In this sensemaking lesson, K–2 students explore how different factors influence seed germination and explain the elements necessary to sprout. Notebook strategies are embedded throughout the explore-before-explain lesson to help students organize budding ideas. The class begins by engaging students’ initial ideas about factors needed for a seed to grow. The lesson is designed to provide students with firsthand experiences collecting data on seeds needing specific requirements to germinate. As students gather data from their explorations, they look for patterns and cause-and-effect relationships to construct and revise an explanation of what requirements seeds need to sprout and the factors that affect the growth of the germinated seeds (seedlings). With teacher guidance, students learn terms for specialized plant structures observed during their exploration. At the end of the lesson, students revisit their initial ideas and revise their claims using crosscutting concepts of patterns and cause and effect to construct a scientific explanation with evidence from their investigations. This article shares a model lesson (see Brown and Keeley 2023) and reflects on the key planning considerations connected to research to help elementary teachers and leaders consider instructional design from a more pedagogical perspective.

A 5E Example Lesson

The following example illustrates the importance of the instructional sequence in orchestrating the gradual advancement of student understanding of the needs of seeds and plants (Brown and Keeley 2023) related to cognitive science and three-dimensional learning. Each section links the instructional design to research to promote students’ active meaning-making.

Engagement

Second-grade students described what they noticed about a plant that had just emerged from the soil. They had a flurry
of ideas. One student said, “It is green.” Many students remarked, “They [referring to the plants] are just leaves.” Another student stated, “It wasn’t there yesterday.” These ideas led us to our next question—What do I wonder? Again students’ wonderment was bountiful. Students commented, “I wonder what it will turn into,” and “I wonder how big it will grow.” Another student said, “I wonder what made it pop up.” Students delved into this question further and discussed how the past few days had been similar and different from the previous weeks. Students quickly claimed today it was “warm” and “felt like summer” when it was still cold with snow last week. Students’ “notice and wonder” questions allowed them to engage in class discussions and served as a bridge to further engagement of student ideas. Next, students considered the “Needs of Seeds” formative assessment probe (Keeley, Eberle, and Tugel 2007). Nearly all students thought germinating seeds needed sunlight, soil, and water based on their experiences with the needs of plants. Students were torn on whether seeds needed warmth, food, and fertilizer. Students focused on their past experiences planting and growing flowers versus clarifying why certain variables in the probe were essential for a seed to sprout (germinate) and grow into a seedling. Charlie explained, “They [referring to seeds] need water and soil or they cannot grow.” The “Needs of Seeds” formative assessment probe set up the variables tested during the exploration and challenged students’ naive ideas about the differences between the needs of seeds and a growing plant.

The Importance of Grounding Learning in Phenomena

Using “notice” and “wonder” routines is a practical discourse framework that helps move to more equitable learning experiences for all students (Windschitl Thompson, Braaten, and Stroupe 2012). Asking “what do you notice” invites uninhibited participation (i.e., not tied to fears of assessing ideas) and elicits students’ insights based on their experiences (see Krashen and Bland 2014; Affective Filter Hypothesis). Neurologist and teacher Judy Willis contends that questions like “what do you wonder” are among the highest-yield instructional strategies since they focus the brain’s attention and set up a need to know (McTighe and Willis 2019). If students’ wonderment ideas are accurate, this validates prior knowledge and sound reasoning. If their forecasting and predictions are incorrect, the brain wants to discover why and seeks an explanation. Cognitive theory tells us that students’ ideas are valuable assets to learning. Starting lessons with students’ ideas and experiences about phenomena make learning accessible to all students and taps into their innate curiosities, a vital learner-centered component of learning science best (National Academies of Sciences, Engineering, and Medicine 2018). Moreover, students’ lived experiences provide insights into how the world works; an essential component of constructivist theory is that all learning builds on existing ideas (Bransford, Brown, and Cocking 2000).

Exploration

Students’ explorations were an extension of the assessment probe and focused on constructing data as evidence for the variables necessary for seed germination. First, students worked in pairs to plant radish seeds (using ice cube trays or egg cartons as planters; Figure 1). The class followed the teacher’s directions on how to set up the investigation so that each well in the container could be used for a separate test (soil vs. no soil, water vs. no water, light vs. no light). Then, students would use their containers in pairs to start the investigation.

