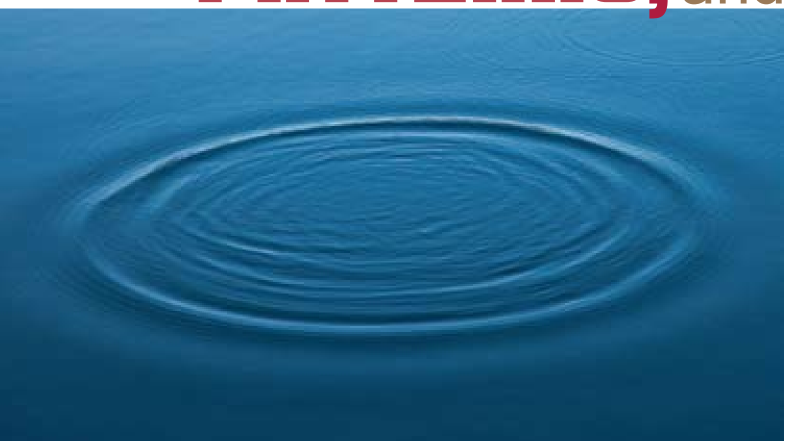
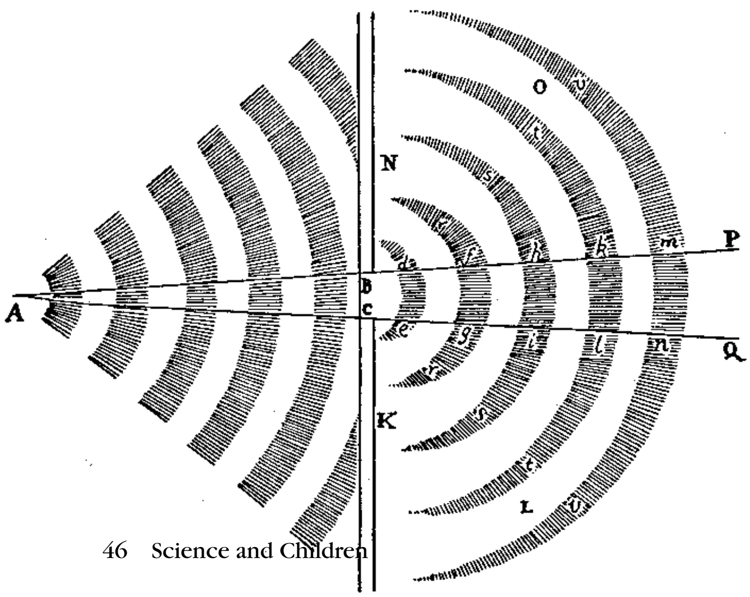
Experiences,

Patterns, and



Explanations



Make school science more like scientists' science

By Kristin L. Gunckel

Second-grade students busily tapped their tuning forks on desks, chairs, and books in the classroom. Holding the tuning fork close to his face to hear the hum, one student jumped back and sported a surprised look from the tickle he felt on his ear. Another student dipped her tuning fork into a plastic cup of water, only to be thrilled to see the water splash right out!

In an activity sequence that took place over several days, the class learned about sound and how people hear sounds. Following each activity, students engaged in whole-group sharing sessions and individual journal-writing sessions that were designed to help them see the patterns that emerged from their explorations. These students were engaging in many experiences with phenomena related to sounds. However, the explanations they were using for how we hear sounds were not explanations they invented or discovered on their own. They were also not explanations that they had memorized for a test. What distinguished the learning that took place in this classroom was the purposeful attention that the teacher paid to help her students recognize the patterns in their experiences. The activities were carefully chosen to illustrate these patterns. In this article, I describe how the Experiences-Patterns-Explanations (EPE) model of science can be used to help students connect explanations to patterns in experiences.

Scientists' Science

Finding patterns in experiences is an important scientific practice (Anderson 2003; Sharma and Anderson 2009). Scientists' work involves explaining how our world works. To do this, they take the many seemingly unconnected experiences that we encounter in our lives, find the patterns in all of these experiences, and develop explanations (called *theories* and *models*) for these patterns. Powerful theories can explain many patterns. In all of science, there are only a small number of powerful theories that account for many patterns drawn from millions of experiences. For example, the mechanical wave theory explains many patterns in our experiences with sound. Wave theory explains how sound travels from one location to another, why there is no sound in a vacuum; variations in pitch; and harmonics, resonance, and dissonance in the sounds we hear. Each of these patterns, in turn, is supported by millions of individual observations made by scientists over many years of scientific work.

