Inquiry-Based Science
and the Next Generation Science Standards:
A Magnetic Attraction

An emergent inquiry unit allows students to reach their own conclusions about magnets.
By Jennifer Richards, Ann Johnson, and Colleen Gillespie Nyeggen

The Next Generation Science Standards (NGSS) and the guiding Framework provide a vision of science instruction that is thoroughly integrated in nature. As stated in the Framework:

Standards and performance expectations that are aligned to the framework must take into account that students cannot fully understand scientific… ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined. At the same time, they cannot learn or show competence in practices except in the context of specific content. (*A Framework for K–12 Science Education* 2012, p. 218)
The need to integrate scientific content and practices is clear in the very wording of the NGSS Performance Expectations. But what does it really look like for science classroom instruction to be integrated to this degree?

In this article, we provide an example of an emergent fifth-grade inquiry into magnetism in Ann Johnson’s class that demonstrates the level of integration indicated in the NGSS. The inquiry stemmed from a student’s question of whether magnets can work underwater. It progressed over the course of six classroom periods, largely in response to students’ developing ideas. Note that Ann was not aiming to align with the NGSS; in fact, the inquiry predated the release of the Framework. Instead, her primary aim was authentic scientific pursuit of a student’s wondering. It was in this context, and through working with the students’ ideas, that integration occurred. In the next section, Ann reflects on how this inquiry unfolded.

Ann’s Perspective on the Emergent Inquiry

In the summer of 2009, I attended a two-week science inquiry workshop headed by Dr. Andrew Elby. My previous approach to the science curriculum—vocabulary, text passages, and the occasional cookbook experiment—was failing to transmit my love of science or the key science concepts to students. Through pursuing my own science ideas as a learner and watching video of students engaged in inquiry, I came away with the following insight: Have faith in my students’ innate curiosity about the natural world, and science will come “naturally.”

The following year, I had a class of “average” fifth graders: no “Talented and Gifted” students and no students with special needs. All year long, we inquired about various scientific topics through discussion and investigation. Toward the end of the year, the class voted on a topic they wanted to return to and explore further. The winner was, “Will magnets work underwater?”—a student’s question that arose during our earlier work with magnets.

Our first challenge with the question was how to test it. We started by seeing if magnets attract in a cup of water, measuring by feel and whether they snap together when released. Students tried it out and concluded that they attracted, but several students thought it was because there simply wasn’t enough water in the cup to block the magnet. At this point, the traditional teacher in me could not resist asking if that was any different from how magnets work in air. I tried demonstrating this concept by holding one magnet and having a student hold the other magnet in the air and moving them apart until we no longer felt the attraction, but my demo fell flat—the students were in inquiry mode, committed to getting the answer independently. So, with minimal input from me, students designed an investigation to determine at what distance magnets attract underwater. Students decided to make centimeter-wide marks on the bottom of a container. Once the container was filled with water, magnets were held at each set of marks to determine where they attracted (see Figure 1).

The students conducted their investigation the following day and discovered that the magnets behave identically in water and air. Before this activity, one student insisted that the water would block the magnets if we just used enough. Now, after she tested it for herself, she considered the evidence and changed her thinking. She conceded that...
perhaps the water has nothing to do with it; it’s simply the distance between the magnets—the magnetic field decreasing with distance.

At this point, the focus shifted slightly. Several students had noticed a sentence in our textbook saying that magnets can be blocked by certain materials, with no further explanation or information. They concluded water did not block magnetism, but they were determined to find something that did. As a class, we tested rubber, glass, wood, bricks, plastic, cloth, aluminum, and our hands. The magnets did not seem to attract with a thick piece of tree trunk or the thickest part of our hands, but the students were not satisfied. They wanted to know WHY the magnets didn’t work. Do we just need stronger magnets? What if the wood was thinner? Is there something in our bodies that blocks the magnets? Is magnetism similar to electricity: Are there magnetic insulators and conductors? Then one student hit upon an idea that grabbed the whole class: Maybe magnets have a harder time working through solids than liquids or gases. Another student suggested we try ice to put this idea to the test: “If it works through water, then you can just turn water into a solid and see if that would work because it’s still the same substance.”

We tried this idea the next day, testing the magnets through a piece of ice that was precisely as “thick” as the water we tried, and the magnets did not seem to attract. One student noted that “in a liquid, all of the atoms... they’re not tightly packed like they are in a solid, where they’re so tightly packed.” Students wondered if the atoms in a solid are too tightly packed to allow the magnetism “through,” but again, no one was satisfied. The answer, many insisted, is that we just need stronger magnets.

And so it went—every time we seemed to answer one question, another took its place. We agonized over using stronger magnets: Won’t it nullify our previous results if we change magnets? The students were deeply engaged in doing science—not following a specific series of steps, but engaging in an systematic sense-making process. Ultimately, they decided that using stronger magnets was justified by our larger question: Will anything block magnetism? When the stronger magnets did work through the wood, the class was still not content. (Note: Strong magnets should be handled with caution as they may stick to things unexpectedly. The teacher conducted all of the testing with strong magnets.) They hypothesized that the magnetic field is now larger, so maybe the magnets aren’t working through the wood, but around it. What amazed me was how skeptical and thorough these students had become. They were not just looking to validate their ideas or be “right.” Instead, they were constantly subjecting their findings to tough scrutiny and considering numerous possibilities for what they were seeing.