First, students put soil in two wells opposite each other. Next, they added two radish seeds underneath the soil in each of these wells. This test would see if seeds would germinate with soil and no water.

Second, students placed water in two wells opposite each other. Then, they put two radish seeds in each of these wells. This test would see if seeds would germinate with water and no soil.

Third, students put soil in two wells opposite each other. Next, they added two radish seeds underneath the soil in each of these wells. Then students added water to the soil until it was damp. This test would see if seeds need soil and water to grow.

Fourth, students placed two radish seeds in two empty wells across from each other. The students did nothing to these seeds; this was a test of whether a radish seed would germinate on its own.

Finally, students covered four small Dixie cups with foil. To collect data on sunlight, students placed half of the treatments (listed in 1–4 above) under foil and left the others in the sunlight. Hence, this final test helped determine whether light is necessary for each of the conditions for seed germination.

The test results quickly came in, and after only three days, students started to see patterns and causal relationships among variables and seed germination. For example, students observed little yellow stems and tiny yellowish-green leaves sprout from the seedlings in water. These seedling changes occurred in light and dark conditions. As students crowded around their seedlings, they made quantitative (see Figure 2) and qualitative observations and drew their seedlings’ development, labeling plant parts. Students’ observational drawings (see Fries-Gaither 2022) were crucial artifacts of their developing understanding of science ideas using science practices like interpreting data and crosscutting concepts, such as cause-and-effect relationships (NGSS Lead States 2013). After five days, students had the following evidence of factors influencing seedling development:

- Seeds on their own—no water or soil—did not grow.
- Seeds in the soil only grew if they were also watered regardless of the light conditions (dark or light).
• Seedlings in the water grew regardless of dark and light conditions.

At the end of the exploration, students wrote evidence-based claims where they labeled the different treatments for their planters (i.e., ice cube trays or egg cartons) and whether they were necessary for plant growth. Students used patterns across data from each treatment as evidence of the needs of seeds. For example, the seed germinated in both conditions where the seeds had water (light and dark). Thus, students used this data as evidence that water is essential for seed germination. In addition, students learned that soil alone (with and without water) in light and dark conditions was not key in seed germination. Students had no evidence that soil alone was necessary for seeds to sprout. The conversations focused on considering similar situations across the variables as evidence for sensemaking. Rather than considering all of the variables and the data tested at once, students started the data analysis process by looking at similar treatments. Scaffolding the process of constructing an evidence-based claim helps students use data as evidence for developing scientific ideas (Fries-Gaither 2022). Students were able to explain in their “how to grow a plant,” as Charlie explained, “Plants groo (grow) from seeds and ned (need) water.”

Students continued the exploration beyond the initial tests. They found that their seeds continued to germinate over the next week if they had water (light and dark) while seeds did not germinate in the other treatments. After a week students planted their seeds in Styrofoam cups and took them home.

The Importance of Developing Ideas by Doing Science

Students need the opportunity to collect data, analyze it, and determine how to make sense of what the data may mean. We start our instructional design by looking inward at our current practices and identifying a hands-on demonstration or investigation for clarifying evidence for student learning. Simultaneously, we consider essential questions to ensure minds-on experiences for students. Importantly, we ask:

• What would count as successful understanding?
• What evidence would we accept as understanding?
• What methods could students use to collect the evidence?

These questions are essential for teachers and should be discussed with students to ensure they use data as evidence for their science sensemaking.

The answer to these questions is inherent to who is doing the hard intellectual work in the classroom. Having students construct evidence-based claims is a vital aspect of the learner-centered classroom (see Bransford, Brown, and Cocking 2000), calling upon children’s innate intellectual abilities to know their world (supported by developmental psychol-
FIGURE 2
A student measures the height of a seedling.

The Importance of Notebooking To Promote Student Sensemaking

Having students look for patterns and causal relationships in data to be used as evidence for sensemaking is enhanced by the artifacts they create of their experiences. Teachers can use science notebook strategies to identify appropriate methodologies that help students organize developing understanding in a whole host of ways: They can have students clarify their thinking about data as well as their observations to make scientific claims; they can give students time and space to plan their investigations; they can provide sentence starters and stems to help scaffold student thinking, to hone in on the most salient parts of exploration; they can add scoring criteria and “look fors” so students are planning with the desired results in mind (Fries-Gaither 2022). In all these ways, the science notebook becomes an invaluable thinking and learning tool for students and a critical formative assessment to guide science and cross-disciplinary instruction. Teachers can look for evidence of three-dimensional thinking in student work (aligns with NGSS). From a cross-disciplinary angle, students’ notebooks serve as a written artifact of their understanding, connecting to contemporary technical writing standards in English language arts (NGAC and CCSSO 2010).

