

Notice and Wonder: Foundations for Scientific Inquiry in the Critical Zone

AGI Earth Science Week 2018: Earth as Inspiration

Summary

Observing, questioning, hypothesizing, interpreting, and communicating about the world around us are foundational research skills practiced in every scientific discipline. These skills can be developed at any age through the framework provided by two words: *Notice* and *Wonder*. We provide information about how “I notice...” and “I wonder...” can be used to engage in scientific practices and explore the *Critical Zone*, the outermost layer of Earth that forms its surface and ecosystems. With Notice and Wonder in our scientific toolkit, we provide an example of how you can use these practices to qualitatively and quantitatively explore a particular phenomenon in the Critical Zone: Where does water go when it rains?

The Critical Zone: Earth’s Outermost Layer

The Critical Zone is where terrestrial life, including humanity, resides. The Earth’s Critical Zone is defined as the surface of Earth extending vertically from the boundary between vegetation and atmosphere, down through soil and weathered bedrock, to belowground depths where groundwater and bedrock interact. The Critical Zone provides many of the resources terrestrial organisms and ecosystems need, including fresh water, suitable soils, and balanced atmosphere. Critical Zone science is an emerging field of Earth surface and environmental science that crosses multiple scientific disciplines to study the Critical Zone, how it supports life, and how it responds to change. Numerous Critical Zone Observatories (CZOs) have been established around the world to support Critical Zone research. In the U.S.A., nine CZOs exist in a wide range of environments, from the tropical Luquillo Mountains of Puerto Rico, to the agricultural plains of the Midwest, to the montane forests of California’s southern Sierra Nevada. These diverse landscapes serve as natural laboratories to study similarities and differences in Critical Zone properties and processes, such as water storage in soils and rates of vegetation water-use.

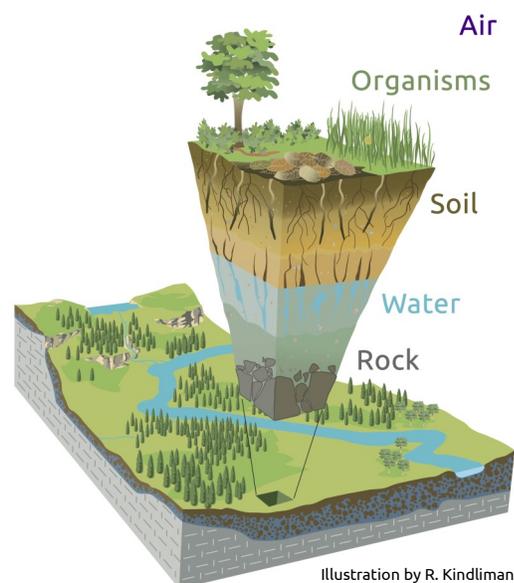


Illustration by R. Kindlimann

Exploring the Critical Zone with “I notice...” and “I wonder...”

Scientific research and engineering solutions are at their core inspired by someone noticing and wondering: At what rate does this process occur? How can I solve this problem? Children and adults often practice these observation and question skills in everyday settings: “Olive oil smokes at a lower temperature than canola oil.” “Some hydrangeas are pink and some are blue; how does their color change?” “The rocks in the creek are several different colors; I wonder where they all came from.” Students can use the sentence starters of “I notice...” and “I wonder...” to explore Earth surface and environmental phenomena, from everyday processes to spectacular events.

“I notice...” and “I wonder...” applications are particularly powerful when exploring the Critical Zone, where we as people spend most of our time. Something often visible, audible, and touchable—though sometimes not—that we can explore in the Critical Zone is water. Have you ever noticed while watering a garden, you can sometimes hear gurgling sounds coming from the soil? Or during and after a rainstorm, water will sometimes pool and form mud puddles? Perhaps this could make you wonder, why does the water pool in some areas and drain in others? What is happening when a soil gurgles? And where does the water go once it is underground? On the next page, we explore this phenomenon of water cycling in the Critical Zone and provide multiple activities for incorporating Notice and Wonder prompts into a water cycling unit.

Materials needed for “I notice...” and “I wonder...” exercises are simple: a piece of paper, a pencil, and any time from five to fifty-five minutes. Optional but helpful materials during Notice and Wonder activities also include designated notebooks, colored pencils, magnifying glasses, and tape measures. Students record sense-based observations during the Notice portion of the exercise: What do they see, hear, feel? How large? How many? What patterns can be identified? Students can create lists, drawings, tables, and maps to document their observations. During the Wonder portion of the exercise, students think of what they want to know more about—the how, why, where, how much, how fast, and who behind their observations. They document their questions and hypotheses, such as cause-effect relationships, functions of particular structures, and predictions of how a property or process may change over time or across space.



