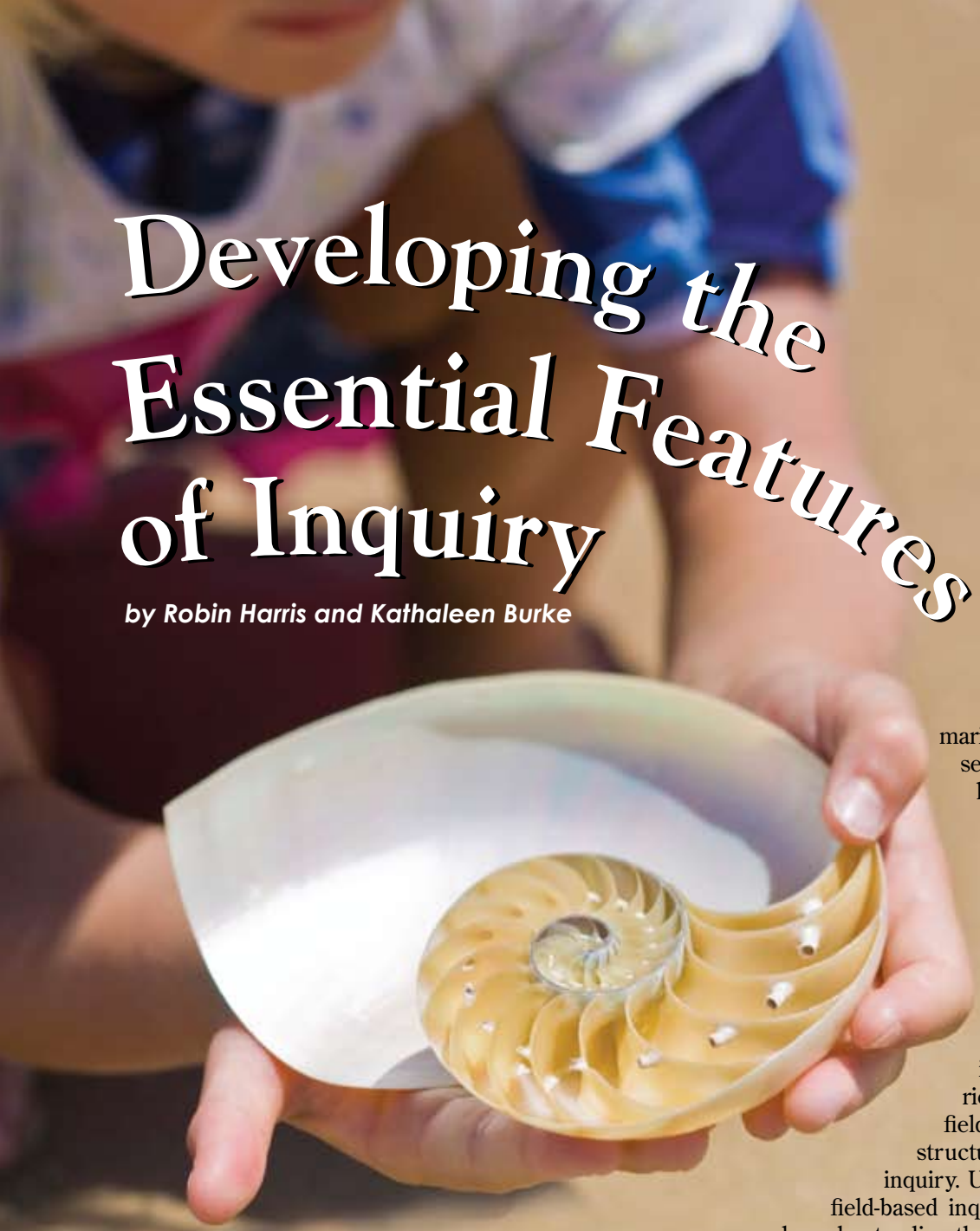
Developing the Essential Features of Inquiry

by Robin Harris and Kathaleen Burke



This lesson can be used at the beginning of the year to teach students how to conduct inquiries using the essential features described in *Inquiry and the National Science Education Standards* (NRC 1996, p. 29). The poster (Figure 1) is a modified version of the essential features and is used as a reference throughout this lesson. Once your students are familiar with the essential features of inquiry and how to refer to their work by using the inquiry poster, you will be able to check for understanding regarding inquiry for the rest of the school year (see Figure 2). You can also use the initial inquiry learning activities as reference points throughout the school year. There are two summaries for your use, as well. Figure 3 summarizes focus questions for each section of the lesson. Figure 4 lists a variety of embedded assessments you might use.