The importance of notebooking in the sensemaking process cannot be overstated. The purposeful use of notebooking strategies makes science accessible to all students. Regardless of students’ backgrounds and experiences, the combination of shared classroom experiences and the scaffolding notebooking promotes learning at a deep conceptual level. As a result, students’ science notebook becomes a highly individualized representation of their meaningful, intellectual work to learn science.

Explanation

Students gathered in a circle to share their evidence-based claims and participate in an interactive read-aloud of Rosie Sprout’s Time to Shine (Wortche 2011). The engagement was high and students discussed clarifying questions about the narrative and pictures to help them connect the reading and their experiences in class. The class paused when the book dis-

Three-Dimensional Learning Targets from A Framework for K–12 Science Education

- **Performance Expectation:** K–2. Plan and conduct an investigation to determine if plants need sunlight and water to grow. (2-LS2-1)
- **Disciplinary Core Idea:** Grades K–2: LS2.A. Plants depend on water and light to grow.
- **Scientific Practices:** Analyzing and Interpreting, Carrying Out Investigations, Constructing Explanations
- **Crosscutting Concepts:** Patterns, Cause and Effect
cussed plants needing light, soil, and water to grow (key science ideas in grades K–2; NGSS Lead States 2013). Students considered whether the book was similar or different from their experiences with seeds and seedlings. Aiden noted, “Our plants did not need soil or light to grow and only water.” The book used many words from class, like seed, root, stem, and sprout. These terms introduced plants as having different parts that help them survive and grow (Key science ideas in Grades 3–5; NGSS Lead States 2013). Students enjoyed how Rosie took daily measurements, much like we had in class.

Developing Scientific Ideas Requires the Alignment of Activities to Standards.

Teachers can anticipate the essential scientific vocabulary for concepts and processes that are necessary for successful science understanding. The key is that any terms that are introduced occur after the exploration of scientific phenomena. In this way, teachers enhance student knowledge by helping them understand the underlying scientific principles that may be inaccessible from hands-on experiences alone. Readings, discussions, and lectures become rich learning experiences because they connect ideas and students’ frameworks for understanding. The disciplinary core ideas, crosscutting concepts, and science and engineering practices from Next Generation Science Standards (NGSS) are good places to start when identifying essential academic vocabulary and a way to make sure students’ sensemaking aligns with modern standards (NGSS Lead States 2013).

Evaluate

Now that students could explain some essential germination and seedling growth requirements, they revisited the probe, making new claims supported by their explorations. Students revised their initial ideas and constructed an evidence-based claim that included the factors we tested that seeds needed to sprout. Students were also encouraged to draw pictures of plants and use words like seeds, water, roots, soil, and sun to draw plant parts and explain what the young plants (seedlings) need to grow. Students could also describe similarities and differences between the needs of seeds and the needs of the young plants (seedlings) using the same factors listed in the probe. They must recognize that the disciplinary core idea that a plant needs sunlight to grow applies to the seedling and not to a plant’s seed.

Importance of Reflecting on Thinking and Developing an Understanding of Sensemaking.

Evaluation time is an opportunity for students to reflect on their new conceptions of science and for teachers to determine the accuracy of student ideas and what students have learned. Students should think about what they have learned and how far they have come intellectually—that is, engage in metacognition, which significantly affects learning (Bransford, Brown, and Cocking 2000). Students with strong metacognitive skills are positioned to learn more and perform better than peers who are still developing their metacognition (Wang, Haertel, and Walberg 1990). The evaluation time allows teachers to assess whether students have developed knowledge (i.e., whether students’ ideas have changed since the beginning of the lesson and whether they have gained new, more sophisticated understanding).

Conclusions

Teachers who prioritize sensemaking find that the context explorations engage students in science and cultivate their beliefs that they are essential agents in creating classroom knowledge. Context affects learning and motivation. Situating all learning in students’ explorations and the resulting evidence-based claims gives meaning and purpose to all activities. The result is that students gain higher levels of sensemaking because understanding from both explorations and explanations combine to create meaningful learning experiences.
REFERENCES


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