We continued down this path until we hit an impasse. We could not find anything that blocked these magnets, nor a clear explanation online of whether anything entirely could. I was just as stumped as the students. Ultimately, this student-driven foray brought us to a question that still perplexes “real” scientists: Is it possible to truly block a magnetic field? And in this process, my students have realized that they, too, are real scientists.

**Authentic Integration of Content and Practices**

What we want to highlight from this example is that important scientific ideas and practices were integrated as students inquired into whether anything could block magnetism. Connecting to the *Next Generation Science Standards* (p. 58) maps the inquiry onto the scientific content and practices described in the NGSS. Specific consideration is given to how activities that emerged over the six-day inquiry correspond to science practices and how...
students’ explorations brought them into contact with and further developed disciplinary core ideas about magnetism and matter.

Additionally, while students did not always come to canonically correct answers, they grappled with deep, important issues (e.g., how the nature of a material might affect its interactions with magnetic fields) that will prime them well for future learning. We do not expect this level of sophistication in student thinking to be unusual. Literature in science education details rich resources that elementary-school students have for engaging in science, including their own experiences in the world, intuitions for setting up fair tests, and a natural propensity for wondering why things happen the way they do (e.g., Bresser and Fargason 2013; Gallas 1995; Hammer and van Zee 2006; Rosebery and Warren 1998).

The Importance of Ongoing Formative Assessment

In such an open setting, the teacher must pay close attention to the sense students are making of their scientific activity as it unfolds. This necessitates listening carefully to students’ experiences and intuitions and working with students to build on and refine their ideas in scientific ways. For instance, one set of criteria Ann had in mind while listening to students were the “3 C’s of scientific thinking” (see Figure 2). She regularly considered whether students’ ideas were exhibiting these characteristics and used them to press students’ thinking deeper. She also kept track of students’ ideas publicly on the visualizer and had students write individual responses to ideas or questions that arose in discussion; both sets of artifacts were used to continually monitor student understanding and inform instructional next steps. The final section discusses other principles Ann gleaned from her experiences facilitating this inquiry and others like it in the elementary school classroom.

Guiding Principles for Responsive Inquiry Teaching

- First and foremost, the teacher must develop an atmosphere of respect for ALL ideas expressed in discussions. The teacher sets the tone by showing respect herself: listening closely to each student, paraphrasing, questioning further, summarizing, recording ideas in a visible place, and asking for reactions. Figure 3 shows active listening principles Ann’s class developed and referenced in discussion to promote a supportive atmosphere.
  - Resist the urge to jump in and correct misconceptions or answer questions. The process of students doing their own thinking is what energizes this learning method! Allow students to work through and modify their ideas.
  - INSIST that students give evidence for their ideas. Students may discount their everyday observations as “not scientific,” but we want students to see such observations as foundational to the development of scientific knowledge.
  - Similarly, press students to explain WHY and HOW something is happening, not just what WILL happen. This will frustrate many students but also leads to those “Aha!” moments that may turn them into lifelong scientists.
  - As much as possible, follow the students’ lead in designing investigations, especially ones with flaws—nothing teaches the value of a scientific way of approaching a problem better than an invalid investigation!
  - Move frequently between whole class, small group, partner, and individual participation to ensure that all

**FIGURE 3.**

Active listening principles.
students are comfortable with the discourse.

- Don’t insist on scientific vocabulary during inquiry discussions. Students may be able to describe processes like weathering, erosion, or deposition without using the correct words. The vocabulary will “stick” much easier when the concept is in place first. And conversely, don’t let students drop “scientific” words into a conversation unless they can explain them fully.

- Be an inquirer yourself! Be very open about not knowing answers if you don’t, and share your personal questions with the class.

- Keep track of possible inquiry topics for the future. Ann’s class has an “I Wonder” chart to record questions and ideas that emerge.

We hope that the extended example and accompanying principles serve as fodder for thought about engaging with students in authentic scientific inquiry and the integration of content and practices that arise within that pursuit.

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References

Connecting to the Next Generation Science Standards (NGSS Lead States 2013)
3-PS2 Motion and Stability: Forces and Interactions, 5-PS1 Matter and Its Interactions
www.nextgenscience.org/3ps2-motion-stability-forces-interactions
www.nextgenscience.org/5ps1-matter-interactions

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<tr>
<th>Science Practices</th>
<th>Connections to Classroom Activity</th>
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<tr>
<td>Asking Questions</td>
<td>Throughout the inquiry, students iteratively asked questions about whether magnetism can be blocked by certain kinds of materials, devised experiments to test their questions and analyzed results, and proposed and debated evidence-based explanations for the behavior of the magnets.</td>
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<tr>
<td>Planning and Carrying Out Investigations</td>
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<td>Analyzing and Interpreting Data</td>
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<td>Constructing Explanations</td>
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<td>Engaging in Argument from Evidence</td>
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<th>Disciplinary Core Ideas</th>
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<td>PS1.A: Structure and Properties of Matter</td>
<td>Students considered the molecular spacing in different materials they tested (e.g., in liquids vs. in solids) and whether this would influence their magnetic permeability.</td>
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<tr>
<td>• Matter of any type can be subdivided into particles that are too small to see...</td>
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<td>PS2.B: Types of Interactions</td>
<td>Students reasoned that magnetic forces depend on magnets’ strength and the distance between them, and posited similarities between magnetism and electricity.</td>
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<td>• Electric, and magnetic forces between a pair of objects... depend on the properties of the objects and their distances apart...</td>
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<th>Crosscutting Concepts</th>
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<td>Cause and Effect</td>
<td>Students proposed cause and effect relationships based on patterns observed in the data.</td>
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