The lesson is divided into several activities, which may be spread out over several days and interspersed with your other beginning-of-the-year lessons. Students learn the essential features of inquiry through direct experience by conducting an initial field-based inquiry. You provide structure and model the parts of inquiry. Using the poster and an initial field-based inquiry helps students come to an early understanding that inquiry is not linear.

Conducting investigations in the field

Each year, students at my school participate in an Adopt-a-Beach Fall Cleanup program as a school team. This community-service activity serves as an opportunity for students to learn the inquiry process through the following activities.

This lesson can be easily adapted to other environments, as well. In the past, I have used it in a greenhouse setting, where students developed plant-related investigations. I have also used it in forest and marsh ecosystems, and in urban areas using only the school-

FIGURE 1 Essential features of classroom inquiry and their variations

Less ----------Student self-direction----------More
More---------- Direction from teacher or material----------Less

Feature				
1. Learner engages in scientifically oriented questions	A. Learner engages in question provided by teacher, materials, or other source	B. Learner sharpens or clarifies question provided by teacher, materials, or other source	C. Learner selects among questions, poses new questions	D. Learner poses a question
2. Learner gives priority to evidence in responding to questions	A. Learner given data and told how to analyze	B. Learner given data and asked to analyze	C. Learner directed to collect certain data	D. Learner determines what constitutes evidence and collects it
3. Learner formulates explanations from evidence	A. Learner provided with evidence	B. Learner given possible ways to use evidence to formulate explanation	C. Learner guided in process of formulating explanations from evidence	D. Learner formulates explanation after summarizing evidence
4. Learner connects explanations to scientific knowledge	A. Learner given all connections	B. Learner given possible connections	C. Learner directed toward areas and sources of scientific knowledge	D. Learner independently examines other resources and forms links to explanations
5. Learner communicates and justifies explanations	A. Learner given steps and procedures for communication	B. Learner provided broad guidelines to use to sharpen communication	C. Learner coached in development of communication	D. Learner forms reasonable and logical argument to communicate explanations

Adapted by the Buffalo Science Teachers' Network (*http://bstn.wikidot.com*) from National Research Council. 2000. *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press, p. 29.

yard. These activities might even be conducted using the time-honored inquiry question "How many drops of water can fit on the head of a penny?"

No matter where the fieldwork takes place, the basic process is the same: Students are given time to observe and wonder. What changes is the equipment necessary to conduct investigations. You can lead your students in a variety of different directions; if you have to restrict experimentation because of limited resources, then do so. You might be amazed by the ingenuity of your students when you give them the parameter "You may only use the equipment on the demonstration table to design and collect data for your investigations."

Part 1: Engaging in scientifically oriented questions

In the classroom

In preparation for the first fieldwork day, students set up their scientific daybook (journal), with a page for observations. As a class, we brainstorm ways of observing without scientific tools. After a bit of brainstorming, I prompt students by holding my hand to my ear, and they respond by naming the five senses. (At this point, I warn students that we don't taste anything in science class.) Students list these prompts at the top of their observation page: *I see, I hear, I smell,*

FIGURE 2 Essential features of classroom inquiry quiz

Name _____ Hypothesis _____

Feature	Write what you and your group did for this inquiry. Separate the work you did by each essential feature of inquiry.
1. Learner engages in scientifically oriented questions	
2. Learner gives priority to evidence in responding to questions	
3. Learner formulates explanations from evidence	
4. Learner connects explanations to scientific knowledge	
5. Learner communicates and justifies explanations	

I touch or feel, and *I sense.* I also use this brainstorming to find out what my students know about our local beaches. I ask them what they heard, saw, and smelled when they last visited the beach. This activity sets the stage for when we go to the beach for cleanup and observation writing. This is all preliminary to generating questions for their inquiry.