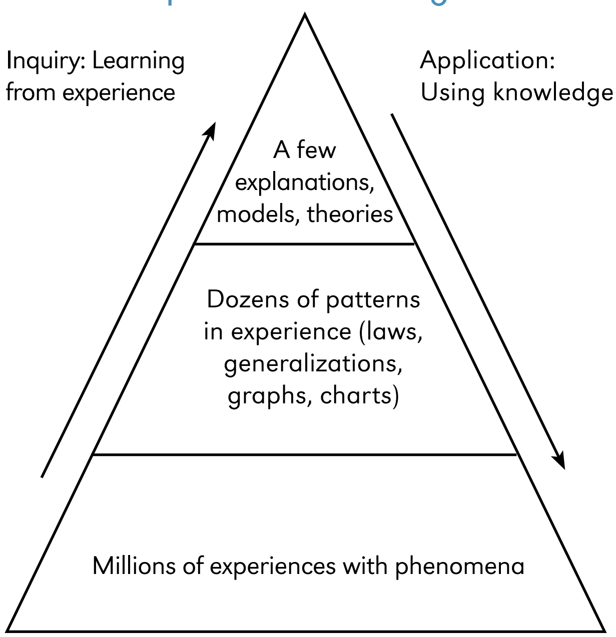
The EPE triangle represents scientists' view of science (Figure 1; Anderson 2003; Sharma and Anderson 2009). The millions of observations and data points form the base of the triangle, the patterns (including laws and generalizations) derived from these experiences form the middle of the triangle, and the few theories that can account for all of these patterns and experiences form the apex of the triangle.

Scientists use two important practices: inquiry and application (Anderson 2003; Sharma and Anderson 2009). On the left-hand side of the triangle, inquiry is shown as learning from experience. Scientists find patterns in millions of experiences with phenomena, then develop a few explanations to account for those patterns. The mechanical wave theory developed over centuries. The Greeks made many observations about phenomena, such as vibrating strings. Later, the Romans made connections between patterns of sound moving through air and waves moving away from a pebble dropped in water. The work of many 18th- and 19th-century scientists contributed new observations and new patterns. Using creativity and ingenuity, scientists proposed explanations for these patterns that coalesced into the mechanical wave theory to explain sound. It is important to note that the development of scientific theories is not a linear process, as scientists return to the data many times to test their ideas. The patterns emerge from the data, but the explanations require testing and retesting of hypotheses as old explanations are thrown out and new explanations are proposed.

Engaging in inquiry is not the only thing that scientists do. They also apply the explanations that they develop to understand other phenomena or experiences. Scientists and acoustical engineers use mechanical wave theory to explain such phenomena as sonic booms or to design concert halls or highway sound barriers. This top–down process of application is shown on the right-hand side of

Figure 1.

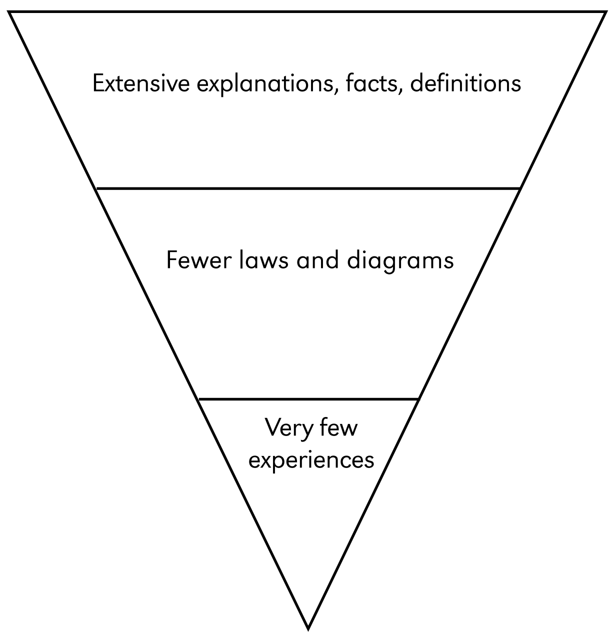
"Scientists' science," the Experiences-Patterns-Explanations triangle.



(ANDERSON 2003; SHARMA AND ANDERSON 2009)

Figure 2.

Traditional school science triangle.



the triangle in Figure 1. Often, the process of application leads to the collection of more observations, which may lead to new questions and the recognition of new patterns. In science, inquiry and application work together.

School Science

Contrast scientists' science with traditional school science. School science necessarily simplifies scientists' science because students do not have the background experiences to engage in the complex conversations about data in which scientists engage. However, in trying to simplify scientists' science, traditional school science can limit learning to facts, diagrams, definitions, and isolated process skills (Sharma and Anderson 2009). School science has begun to move away from this scenario, but there is still progress to be made.

The EPE triangle for traditional school science looks reversed from the scientists' science triangle (Figure 2, p. 47). There are many explanations to learn and some laws and generalizations (patterns) to memorize, but few experiences are provided to help students understand the basis for the explanations. There is no place on the triangle for inquiry or application practices. With few experiences available, students are unable to recognize patterns and are left with isolated facts that seem to account for nothing in particular. As a result, students have few ways to use traditional school science to make sense of the world. One goal of science education should be to provide students with the sense-making tools that scientists' science offers and provide students with opportunities to engage in the inquiry (learning from experiences) and application (using knowledge) practices that characterize scientists' science.

