



Phenomena-Based Instruction in the K–12 Classroom

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Introduction

Before entering formal learning settings, children have had a variety of direct experiences with their physical environment thanks to their parents and caregivers (National Research Council, 2007)—hearing sounds of animals, experiencing rain, splashing in puddles, dropping objects, feeling the sun, etc. Children are naturally curious about the world and learn a lot just by participating in everyday activities and observing what is happening around them. Their knowledge may not be deep, but they have had a wide range of observations and interactions by the time they begin school.

Parents are instrumental in continuing to provide opportunities for their children to interact with the world at all ages, and a rich, formal science education can also build on this natural sense of wonder about the world and its happenings. Teachers can spark a desire to learn more. Personal interests, experiences, and enthusiasm are critical for sustaining the learning mindset embraced by young children. The nature of science is to deepen our understanding of the world, especially about observed events we are motivated to explain. Schools must provide the context for students to continue adding to and refining their prior learning.

In recent years, science education has transitioned from conveying facts-based knowledge to a model of learning that is based on active, student-directed inquiry. The writers of *A Framework for K–12 Science Education* (2012) proposed a vision in which all K–12 students actively use science and engineering practices and apply crosscutting concepts to deepen their understanding of core ideas. Students engage in this three-dimensional learning by asking relevant questions, solving genuine problems, and acquiring tools to use in their future careers and lives.

Next Generation Science Standards (NGSS) (2013), written in response to the *Framework for K–12 Science Education*, focus on students using science and engineering to make sense of observable events, or phenomena, in the natural and designed worlds. Phenomena provide a springboard for teachers to build on students’ natural curiosity and encourage active learning (Achieve, 2016). Students are challenged to figure out why or how phenomena happen and to apply that understanding to solve real-world problems. Learners work much like scientists and engineers. Through the process of working, they gain a deeper understanding of valuable information.

What Are Phenomena?

The seemingly magical, real-world happenings experienced by young children are examples of phenomena and can be explained scientifically. The word “phenomenon” refers to an observable fact or event occurring in the universe. Most phenomena are not especially flashy or unexpected, but rather are everyday occurrences. Examples include weather, changing seasons, patterns of stars, water boiling and freezing, soda fizzing, fruit ripening, and lifecycles of plants and animals, to name a few. Scientists work to explain phenomenal phenomena, but most phenomena are less remarkable.

In the classroom, it is not possible for all phenomena to be experienced or observed firsthand. In these cases, representations or models of natural occurrences can act as surrogates for direct experiences. For example, students may examine a set of data to learn more about climate change or use a model to understand our solar system. When it isn't feasible to personally observe a phenomenon, watching a video or working with a model can be an effective substitute for the real thing.

Students of all ages can use phenomena, both inside and outside the classroom, to generate questions, solve related problems, and make sense of their world. Phenomena can serve as the initial hook to engage learners. They can also be used as the driver in a lesson-sequence to lead students to a much deeper understanding of science.

Penuel and Bell (2016) point out that not all phenomena are equal; some are more salient and better suited for use in classroom environments. They consider phenomena to be “anchors” if they exhibit certain qualities. Anchor phenomena build on everyday or family experiences and are compelling for students. They are complex enough that students cannot explain them or design solutions to related problems after a single lesson. Anchor phenomena require students to use reading, writing, communication, and mathematical skills to explain them. While exploring anchor phenomena, students develop an understanding of science and engineering practices, crosscutting concepts, and disciplinary core ideas covered in multiple NGSS performance expectations.

A Teacher's Role in Using Phenomena

Teachers play a critical role in achieving the student-driven science education envisioned in the *Framework for K–12 Science Education*. They have flexibility to choose from a variety of pedagogical techniques, sequences of activities, and topics. To provide an equitable education for all students, teachers must build on the interests and curiosity of their students and encourage full engagement and participation from them, so that all students are motivated to learn.

Teachers must determine which anchor phenomena to use with their students. If the point of using phenomena is to drive instruction and help students deeply engage in science, then the phenomena that are used must be culturally and personally relevant to their students. Selected phenomena should highlight the notion that science ideas can explain aspects of the real world or aid in designing solutions to problems that matter to students and their communities.

Students in classrooms across the country—or even across a single classroom—won't have identical backgrounds or relate to phenomena in the same way. Teachers need to consider diverse perspectives when choosing phenomena and be prepared to support student engagement in different ways. For example, teaching students in Wisconsin about earthquakes would be less relevant and less likely to grab students' attention than teaching about thunderstorms. Teachers can select one or two anchoring phenomena to reach instructional targets and encourage students to identify related phenomena that are meaningful to their own lives. It isn't necessary to spend equal amounts of instructional time on all phenomena introduced in a learning sequence, but it is important to highlight some that students have personally experienced.

It's also important to provide students with opportunities that allow them to dig deeply into a phenomenon to uncover core science ideas they are expected to learn. Watching a model of a volcano explode can be an exciting activity, but it doesn't necessarily help students understand the natural and geologic mechanisms that cause the formation of landforms due to volcanic activity. Teachers should feel free to use discrepant events, but phenomena need to go beyond engaging students. They need to drive units and keep students working to figure out scientific explanations or solve problems.