At the beach on cleanup day

Because we work on this project each year, the beach site is well known to us. Please explore a potential site well in advance of any class field trips. Remember to clear your field experience with your school administrators and have all necessary permissions completed well in advance of your trip. On our first visit to the beach, students are instructed to write down their observations. I spread students out along the beach, with approximately 3–5 meters between them, and instruct them not to talk during the 5–10 minutes of making observations and writing them in their daybooks. I remind students of the prompts in their notebooks by saying they can start their observations with *I hear…*, *I see…*, *I smell…*, *I touch or feel…*, and *I sense…* Students are once again reminded not to taste anything. Students are instructed to write for 5–10 minutes. If they finish observing before this time, they are to sit quietly until given a signal by the teacher to come together for the beach cleanup activities. Not talking and sitting away from others is hard for students, but this allows them to concentrate on their surroundings, which is my objective. We practice this skill before the beach fieldwork with one- and two-minute silent observations in the classroom.

Back in the classroom (on another day)

Students take out their observations and we begin the next part of this first essential feature of inquiry activity: formulating questions. Students are asked to reread their observations and from them write several questions that pertain to what they sensed at the beach. They can discuss their observations with others and bounce question ideas off each other as well. Sometimes students get stuck writing questions, so I post a list of question starters. The 6W & H sentence starters (I wonder [**W**hy, **W**hat, **W**ho, **W**hen, **W**here, **W**hich, and **H**ow]) help the questions flow. After 5–10 minutes, I ask students to pick their three favorite questions and write them on their whiteboard. (We use individual-sized whiteboards for this.) Students print their questions and then display them for all to read. We have three minutes of quiet reading and then I ask students to find other people with similar questions. Students group themselves together by the types of questions they ask. For example, questions pertaining to weather, water temperature, wave action, sand, and animals that live in the sand will emerge. This is a noisy time and I spend most of it directing students to others with similar questions. These small groups (3–5 students) make up the investigative teams for the rest of the inquiry lesson. Each group picks at least two questions it wishes to investigate, writes the questions and their names on a card, and turns in the card. We take a look at our inquiry poster (Figure 1) and students are asked to

FIGURE 3 Focusing questions that may be used during this lesson

Inquiry lesson section	Focusing questions
1. Student engages in scientifically oriented questions	How can observations lead to hypotheses?
2. Student gives priority to evidence in responding to questions	What can secondary research tell us about our hypothesis? How do we design an experiment to test our hypothesis? What are our procedures? How do we collect data safely?
3. Student formulates explanations from evidence	What happened that supports your hypothesis? What happened that does not support your hypothesis? Why did these data show what they show? What happened? What do the data say? How accurate are your data? Describe experimental errors. What does this evidence show?
4. Student connects explanations to scientific knowledge	What three connections can we make about our hypothesis to the data we collected at the beach and through research?
5. Student communicates and justifies explanations	What are the group's conclusions? What went right? What went wrong? What are your new questions?

identify which feature of inquiry they have completed (they should identify Feature 1–D.)

Before you start the next activity, it is important to sift through your students' questions and write comments that will help them in the next activity. The first time they do research is the hardest, and your comments and questions on their cards should give them ideas on where to begin that research. Students will need to find information on how to conduct simple experiments. For example, one group of students was interested in identifying and counting the different varieties of shore birds. Their question developed from observations of birds flying around. They had observations on their calls, their behaviors toward each other, and even how often the birds excreted. Your leading questions and comments are used as key search terms for future research and guide the groups through the next activities. For the bird group, I asked, "Where can you find listings of our local shore birds? What national group of bird watchers could help you with your research?"

Part 2: Giving priority to evidence in responding to questions

The first part of this activity takes place in a media center with computer access and as homework assignments. Before students can collect evidence (primary research), they spend time doing what I call secondary research. They do this to find out what might be published on their question. Secondary research can take some time, especially if students write away for information. I usually allot about two weeks for this activity.

Students read the questions you have written on their cards, and make a plan to research their priority question. If the first question on the card does not pan out, students research the second question. In class and for homework, the groups investigate their question by searching for articles and books at the media center and online. Their assignment is to gather information on their question and then turn their question into a testable hypothesis. Students need to be reminded that a hypothesis is not a guess, but a statement about an observation that can be tested. Groups turn in their hypothesis and a set of three statements summarizing the findings from their secondary research.

