Delving Deeper into Science Teaching

An Early Childhood Magnetism Lesson as a Context for Understanding Principles of Inquiry

by Cody Sandifer and Pamela Lottero-Perdue

Despite its decades-long presence in K–16 classrooms, *inquiry-based science teaching* remains an elusive concept. For example, although many teachers would agree that an inquiry lesson can be broadly defined as a lesson in which students engage in the scientific process, our experience has shown that practicing and pre-service teachers can still have difficulty applying this definition as they attempt to identify: (a) the extent to which a particular lesson is inquiry-based (fully, partly, or not at all), and (b) whether a lesson that has been categorized as being inquiry-based is actually a *good* inquiry lesson. Perhaps it should not be surprising that inquiry-based teaching is like other complex activities, such as parenting, mentoring, and creative writing, whose ideal definitions can be challenging to apply in practice.

In this article, we share four principles of inquiry-based teaching to help K-16 science teachers categorize science lessons in terms of inquiry.[1] We then describe a kindergarten-level lesson on magnetism to illustrate the finer details of each principle, as well as to showcase a classroom-tested science activity that teachers might find fun and useful.

PAMELA LOTTERO-PERDUE

Predicting whether objects will stick to magnets

The Principles of Inquiry-Based Teaching

Principle #1: Inquiry-Based Teaching Begins with a Question.

An inquiry lesson seeks to answer one or more questions about concepts or relationships in science. Inquiry questions provide an overall purpose for the entire lesson, and may be generated by the teacher or the students. These questions should be explicitly stated using language that is easily understandable.

Principle #2: Inquiry-Based Teaching Is Student Centered.

The teacher provides structure and guidance, but it is the students—as individuals, small groups, or as an entire class—who are ultimately expected to answer the inquiry question(s) on their own. In addition, whenever possible, the teacher allows students to engage in hands-on scientific activities themselves, rather than doing these activities for the students as demonstrations.

Principle #3: Inquiry-Based Teaching Involves Deep Thinking about the Answers to Inquiry Questions.

Lessons should prompt students to think deeply about scientific concepts and relationships. This can be accomplished through small-group and whole-class discussions, hands-on experiments (which are often cooperative), reading texts to generate questions, and other means.

1. Our principles of inquiry were developed independently from the National Research Council's essential features of inquiry as presented in *Inquiry and the National Science Education Standards* (2000), although they are similar in spirit and focus.

PRINCIPLE #4: INQUIRY-BASED TEACHING EMPHASIZES EVIDENCE-BASED REASONING.

Students are encouraged to provide evidence and reasoning for their predictions, observations, and answers to inquiry questions. This evidence should draw upon everyday experience, experimental data, common sense, and prior knowledge. Students are frequently asked to answer questions like, "Why do you think that?" and "Can you explain your reasoning?"

A Kindergarten Lesson on Magnetism: Which Materials Stick to Magnets?

Key Science Concept: Some metal objects stick to magnets.

General structure: Formal discussions occur in a whole-class format; hands-on activity is intended for small groups of 3–4 students.

Materials

- For each group:
  - One resealable plastic bag (or container) holding an assortment of metal objects that stick to a magnet, metal objects that do not stick to a magnet, and nonmetal objects. Suggested objects: penny, house key, wooden block, aluminum foil, paper clips (some vinyl-coated, some not), gallon jug lid, marble, brass fastener, steel wool sample, swatch of fabric, pencil, pen, and steel washer.
- A prediction/testing handout with large YES, NO, and MAYBE boxes.
- For each student:
  - An unbreakable magnet
  - A lesson assessment handout

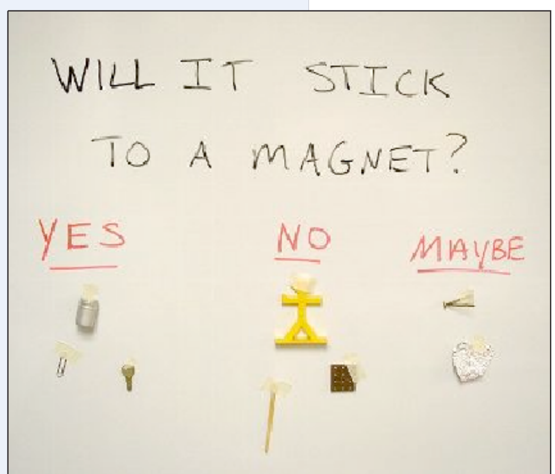
Preparation

- Prepare the bags containing the metal/nonmetal objects. Important: Magnets should not be included in the bags, as they are distributed later in the lesson.
- Create 3′ by 2′ chart (on paper or the board) with column headings YES, NO, and MAYBE.

Lesson outline

1. Show the class examples of different objects sticking to each other magnetically. (Example: toy trains connected by magnets.)
2. Class Discussion:
   a. What are these "sticking objects" called?
   b. Where do you find magnets around your house?
   c. Do you have any questions about magnets? (Write questions on the board.)
3. Say: The class came up with an interesting list of questions! Another question we could ask is "What kinds of objects stick to magnets?" We'll focus on that question today. (Write the question on the board, if not already displayed.)
4. Hand out a materials bag and prediction/testing handout to each group (do not distribute magnets at this point) and ask the students to carefully feel and examine the objects and discuss whether a magnet might stick to each object. Tell groups to make their predictions by placing each object onto the handout in the appropriate box: objects that the group thinks will stick to a magnet should be placed into the YES box, objects that the group thinks will not stick to a magnet should be placed into the NO box, and objects that the group isn't sure about (or objects that the group can't agree upon) should be placed into the MAYBE box.

