimented with stream tables did they get convincing evidence that that their additive model didn’t accurately explain the results.  From this first experience, I decided to draw out their thinking more explicitly and intentionally at the beginning, to show the students that there were a couple of different competing models at work in our class, which is usually how science works in the real world. |
| Air and water particles wear off rock particles, and can make structures like the grand canyon. These processes take longer than most of us can comprehend. | 1. Students view a video and images of the Grand Canyon, and begin a conversation about how it formed.   Teacher Questions: what do you notice about the structure of the grand canyon? (layers, colors).  Why are there different layers and how do you think they were made?  Which layers are the newest and which ones are the oldest? How do you know (students usually reason using gravity, OR use an analogy they readily understand.)   1. Using the stream tables, students design and carry out investigations that control rates of water, and try to engineer rivers, canyons and other features we’ve been studying.   Begin with a very simple task, such as ‘how can you make a river in the sand?’ and ‘what happens if the water rates increase or decrease? By introducing specific tasks, students will figure out responses, and learn something about experimental design as well. | Students’ questions on viewing the Grand Canyon tell you how deep there thinking is going.  Their conversation about how the canyon formed will tell you how their models have been affected by the work with sand and rocks.  The stream table work shows you what kind of questions students are asking, how they are controlling variables (without being explicitly told to do so) and how they are handling data.  During these investigations, the teacher serves as the moderator and facilitator, probing students questions so that they ask the most focused questions possible, and asking whether their experimental design will get them the data they need. | The Grand Canyon conversation at this point was very much informed by the work done previously. As students studied the layers, they easily reasoned that the bottom layers were the oldest, and that the layers were there before the river, since the layers are the same on either side and that wasn’t likely to happen unless they’d already been there. From their responses I began tracking their claims and reasoning on chart paper, mostly to emphasize that they were using other knowledge to reason about these phenomena.  Without the ability to show evidence, through use of the stream tables, in support of these ideas, several students would not have changed their additive models.  Since 4th graders are just beginning to think in terms of variables in an experiment, I saw quite a bit of differentiation in how students performed open-ended tasks, and went back to beginning with a very structured one about creating a river, so that all students would be developing the same model. Then, as groups showed competence in that and demonstrated evidence, I challenged them to ask other questions. |
| The phenomenon of erosion happens at a small scale (one particle at a time). It is invisible to us over short term time scales, but even in our lifetimes we can see the process at work.  Extrapolating large scale features we can image that large scale time frames are involved. | 1. After work with the stream tables, students are challenging to consider how the Grand Canyon might have been formed, including how much time it might have taken. 2. Students now engage in a reading piece, with a guided note-taking graphic, which is more of a reflective task about what they’ve learned. In addition, they are now identifying the vocabulary terms that used to describe the phenomena and processes they’ve encountered. By this time, they will have heard the terms from the instructor and will have started using them orally themselves and in writing on their group work. Reading them will solidify the terms. | Students work in modeling the formation of the grand canyon should show direct references to erosion, and students will usually show a sequence. If they are able to depict water taking away particles from a surface, pushing them against each other and in front of other water particles, and that this happens over a long period of time, students will be demonstrating their comprehension of this model for how land features form on earth.  The guided graphic provides evidence of reading and understanding. | I wasn’t surprised to learn that 4th graders have little sense of the time scales needed here. Those who knew it was a long time quote millions of years, without really knowing what that meant. Others cited thousands. I realized that absolutely times scales won’t make any sense to students at this age, but relative ones do.  It might make sense to do a time-line activity, providing students with events related to the history of earth and asking them where they think they would go on a scale of Earth. I haven’t tried this yet. More interesting would be to ask them why they have that timeline in their head. |
| Assessment | Students complete the first concrete assessment, describing what will happen to objects when subject to erosion.  The second piece is intentionally more open-ended, to allow for multiple representations and depth of models, to show the limitations of students and to allow those who have a deeper knowledge to express it.  A project-based learning task would be appropriate here as well, using the model to explain or predict outcomes such as flooding, and extreme weather events, or to devise engineering solutions for such events. |  |  |

**Figuring out the NGSS Performance Expectations and the science behind them.**

What are the fundamental scientific concepts and model constructs underlying the PEs you are addressing? What do students need to know to get to where they need to be?

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| **Science Idea or Concept** | **Underlying Conceptual or System Model that the instructor needs to understanding** | **Which parts do students need to understand?** |
| Sand comes from the breaking apart of stone | All matter is made of small bits of matter, or ‘particles.’ Not only is everything we can see, touch, feel, or investigate made of this matter, but it all breaks down somehow, either through physical means (breaking off) or chemical (breaking apart and recombining.  Moving particles of any kind carry energy.  Air and water are made up of these tiny particles, so that when either substance hits against something like rock, it will, over time, break off tiny pieces of that rock, as the energy from the particles is transferred to the rock. | Air and water are made of stuff, or matter.  When air, water or a hand hits against something like sandstone, little bits visibly break off. This also happens with other types of rocks, even though you may not see it. |
| Breaking down rock or changing its shape through the weather of water and wind by small particles takes LOTS and LOTS of time | The atoms and molecules that make up matter are so tiny that we can’t see them. We can calculate how much time it will take for enough particles to erode off a rock to create a change that is visible to human eyes.  We can then calculate how much time it would take, given intermittent and differently intense weather episodes, for rock structures to be formed or canyons to be carved out. | The timescale for small events to add up to visible ones is greater than most of us can comprehend. |
| Water carves out rivers in meandering ways, and while we recognize wind’s effects, they’re less well understood. | The meandering curves of rivers are due to the physics of the water particles themselves. Wind motion is more chaotic, subject to other factors such as velocity, temperature and duration. | We can recognize patterns in water erosion, and some in wind, although there are definitely outliers that are hard to understand. |