For example, the bird group found that the Audubon Society keeps records of bird sightings, so students were able to access local data. They found that there were 10 permanent shore bird residents. They were able to find descriptions and use Audubon tally forms to help them with their procedures. The bird group hypothesis became, "There are 10 permanent shore birds at our beach."

The teacher should do a quick check on students' hypotheses and secondary research statements. You can

FIGURE 4 Summary of assessments used in this lesson

Student products	Embedded and ongoing assessment
Observations in science daybook	Check and stamp or sticker for completion
Group questions	Edit to add words useful for keyword searches and practicality
Group secondary research summaries and hypothesis	Check all assigned forms of research present, that summaries contain information relevant to hypothesis, and that hypothesis is in proper format and doable
Experimental design, including data tables and safety concerns	Logical procedures, appropriate tools for data collection, data tables ready for fieldwork, tasks distributed among group members
Collected data with safety in mind	In the field: all experimentation conducted safely, data recorded
Explanations connected to research; mistakes explained by errors in experimental design, equipment, or data-collection techniques (human)	Each connection to hypothesis is explained by evidence gathered in the field or by secondary research; graphic organizer
Group presentation contains all assigned elements	Scoring guide filled out during presentation
Collaborative nature during presentations	Check for active listening, appropriate questions, and interactions
Ability to recognize the essential features of inquiry	Paper-sized version of poster is used to write a summary of inquiry

award points for direct connections to the hypothesis, and if their research statements are observable and not inferences. Examples of student hypotheses include the following: "Flotsam height changes as it moves up the beach."; "The temperature of the water changes from the surface to the bottom at different distances from the shore."; "Sand grain size changes as you dig down from the surface at different places on the beach."

Designing the experimental procedures

Once groups know what research has been done on their question, they design an experiment to test their hypothesis. Some students will have found experiments that other scientists have conducted and will copy those procedures to use. They may have to simplify the experiment based on the available classroom equipment. While they are writing procedures, they should also set up their data tables and assign roles for each group member. You will have to lead them in this the first time. By middle school, students have done many experiments that have been prepared by others, but in this field-based inquiry, they are asked to use that knowledge to build a set of procedures for their own experiment. The bird group made up identification cards of the 10 birds, with pictures, drawings showing sizes, and footprints. Their procedures were set up so that they worked in pairs, one person identifying a bird, the other confirming identification and writing it on a tally sheet. Students drew lines in the sand and only counted the birds that passed by the lines.

Before returning to the field site, students should set up their equipment and try out their experimental procedure as best they can in the classroom. This allows you to do a safety check and for students to practice with their equipment. You can help with setup and equipment at this time, and pack equipment for transportation to the field site. Students should make and check their data-collection lists and tables. Students should be able to pick out controls and variables by now, and their data tables should reflect this knowledge. On the day of the field visit, the tables can be rubber banded to cardboard or attached to clipboards that have a plastic bag over them.

Returning to the beach and collecting evidence

At the field site, students conduct their experiments. In previous years, several parents volunteered to be the extra pairs of eyes, and to help make sure all of the experiments were conducted safely. We planned ahead for this day by having the complete interdisciplinary team return to the beach. The math, English, and social studies

FIGURE 5 Making sense of evidence graphic organizer

Group members _____
Hypothesis _____
_____

1. Write your evidence-based statements in the table.
2. Go back to your secondary research findings and match research findings to your evidence.
3. Try to find new secondary research to support your findings if they are different from your original research.
4. Remember to write down the source of each of your secondary research statements.

Item

Statement made based on evidence	Secondary research finding	Source
1		
2		
3		
More		

General conclusion (write three statements that relate your evidence to your hypothesis):

1
2
3
More

teachers came with work for students to do. Students rotated among the four of us so that only about 30 at a time were conducting science experiments. Parents acted as leaders and moved with a group or two from station to station. When students were at the science stations, they set up their experiments, collected data, cleaned, and packed up their equipment to go back to school. I used colored tubs for each section of eighth graders (I had five sections). Students should refer to the inquiry poster (Figure 1) and identify what they just completed. (They should identify Feature 2-D.)

Part 3: Formulating explanations from evidence

Back in the classroom, students work in their groups to compare their collected data to their hypothesis. The teacher should guide them by visiting each small group and asking questions, and by handing out the Making Sense of Evidence graphic organizer (Figure 5) and asking students to fill in the first column. The following questions might also be used to guide students (see Figure 3).