Identifying Patterns

At our sound stations, students explored whistles and drums and noticed that something moved when each instrument made a sound. Students made drums by covering the top of an empty open coffee can with plastic wrap and securing the plastic wrap with rubber bands. The students then observed what happened to rice on the surface of a drum when the drum was hit with a drumstick. Later, they watched what happened to the same rice when a nearby drum was hit with a drumstick.

They used the rice drums to more carefully describe these movements. The students noted that the tops of the drums moved up and down and the teacher introduced the term *vibrations* as a label for these movements.

The teacher then engaged students in an exploration to help the students see the pattern of vibrating objects making other objects vibrate. Students were instructed to gently tap tuning forks on different objects throughout the classroom. (Tuning forks can be borrowed from the music teacher or purchased online for approximately $20.) Students were to record in their journals the names of the objects that they tapped their tuning forks against and describe what happened.

Following the experiences with phenomena, the teacher carefully guided student discussions to help them recognize the patterns in their experiences. If students did not arrive at the patterns as a group, the teacher stepped in to make the patterns clear. For example, after exploring plastic whistles, drums, and tuning forks, the teacher said to the students, "We've had vibrations happening to us a lot. So, what happened with the whistle?" The students replied in chorus, "It vibrated." The teacher asked, "What happened with the drum?" The students again answered in chorus, "It vibrated." The teacher then asked, "What just happened with the tuning fork?" Once more, the students answered, "It vibrated." The teacher concluded, "There is something with sound that involves vibrations." Students needed to understand what the patterns were before they could use the patterns to explain how people hear sounds.

By the end of the unit, students understood that sounds are produced by vibrating objects and that one

Figure 3.

An Experiences-Patterns-Explanations table for investigating how we hear sounds.

Experiences	Patterns	Explanations
• Blowing whistles • Observing drums • Making rice drums • Exploring tuning forks (one tuning fork and two tuning forks) • Exploring cup phones	• Things that vibrate make sounds • One thing vibrating can make another thing vibrate	Example: When a drumstick hits a drum, the drum vibrates. The vibration makes our eardrums vibrate and that vibration sends a message to our brains that a drum is making a sound.

Inquiry →

← Application

object vibrating can make another object vibrate, even if the two objects do not touch. Students used the patterns they identified through their experiences to explain that when a classmate blew into a trumpet, the trumpet made vibrations that in turn, vibrated a person's eardrum. They described how someone talking into a "telephone" made of plastic cups and fishing line could make the cup and the fishing line vibrate so that the cup on the other end of the line vibrated. The students even explained that the vibrating cup made the eardrum vibrate in such a way that the person on the receiving end could understand what the person on the sending end of the telephone was saying. In each of these examples, the students were confident in their explanations because they understood the patterns that supported them.

Using the EPE Triangle

Identifying the patterns that students need to recognize is probably the most challenging part of using the EPE triangle to restructure traditional school science. Attending to patterns requires careful planning. The first step is to consider the learning goals. In elementary science, the school science learning goals are often scientific patterns rather than scientific explanations. For example, plant and animal adaptations, life cycles, the classification of rocks, and phase changes are all patterns that support powerful explanations that students learn in middle and high school (e.g., natural selection, kinetic molecular theory). In these cases, rather than teaching these patterns as ends to themselves, connecting these patterns to experiences and helping students recognize and use these patterns in everyday life becomes the goal. The second-grade students studying sound did that because they used the pattern of vibrations to explain how humans hear sounds. Being able to use this pattern prepares students for later understanding of the scientific model for vibrating air molecules transferring energy from the sound source to the ear.

One strategy for unpacking the hidden patterns related to the learning goals is to construct EPE tables (Anderson 2003), as shown in Figure 3. Column one of an EPE table lays out experiences that students can have in the classroom or can draw from out-of-classroom activities. It is important that these experiences provide students with opportunities to make observations of phenomena. Next, column two lists the important patterns in these experiences that students must understand to grasp the explanations. Last, column three summarizes the explanations students need to learn. The experiences, patterns, and explanations in an EPE table should be grade-level appropriate. In EPE tables constructed for elementary school learning goals, the explanation in column three delineates what students are expected to understand at the end of the activity sequence. In this example, the students were expected to use the patterns—things that vibrate make sounds and one thing vibrating makes another thing vibrate—to explain how we hear the bass drum in the marching band. The elementary explanation is different from a middle or high school level explanation that uses the scientific model of the mechanical wave theory (sound energy is transferred from one particle to another when particles collide) to explain the same patterns. EPE tables constructed for middle and high school include more details of the powerful models and theories of science in the explanations column. More EPE table examples for common elementary learning goals are available online (see NSTA Connection).

Transforming school science from a traditional emphasis of explanations first, experiences later, requires a new emphasis on connecting explanations to patterns in experiences. Using EPE tables can help teachers begin to think about organizing activity sequences so that students engage in the sense-making practices of inquiry *and* the application of scientists' science in the classroom. ■

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NSTA Connection

Download more EPE tables for common elementary learning goals at *www.nsta.org/SC1009.*

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Content Standards

Standard A: Science as Inquiry

Grades K–4

- Abilities to do scientific inquiry
- Understanding about scientific inquiry

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.