Shifting to Phenomena-Based Teaching and Learning

In phenomena-based instruction, learners make sense of intriguing phenomena using science practices, themes, and facts. As students learn new information and develop new skills, they construct explanations for the phenomena they are investigating and solve problems applying their new understanding. This shift in instruction calls for students to figure out why and how an event happens rather than simply learning facts and details about it. Students' interactions with phenomena encourage them to make sense of the events. This is a new way of thinking about science learning and may not necessarily be the way in which teachers learned themselves.

Willard compares phenomena to breadcrumbs (Shelton & Willard, 2017). He encourages teachers to sprinkle them out at selective times, just as Hansel did with breadcrumbs in the familiar fairy tale, and then use them to guide students as they make choices about various learning pathways. There will not be enough time to investigate all possible phenomena that surface in a learning sequence, and students will need help navigating forks in the road to move forward in productive directions.

When using phenomena-based instruction, teachers can follow a series of steps to plan and implement lessons. Here is a sequence to consider:

1. Review the NGSS performance expectations for the grade level(s)/courses(s) you teach.
2. Reread the Disciplinary Core Ideas (DCIs) that your students are expected to know.
3. Brainstorm phenomena connected to the DCIs that are interesting and relevant, can be explained by your students, and will anchor their learning. Do this with a colleague, if possible.
4. Choose an anchor phenomenon that seems well suited to your situation. Think about questions the students might ask when observing it.
5. Analyze the utility of your existing lessons to see if you will need to develop anything new or if there is something you have used in the past that will work with the chosen phenomenon.
6. Plan for assessing students' understanding of the phenomenon.

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7. Plan and sequence possible lesson activities in which students:
- Observe or experience the phenomenon
 - Engage in exploratory discourse, noticing and wondering things about the phenomenon, and then they share observations and ask questions
 - Try on ideas as they develop initial models of what they think is happening or try to explain the phenomenon
 - Use science and engineering practices to try to answer a driving question about the phenomenon. For example, students can conduct science investigations and analyze data they collect
 - Create or refine their explanations/models of the phenomenon
 - Learn more about existing scientific theories behind the phenomenon by reading, interacting with an expert in the field, etc.
 - Revise their explanations and models as they learn new information. They incrementally build models to add on to their explanations of the phenomenon
 - Share explanations/models and move to a class-consensus explanation/model for the phenomenon
8. Review the plan for assessing students' understanding of the phenomenon, revise if needed, and complete the assessment.

Students build their ideas piece by piece, over time. This process of inquiry is repeated multiple times during a unit and is sometimes referred to as the storyline of learning. Teachers support and guide students as they question, figure out, and fit pieces of the puzzle together.

An Example of Phenomena-Based Learning

I recently led a facilitation for a group of teachers and informal educators in which we explored phenomena and what it means to use them in instruction. Because it was October, and we live in Wisconsin, it seemed natural to think about the fall season and the numerous observable events that occur that time of year. I chose the anchor phenomenon of leaves changing color, and we worked together to figure out how and why some leaves experience a color change. Most of us hadn't thought very deeply about the science behind this event, even though it occurs annually, and we had observed it for decades.

As we informally talked about leaves during the exploratory discourse portion of our inquiry, we generated many questions about leaves related to the phenomenon. We wondered why all leaves didn't change color, why some leaves turned yellow versus orange or red, how leaves knew when to change color, and if the shapes of the leaves played a role in the color-changing process. We were also curious about where else in the United States this phenomenon occurs.

We did a simple chromatography investigation to find out what colors were present in the leaves we were examining. This didn't help us explain why leaves change color, but we found out that although different colors were present in leaves, not all of them were visible at the same time of year. We were all engaged in the inquiry process, and some participants were driven to do more investigating after our session together.

Our endeavor to explain the phenomenon of leaves changing color in fall led us to talk about other fall phenomena. We discovered that there was much more to explore about the season. Someone brought up the migration and hibernation of area animals, and we wondered how they knew what to do and when to do it. We also pondered where the animals went and whether they stayed in the area or traveled far away. In Wisconsin, our growing season ends in fall, and that sparked an interest in seeds, plants, and the ripening process of fruits and vegetables.

A big takeaway for us was that phenomena are all around us, all the time. It wasn't challenging to identify them, it didn't cost much to investigate them, and it wasn't difficult to find online or print materials to learn more about them. Through the process of exploring one phenomenon (leaves changing colors in fall), we realized our students would benefit from learning in this way. We wondered, though, if a phenomena-based learning sequence would align with the NGSS content that students need to learn. We decided it's not an all-or-nothing game.

We were also reminded that observing and explaining phenomena is not something reserved only for school. Parents and other caregivers can play a critical role in encouraging and supporting their children's science learning at home and in their community. Teachers can cultivate partnerships with parents to encourage and support science learning. Providing positive, safe environments at home and in school can encourage children to observe, ask questions, experiment, and seek their own understanding of phenomena.

Conclusion

A recent position statement, adopted by the National Science Teachers Association Board of Directors, calls on stakeholders in science education to adopt and implement three-dimensional science education standards such as the NGSS. Phenomena are to be used to engage students in three-dimensional instruction, and explaining phenomena using evidence and/or designing solutions to problems is the central focus of science instruction. (2018)

In phenomena-based instruction, students can actively seek solutions, design investigations, explain what they want to explain, and ask new questions of their own. From plants growing to the position of the sun in the sky, teachers, students, and their families are surrounded by a rich store of phenomena from which they can draw inspiration. These occurrences offer never-ending possibilities for lessons that will spark students' interest, questions, and learning, helping them not only learn science but become scientists.

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