- What happened that supports your hypothesis?
- What happened that does not support your hypothesis?
- Why did these data show what they show?
- What happened? What do the data say?
- How accurate are your data? Describe experimental errors.
- What does this evidence show?

At the end of this lesson, students should have clear data tables and a set of statements made from the data that list their findings from their fieldwork. The teacher should look at data and statements and make comments on observations and inferences. Statements should be based on what was observed during the collection of evidence and recorded at the beach.

For example, the bird group identified six birds from their original observations and took pictures of three additional birds. They also made drawings of several bird tracks and used these to count numbers. In the first column of their graphic organizer (Figure 5) they wrote in box 1, "We identified six birds" (the list of birds they identified followed). In box 2 they wrote, "We saw three additional birds" (they identified them later), and in box 3 of column 1 they wrote, "We counted 15 tracks of laughing gulls."

Before moving to the next activity, students should be directed to the inquiry poster (Figure 1) and asked to identify the feature they just finished. (Students should identify Feature 3-C.)

Part 4: Connecting explanations to scientific knowledge

For this activity, students work in their groups to compare the statements and findings that they wrote in column 1 with their secondary research information. They work in their groups to fill in the second and third columns of the Making Sense of Evidence graphic organizer (Figure 5) and write conclusions based on the evidence they find during their experiments. You can help with this part of the activity by having their secondary research organized and ready for them to revisit. You might require your students to make up to three connections between their findings and what the research says. This feature of inquiry takes many repetitions to master.

Groups turn in the graphic organizer for grading. You should grade these based on how well their column 1 statements connect to the evidence they collected at the beach, and how well columns 1 and 2 correlate to each other. I find that students have a hard time connecting evidence to scientific knowledge—here is where your comments can help them gain understanding of this concept.

Before moving to the next activity, students should be directed to the inquiry poster (Figure 1) and asked to identify the feature they just finished. (Students should identify Feature 4-C.)

Part 5: Communicating and justifying explanations

Communicating results in groups is the beginning of the class scientific learning community in action. Students present their findings to each other. If the fieldwork was conducted by multiple classes at once, try to arrange a special activity time so that the whole team at once, not just individual class periods, can participate at the same time.

Student posters should contain the hypothesis, a description of the procedures, the original data-collecting tables, a summary of statements made from evidence collected, the research that they found to back up their statements, and a concluding statement that relates findings to hypothesis. You can end this activity by displaying the posters, but it is always more fun if students can take a bit of time to give a short oral presentation of what they found out. This is up to you and your students. Some years we posted findings in the hallways and let students share among themselves. Other years, we picked one experiment from each class and the five chosen groups gave a presentation at a team meeting. One year the PTA wanted to showcase the beach inquiries, so the posters were put up for a back-to-school night.

Students should be directed to the inquiry poster, (Figure 1) and asked to identify the feature they just finished. (Students should identify Feature 5-A or 5-B.)

Lesson closure and assessment

It may seem a bit daunting to complete a long-term, field-based student-centered inquiry such as this one, but remember that it happens one activity at a time, and that you set the timing. I've always taken several weeks to complete it. After oral and written presentations, a simple closing assessment to this lesson could be a short-answer quiz (see Figure 2).

There are several embedded assessments for you to use as each activity unfolds, which are summarized in Figure 4. As final closure and to collect information on what your students learned about the features of inquiry, a quiz is given using an Essential Features of Inquiry poster where just the features are listed, with the rest of the page open for students to write their responses (see Figure 2). ■

References

Harris Freedman, R.L. 1999. *Science and writing connections*. Parsippany, NJ: Dale Seymour.

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

National Research Council (NRC). 2000. *Inquiry and the national science education standards*. Washington, DC: National Academy Press.

Robin Harris (*harrisrl@buffalostate.edu*) is an associate professor in the Department of Earth Sciences and Science Education at Buffalo State College in Buffalo, New York, and project director for the Buffalo Science Teachers' Network. ***Kathaleen Burke*** was a seventh- and eighth-grade science teacher in the Buffalo Public Schools for 34 years (retired) and is presently working as a SEPUP/Lab-aids national consultant while continuing to mentor Buffalo science teachers through the Buffalo Science Teachers' Network.