Water Cycling in the Critical Zone

Water plays vital roles in the Critical Zone: survival and growth of flora and fauna, nutrient mobility, rock weathering, soil production, and surface erosion. While water drives the evolution of the Critical Zone, its cycling is also regulated by the Critical Zone. Deeply understanding this feedback between Critical Zone structure and function, and water properties and processes, is a major goal in Critical Zone research. Below we briefly explain how water travels through the Critical Zone and the effects the Critical Zone can have on it.

When precipitation falls on an area as rain, it may be intercepted by vegetation. This water caught on leaves and trees may eventually be shed to the ground below or may evaporate into the lower atmosphere. Once rain reaches the ground surface, it will follow gravity and either flow off the landscape or infiltrate into the soil below.

Whether a water droplet flows off the surface or infiltrates into the subsurface is determined by several factors. One factor you may want to explore with your class is the structure of the subsurface, in particular soil texture. If soil is very porous or sponge-like, with lots of airspace, water is more likely to quickly infiltrate like wet sand at the beach. If the subsurface is less porous or perhaps hydrophobic because it is very dry, it may have a slower infiltration rate. This slower infiltration rate may trap water on the surface for several minutes, hours, or days, during which time it will eventually evaporate, infiltrate, or run off. If a large quantity of water collects in an area with a slow infiltration rate, pools of water may be observed.

Once in the subsurface, water continues to follow physical forces and flows belowground, often slowly. It may be stored in soil and rock for timescales from weeks to millennia. Through the subsurface, water droplets take different pathways, including: uptake and use by vegetation for photosynthesis, atmosphere re-entry via evaporation, deeper groundwater recharge, continued flow through the subsurface down slopes and into basins such as meadows, and entry into surface waterways such as streams, rivers, and oceans.

“I notice...” and “I wonder...” where water goes when it rains

Use Notice and Wonder prompts with the activities below to explore water cycling in the Critical Zone. The activity collection aligns with multiple *Next Generation Science Standards* such as SEP 1 and 6; CCC 6; and DCI ESS2.C. This unit is also designed to span the first four stages of the *BSCS 5E Instructional Model* of Engagement, Exploration, Explanation, Elaboration, and Evaluation.

Activity 1: Tour of water pools after rain

- Notice: Water pooling around your school or a nearby park after it rains. Where does water pool? Where doesn't it pool? Does the ground feel extra-squishy in some places? Include sidewalks, parking areas, gardens, lawns, playgrounds, etc. Write down descriptions of where you notice pooling, perhaps including drawings and incorporating maps. Higher grades can use soil moisture meters in addition to qualitative observations.
- Wonder: Students answer this prompt on their own. Ask students to share some of their Wonders with the class. Follow up this activity with Activity 2, or explore and experiment with one or more of the class' Wonders.

Activity 2: Water droplet absorption tests

- Notice: Differences in water droplet absorption on different media in your classroom or around your school. Students use pipettes to apply individual water droplets on media such as sand, clay, wood, rocks, garden soil, leaves, and concrete. Use a stopwatch to time how long it takes for the water droplets to “disappear” and record the “disappearance” time for each droplet on each medium. Students should notice similarities and differences in the structure of each medium (coarse vs smooth, large or small or no visible pores or cracks), which media had the fastest and slowest “disappearance” times. Microscopes or magnifiers are useful for observations. Higher grades can use concept mapping to categorize the media.
- Connect to Activity 1: Ask students to apply knowledge gained from the water droplet tests to what they observed on the water pools tour. Use writing, drawing, and concept mapping with your class to develop connections and explanations.
- Wonder: Students answer this prompt on their own. Ask students to share some of their Wonders with the class. Use the proposed extensions below to elaborate on water cycling in the Critical Zone, or consider researching or elaborating on one or more of the class' Wonders.

Extensions: Observing changes over time and space

- Observe water pools and soil moisture at a study site over multiple days or seasons. Observations could include changes in the width and depth of a pool of water or measurements of soil moisture.
- Research how landscape position can affect soil moisture and water flow. Some questions you could pose and study with your class are: How wet is the top of a hill versus the bottom of a hill after a storm? Where and how do meadows form?
- Use data from observatory networks in your classroom. Datasets of precipitation, snowpack, soil moisture, temperature, groundwater well depth, streamflow, and evapotranspiration are available on the *U.S. NSF CZO Program's* website: <http://criticalzone.org/national/data/datasets/>. Use these data to explore measurements from the CZO closest to your school—or farthest. Make graphs of one day, week, month, or year of a dataset. What does your class notice and wonder about the water cycling trends at different sites? At different times of the year?