5. Class Discussion: (For each object.)
   a. Ask: Do you think this object would stick to a magnet? Why do you think that?
   b. Tape the object to the chart paper or board in the appropriate YES/NO/MAYBE column.
6. Post-Prediction Class Discussion:
   a. How are the objects in the YES column similar to each other? How are the objects in the NO column similar to each other?
   b. Do we have an initial rule for the types of objects we think will stick to magnets? (Accept all possible rules at this time.)
7. Exploration: Give each student a magnet, and instruct the students to test whether each object sticks to a magnet. Walk around the room to monitor the investigation, pose questions, and provide guidance and support. Tell the groups that, when each student has had the opportunity to test every object, group members can place the objects into the appropriate YES (sticks to a magnet) and NO (does not stick) boxes on the handout. An object might be placed into the MAYBE box after testing if one part of the object sticks to a magnet, but another part of the object does not.
8. Post-Exploration Class Discussion:
   a. Which objects stuck to your magnets?
   b. Move the taped objects on the chart from their original YES/NO/MAYBE columns into the correct columns, as needed.
   c. If there are conflicting results, repeat the test in front of the class.
   d. Ask: What is the rule for the kinds of things that stick to magnets? How do you know this rule is true? (Elicit the students' rules and supporting evidence.)
   e. Ask: Is there anything else in this room that you think might stick to a magnet? Is there anything in this room that you think might not stick to a magnet?
9. Extension: Allow students to explore the room and test different objects to see whether they stick to magnets. Walk around the room to make additional suggestions about objects that the students might test (doorknob, chalkboard, etc.)
10. Post-Extension Class Discussion:
   a. What did you find? Was there anything interesting or surprising?
   b. Does our rule still work?
11. To end the lesson, have the students (a) draw (and label) two objects that stick to magnets, and (b) draw (and label) two objects that do not stick to magnets.



CODY SANIFER

Relating the Magnetism Lesson Back to the Principles of Inquiry-Based Teaching

We will now reexamine the principles of inquiry-based teaching in the context of the above magnetism lesson so that these principles can be viewed "in action."

PRINCIPLE #1: INQUIRY QUESTION.

In the introductory (engagement) section of the lesson, the lesson's purpose is communicated to the students in the form of an explicitly stated inquiry question: *What kinds of objects stick to magnets?* This easily understandable question sets the stage for the lesson's activities and learning goals, and—importantly—is a query to which the students probably do not already know the answer. This overarching question is distinct from other kinds of questions (e.g., "What do you know about magnets?" or "Why do you think that happened?") that teachers routinely pose to students to provide short-term guidance.

PRINCIPLE #2: STUDENT CENTERED.

The students are at the center of the learning process in the magnetism lesson because they perform the experiment themselves and are ultimately responsible for using their experimental observations (data), background knowledge, and prior experience to answer the inquiry question. The students' hard work is done with critical help and support of the teacher, however. The teacher carefully selects the tested materials, asks thoughtful questions, guides data collection, and manages the whole-class discussions of students' experimental results and ideas.

The principles of inquiry have another use: as a tool for self-reflection.

PRINCIPLE #3: DEEP THINKING.

In the lesson, students are not focused on the memorization of correct answers and vocabulary words. Rather, they are exerting significant mental effort as they: reflect on the existence of magnets in their homes, share their initial ideas and predictions, present and discuss their scientific observations, thoughtfully generate and discuss possible answers to the inquiry question, and ultimately decide which answer is accurate. Additionally, the hands-on activity in the magnetism lesson is purposefully connected to the development of the concept that some metals stick to magnets.

PRINCIPLE #4: EVIDENCE-BASED REASONING.

Evidence is the basis upon which students can decide whether to accept, modify, or discard a budding idea, long-believed concept, or a newly proposed answer to an inquiry question. In terms of teacher support for reasoning, prompting students for evidence at all stages of the lesson is important, as it is difficult for students to revisit and revise their ideas if they were not asked to provide evidence earlier in the lesson for their original thoughts.

In this spirit, students in the magnetism lesson are asked to share their reasoning repeatedly as they: share their initial predictions of which objects might stick to a magnet, consider how the predicted sticking and non-sticking objects are similar or different, and discuss possible rules for the kinds of objects that stick to magnets.

The Most Important Goal

Our primary goal in sharing the four Principles of Inquiry-Based Teaching is to offer a set of clear guidelines for teachers to draw upon as they read a science lesson for the first time and try to assess the degree to which the lesson is inquiry-oriented. Furthermore, the principles might suggest specific modifications that can be introduced into the lesson so that it becomes more closely aligned to the notion of "inquiry."

A secondary goal for sharing the inquiry principles relates to lesson implementation. While a lesson might appear on paper to be 100% inquiry-focused, the power of the inquiry approach is lost if the lesson is implemented in a traditional fashion. The principles of inquiry therefore have another use that is perhaps equally as important as the first: as a tool for self-reflection to gauge whether our own teaching choices are supportive of inquiry.

Either application of the principles of inquiry, whether for lesson analysis or self-reflection, supports the one aim that we all agree is paramount: providing the best possible science experiences for our students. And whether those science experiences are ground in biology, chemistry, or a simple lesson in magnetism, having our students generate their own answers to inquiry questions, think deeply about scientific phenomena, and provide evidence for their ideas can only enhance these learning experiences. ✎

Dr. Cody Sandifer and Dr. Pamela Lottero-Perdue are science education faculty in the Department of Physics, Astronomy, and Geosciences at Towson University in Maryland. As part of their job duties, they teach science content, teaching methods, and science internship courses for early childhood and elementary education majors.