**Identifying and Explaining phenomena**

A phenomenon is any event, incident or state in the physical world that evokes questioning and wonder. It is something about the world that offers a mystery or puzzle that we want to solve, and we know we want to solve it because we immediately begin asking questions. Phenomena can include all manner of observable aspects of the world, such as whether events, rocks, a chemical reaction, etc. But phenomena can also be images or video or even descriptions of all these things, or data that captures something about an event. Sources for finding these phenomena include text and images on the internet, conversations with scientists, student observations, and data sets. As long as it relates to the natural world and prompts questions, it can be a phenomenon.

The challenge is to choose phenomena that will simultaneously engage students as well as narrow their work so that sense-making can happen.

What are some appropriate phenomena that relate to the concepts and models I identified earlier?

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| **Concept** | **Phenomenon that will illicit questions and provoke inquiry** | **Resources needed to use the phenomenon in the classroom (i.e, xeroxed data sets, lab set up, etc)** |
| Matter is made of particles; wind and water are matter; wind and water can break down sandstone into sand | Providing samples of sand, and of sandstone, and inviting students to find different ways for breaking off sand particles. | Sand samples  Sandstone samples  Hair dryer (to simulate wind)  Running water (to simulate river) |
| Rock and canyon formations happen when rock or land exists, and other forces erode particles from them slowly over time. Rock and canyons don’t grow up from the earth. | Images of Rock structures, through video and stills. | Slideshow video  Still images printed in color, in protected sheets  Dry-erase boards or chart paper  Stream tables, and all their parts |

Questions for the Instructor for help in Lesson Design

**How will you introduce the phenomena and how will students be prompted to generate and collect.**

The biggest ideas in this unit have to do with uncovering misconceptions that rock formations somehow form by particles building on themselves, rather than a rock having parts broken off one at a time. Similarly, some students will have to work to accept that an area like the Grand Canyon first existed as layers of rock strata, which built up over time, and that then water flowed on top of it and slowly wore away particles until the river formed a canyon.

By asking students to create initial models about simple phenomena, such as where sand comes from, you use an intuitive idea about sand particles breaking off, which they can see and feel and depict, to help them extrapolate to more challenging phenomena and even those that geologists have trouble explaining.

Because all of these phenomena prove engaging for 4th graders, as they are puzzles they’re not sure how to explain, it’s imperative to build in time for questions that can be recorded somewhere. Students will likely answer most of them through their study, but you also may want to revisit them.

**What tool will you use to uncover initial thinking from students? Examples might include an agree/disagree tool, a group modeling task, or an informal writing prompt.**

As with any introduction to new topics, creating a tool to find out where students are is a good idea. Although we don’t have one yet for this unit, I would like to use an agree/disagree tool with statements like, ‘the grand canyon formed over a few years,’ or ‘sand on beaches mostly comes from the oceans’ or ‘this rock structure formed as other rocks were dumped onto it.’ Such statement elicit where students are and allow for good debate at the beginning.

In this unit, we use a number of group modeling tasks, or asking to students to make their own thinking visible as they explain how some phenomenon might have happened.

**What do you think students will originally ask and think about this idea? Try to anticipate what students might say, but note that you will likely always be surprised at the range of different ideas.**

After you teach a unit like this once, you’ll have a good idea what students might say and ask. Typical questions around these phenomena might include:

* How does sand get to beaches?
* What is sand made of?
* Where does sand come from?
* What are rocks made of?
* Where does the water come from that makes rivers in canyons?
* How old is the Grand Canyon?
* Why are there different colors in the layers of the GC, like in cake?
* If water and wind do this to matter, why aren’t there more weird rocks?

**What will I do for students who are deficient in prerequisite ideas for this level? What review can I build in that work for all students, or how can I differentiate so as to meet all needs?**

Consideration of this question is to remind the instructor of all the ways that differentiation is happening. In the unit outline, students are asked to complete tasks in ways that allow for individual learning. Maintaining individual notebooks, explaining and diagraming one’s understanding of a phenomenon, carrying out an investigation designed by students are all ways that students can access the material. As students engage in structured dialogue, they gain access to what other students know and are able to fill in gaps that way.

**How will you include common core communication strategies into your lessons?**

Structured dialogue, writing prompts and directed notebook or modeling assignments, as well as the incorporation of a specific reading text and a structured guide to accompany it are all intentionally incorporated to help students advance their communication skills in this unit.

It is helpful to have various strategies ready to work into a lesson sequence, and to identify assessment prompts before beginning a lesson outline.